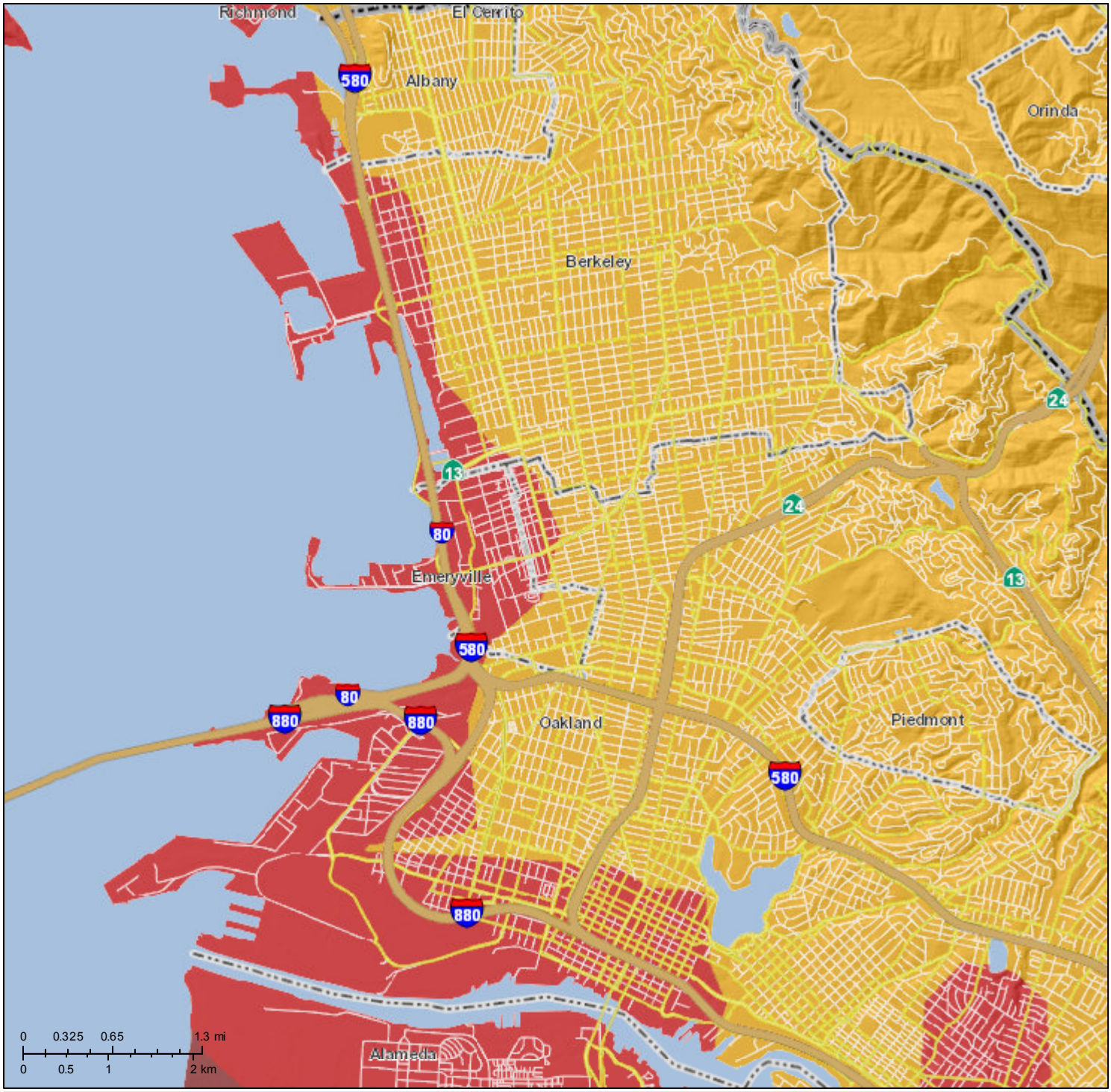


Legend

- Light - MMI 5
- Moderate - MMI 6
- Strong - MMI 7
- Very Strong - MMI 8
- Violent - MMI 9
- Very Violent - MMI 10

San Francisco Bay Area Hazards

This map is intended for planning only and is not intended to be site specific. Rather, it depicts the general risk within neighborhoods and the relative risk from community to community.

ASSOCIATION OF BAY AREA GOVERNMENTS
RESILIENCE PROGRAM

November 2, 2015

ABAG GIS

The Sherwin-Williams Company

Summary of Geotechnical Results and Conceptual Geotechnical Engineering Recommendations for The Sherwin-Williams Company Emeryville, CA Manufacturing Facility

June 10, 2005

Technical Memorandum

Technical Memorandum
Results of Preliminary Geotechnical Investigation and Conceptual Geotechnical Engineering Recommendations

This technical memorandum (TM) presents the results of our preliminary geotechnical investigation and provides conceptual geotechnical engineering recommendations for design and construction of the proposed future development at the 8-acre Sherwin-William's facility in Emeryville, CA. The purpose of this TM is to provide Sherwin-Williams with preliminary geotechnical engineering recommendations to facilitate conceptual site development planning with SRM Associates (SRM). The information contained in this TM is considered preliminary, as the primary objective of the investigation was to characterize the overall site geotechnical conditions for planning level evaluations. The recommendations provided herein are based on review of available site data, the results of CDM's preliminary geotechnical investigation, discussions with SRM and Sherwin-Williams representatives, and review of the Parcelization Map, dated May 17, 2004, prepared by ROMA Design Group in association with BKF Engineering.

Purpose and Scope

The purpose of this study was to conduct a preliminary geotechnical investigation to characterize the site subsurface conditions and provide preliminary design recommendations that would be used by SRM to evaluate conceptual design options and perform supporting economic analyses.

Specifically, our scope of work included the following tasks:

- Conduct a preliminary subsurface exploration program consisting of 2 test borings and 6 cone penetration tests (CPTs) at the site;
- Conduct laboratory tests on selected soil samples to assist with classification of soils encountered and determine engineering properties;
- Develop conceptual geotechnical engineering recommendations for foundation design and construction associated with future development as defined herein;
- Present data collected as part of the investigation.
- Prepare this technical memorandum presenting the site characterisitics and CDM's preliminary geotechnical recommendations based on ROMA's Parcelization Map (2004).

Proposed Future Development

The proposed future development plan has not been finalized but based on review of the Parcelization Map, the site will be redeveloped to include a mix of residential and commercial land use with a central open space and links to future greenway or bike trail extensions, refer to Figure 1, Conceptual Site Map. The 8-acre site is subdivided into five parcels using a variety of structure types and height relationships. In general, the development plan includes multi-story structures with podium style parking on the lower levels with provisions for two high rise tower elements ranging in height from 120 feet to 200 feet. A generalized description of the size and intended land use for each of the five parcels is provided below.

- Parcel A: approximately 0.62 acres, mixed residential and commercial use, existing building to remain with structure height up to 50 feet.
- Parcel B: approximately 1.44 acres, mixed residential and commercial use, multi-story structure up to 65 feet in height with podium style parking on lower level, demo existing structures.
- Parcel C: approximately 1.37 acres, mixed residential and commercial use, multi-story structure up to 65 feet in height with podium style parking on lower level, demo existing structures.
- Parcel D: approximately 0.95 acres, mixed residential and commercial use, multi-story structure up to 120 feet in height with podium style parking on lower 3 to 5 levels.
- Parcel E: approximately 1.46 acres, mixed residential and commercial use, multi-story structure up to 65 feet in height including a tower element up to 200 feet high with podium style parking on the lower 3 to 5 levels. The northern portion of this parcel may include a multi-level parking structure up to 65 feet high.

To conduct our analysis and develop our recommendations, CDM made the following design assumptions regarding the proposed development.

- **Multi-level parking structure:** Multi-level parking structures are planned for Parcels B, C, D, and E. For purposes of this study, we have assumed the parking structures will have no below grade parking and up to 6 levels of above grade parking;
- **Mixed-use commercial/residential units:** As currently planned, the site consists of mixed use commercial and residential units with no below grade space and range in height from low rise (up to 2 stories), mid-rise (up to 5 stories), and high rise (over 5 stories). The current development plan indicates that parking will be located beneath the first and upper ground levels beneath each building; and

- **Central parking and asphalt-paved streets**: For purposes of this study, we have assumed that little to no site regrading will be required.

As an overall site consideration, this evaluation is based on the condition that final site grading will be minimal and that the first floor of all structures will be essentially at grade or embedded no more than 5 feet below the existing grade.

Several existing buildings (Buildings No. 1 and 31) along Horton Street are to remain and will be incorporated into the development. The remainder of the existing structures will likely be demolished as part of the new development.

Note that the redevelopment plans for the site are conceptual in nature and other building types may ultimately be considered. Figure 1, Conceptual Site Development Plan, illustrates the proposed conceptual site development plan including proposed building structure heights within each parcel (ROMA, 2004).

Existing Site Conditions

The project site (Site) is located at 1450 Sherwin Ave in Emeryville, CA. The parcel encompasses about 8 acres and is located in an historically industrial neighborhood approximately ¾-mile east of the San Francisco Bay and along Temescal Creek. The site is bounded on the west by Union Pacific Railroad tracks, on the north by Chiron Corporation property, on the east by Horton Avenue and on the south by Sherwin Avenue. The site is an active paint manufacturing facility and is currently occupied by several 1 to 3-story administration and manufacturing structures with multiple aboveground tanks used to manufacture paint products. It is our understanding that all the existing structures at the site are supported on relatively shallow spread footings and that numerous structures have been removed from the site (areas underlying Parcels B and D). However, the foundations for these demolished structures were not removed during demolition and are covered by fill and pavement.

Currently, a significant portion of the site is enclosed by a soil-bentonite and cement-bentonite slurry wall. This impermeable wall is approximately 3 feet thick and extends to an approximate depth of 22 feet depth. Beneath Parcel D, an environmental cap was constructed to encapsulate metals-impacted soils and to reduce potential exposure pathways, surface water infiltration and subsequent contaminant migration. The approximate location of the slurry wall and environmental cap are shown on Figure 2, Boring Location Map. The area of the cap is paved with asphalt and is about 2 to 4 feet higher than the surrounding site grades. The remainder of the site grades range from about El. 10 to El. 20 feet.

A groundwater extraction and treatment system consisting of 13 extraction wells is in operation at the site.

Geotechnical Exploration Program

CDM's geotechnical exploration consisted of drilling two mud rotary borings and six Cone Penetrometer (CPT) soundings up to depths of 100 feet at selected locations across the site. The mud rotary borings and CPT soundings were performed by Gregg Drilling and In-Situ of Martinez, California, on January 28 and 29, 2003. The purpose of the investigation was to characterize the subsurface conditions and determine engineering properties of soils to support development of remedial alternatives and conceptual design planning.

Soil Borings

Two test borings, CDMSB-11 and CDMSB-12, were drilled as part of this investigation. Test boring CDMSB-11 was drilled near the northeastern corner of the property that extends along Horton Street. Test boring CDMSB-12 was drilled near the southwestern corner of the property along Sherwin Avenue. The test borings were located in the field by chaining from existing site features and were monitored in the field by a CDM representative.

Sample collection alternated between a California Modified Split-Spoon Sampler and a Standard Penetration Test (SPT) in general accordance with American Society of Testing Method (ASTM) D1586. Soil samples in the test borings were typically collected at 5-foot intervals over the depth of the boring. Relatively undisturbed samples were collected using a California Modified Split-Spoon Sampler lined with 1-inch brass rings. Generally, the lower 6 rings of the sample were sealed in plastic bags and placed in rigid tubes with resealable end caps for transport to the laboratory. The SPT sampler was unlined and the retained sample material was placed in sealed plastic bags for transport to the laboratory. The drill rig utilized a 140 lb hydraulically driven auto-hammer to drive the sampler 18-inches. The blow count for each six-inch driven interval was recorded and the penetration resistance (N) was determined by adding the second and third 6-inch penetration resistance blow counts.

Water levels in the test borings were estimated from the condition of the samples obtained and by the observed water levels within the borehole at the time of drilling, if any. Both test borings were drilled to a depth of 101.5 feet below ground surface (bgs). At the completion of drilling, each boring was backfilled using Portland cement that was pumped through a 1-inch tremmie pipe to 100 feet bgs. Excess bentonite drilling mud and soil cuttings were collected and placed in 55-gallon drums for characterization and disposal.

In addition to the test borings conducted for this study, CDM reviewed three additional test borings, B11 through B13, which were drilled by others near the project area. The information contained on these logs was incorporated into our evaluation. These borings are located on the adjacent Chiron property, which is to the northeast of the Sherwin-Williams site adjacent to Parcels D and E.

A summary of the subsurface conditions encountered in the explorations is included in Table 1, Summary of Subsurface Explorations. Locations of the test borings

(CDMSB-11 and CDMSB-12 and B11 to B13) and the CPT soundings described in the following section are shown on Figure 2, Site Map. Copies of CDM boring logs, as well as boring logs B11 to B13 prepared by others are included in Appendix A.

Cone Penetrometer Soundings

A total of seven CPTs were planned for this investigation, however, near surface refusal on two attempts, attributed to possible buried foundation footing at location CPT-3, resulted in abandonment of this location. Therefore, a total of six CPTs (CPT-1, CPT-2, and CPT-4 through CPT-7) were conducted to provide information regarding subsurface conditions at the site. A copy of these CPT test data including the interpretation report is included in Appendix B.

Geotechnical Laboratory Testing

Laboratory tests were performed on selected split spoon samples and Shelby tube samples obtained from the test borings CDMSB-11 and CDMSB-12. The following analyses were conducted to characterize material index and strength properties:

- Grain size analyses using ASTM D422,
- Atterberg Limits using ASTM D4318,
- Moisture Content and Dry Unit Weight using ASTM D2216 and D2937, respectively,
- Direct shear tests performed in accordance with ASTM D3080, and
- Consolidation tests using ASTM D2435.

Results of the laboratory tests are summarized in Table 2, and a copy of the laboratory report is included as Appendix C.

Site Geology

The Sherwin-Williams site is located immediately to the east of the former margin of San Francisco Bay and is underlain by a variety of natural and culturally-modified soils.

Soil and Groundwater Conditions

The subsurface conditions encountered in test borings CDMSB-11 and CDMSB-12, B11 to B13, and the CPTs consist of a variety of different soils that CDM defined as follows:

- Layer 1: Silty/clayey gravel with sand
- Layer 2: Black sandy clay
- Layer 3: Clayey sand/ Silty sand
- Layer 4: Sandy clay
- Layer 5: Sand/ Gravelly sand/ Silty Gravel

Layer 1: Soils designated as fill (Layer 1 – silty clayey gravel with sand) were encountered in every test boring and CPT as the topmost Layer. The thickness of this Layer is estimated to be between 4 feet and 22 feet at borings and CPT locations. Layer 1 includes clay, silts, sand and gravel and may contain organic material and debris consisting of glass, concrete or brick fragments. USCS-classification of Layer 1 includes GP, GC, SM, ML, and CL. The SPT and California Modified Split Spoon Sampler N-values measured in the test borings as well as the CPTs indicate a wide range of density and consistency; loose to medium dense in granular soils and medium stiff to very stiff in fine grained soils, respectively.

The presence of debris, including glass and brick fragments, along with interlayed gravel observed in some borings suggests that certain areas are overlain by artificial fill materials. The thickness of artificial fill at these locations is estimated to be on the order of about 7 feet thick. Artificial fill is expected beneath/adjacent to existing and/or abandoned building foundations.

Layer 2: Layer 2 soils consist of mostly fine-grained soils containing organic compounds (Layer 2 – Black sandy clay). Layer 2 is generally described as soft, dark grayish to black, clay with medium to high plasticity with organic odors and varying amounts of silt and sand. The SPT and California Modified Split Spoon Sampler N-values measured in the test borings as well as the CPTs indicate that this stratum is soft. USCS-classification of Layer 2 includes CL and CH. Layer 2 ranges in thickness from 10 to 33 feet at the test boring locations. The bottom of Layer 2 extends to depths ranging from 19 to 43 feet below existing site grades in explorations where this layer was encountered. It appears that the thickness of Layer 2 is variable throughout the site and may be controlled be deposition/erosion along Temescal Creek.

Layer 3: Soils assigned to Layer 3 (Clayey sand/ Silty sand), generally directly underlie Layer 2, however, in some places Layer 3 directly underlies Layer 1. Layer 3 and layer 4 are inter-layered. Layer 3 is generally described as clayey sand, clayey sand with gravel with interbeds of clayey gravel. USCS-classification of Layer 3 includes SC and GC. Layer 3 ranges in thicknesses from 3 feet to greater than 16 feet at the test boring locations. The SPT and California Modified Split Spoon Sampler N-values measured in the test borings as well as the CPTs indicate that this layer is medium dense to dense.

Layer 4: Layer 4 (Sandy clay) generally consists of clay with varying contents of sand, silt and/or gravel with trace organic compounds. The plasticity of this layer is predominantly described as medium to high. USCS-classification of Layer 4 includes CH and CL. Layer 3 and layer 4 are inter-layered. Layer 4 ranges in thickness from 3 to greater than 53 feet thick at the test boring locations. The SPT and California Modified Split Spoon Sampler N-values measured in the test borings as well as the CPTs indicate that this layer is medium stiff to very stiff.

Layer 5: Layer 5 (Sand/ Gravelly sand/ Silty Gravel) generally consists of sand, gravelly sand, and silty gravel. USCS-classification of Layer 5 includes SP, SW and GM. Layer thicknesses range from 5 to 13 feet thick at the test boring locations. The

SPT and California Modified Split Spoon Sampler N-values measured in the test borings as well as the CPTs indicate that this layer is medium dense to very dense.

Groundwater beneath the site varies from depths of 10 to 14 feet below existing ground surface. The extraction well network was operating during this work.

A summary of the subsurface conditions is presented in Table 1. Figure 3, Isopach Map – Base of Layers 1 or 2, illustrates the approximate base or bottom of shallow unsuitable soils. Using this figure, it is possible to estimate the thickness of unsuitable soils (base of Layers 1 and 2) by adding the ground surface elevation (black) contour line to the contour value depicted by the base of Layer 1 or 2 (red) contour line. The sum of these values represents the interpreted thickness of the underlying unsuitable soils.

Assessment of Geologic Hazards

The geologic hazards at the site are attributed to the regional seismicity. Specifically, the seismic hazards include fault surface rupture, liquefaction of saturated granular soils, and ground shaking. The hazard potential associated the seismic potential for the Site is presented below.

Surface Fault Rupture

Based on review of current publications available from the California Geological Survey (CGS), Alquist-Priolo Earthquake Fault Zone map (CGS, 2003) there are no known or identified active or potentially active faults intersecting or trending into the Site (Jennings, 1992; WGCEP, 1996). The nearest known active fault is the Hayward fault, situated approximately 3 miles northeast of the site. Other active regional faults such as the San Andreas, Calaveras, Rodgers Creek – Healdsburg, Concord-Green Valley, San Gregorio, and Greenville faults are located at least 15 miles from the site. Refer to Appendix D for the EQFAULT (EQFAULT, 2000) preliminary listing of active regional faults with estimated moment magnitudes and peak site accelerations values, based on Abrahamson & Silva (1997). Based on review of published information, the potential for fault surface rupture is considered low.

Liquefaction

Liquefaction is a soil behavior phenomenon in which loose saturated granular soils lose their inherent shear strength due to increased pore water pressures as a result of cyclic loading, such as ground shaking during a strong earthquake. While a detailed liquefaction analysis was not conducted for this site, the liquefaction potential for the site ranges from "very high" to "moderate" (CGS, 2003). This determination is generally consistent with site investigation results. However, the continuity of potentially liquefiable zones at the Site was not evaluated as part of this study.

Potential consequences of liquefaction include bearing capacity failure, flotation of lightweight embedded or buried structures, landsliding (lateral spreads and flow slides), and differential settlement. Among these deformation mechanisms, large permanent ground deformations resulting from liquefaction-induced settlement is

considered to be the most significant potential mode of liquefaction-induced ground failure at the Site.

Planned Future Site Remediation

Portions of the site are underlain by impacted soil and groundwater and a variety of remedial approaches are being evaluated. An area approximately 200 feet by 200 feet and located to the north of the existing Building No. 31 and within the area of the raised cap will be remediated (Parcel D). The existing retaining wall surrounding the raised cap will also be removed. Remediation may include removal or in-situ/ex-situ treatment of the contaminated soils to a maximum depth of about 20 feet and replacement as needed with compacted structural fill.

Alternatively, soil-mixing consisting of in-situ mixing of cement-ferrous sulfate slurry with the existing soils to a maximum depth of about 20 feet may be conducted. Soil-mixing, if used, will likely result in a zone of remediated soil with compressive strengths in the range of 100 to 1,000 pound per square inch (psi), depending on final mix design.

It should be noted that future structures supported on shallow foundations that bear on this zone of stabilized soil and extend on to zones of soil not previously treated will require special attention with respect to differential settlement since the mixed soils will be significantly less compressible than the existing, untreated soils present at the site.

Conceptual Geotechnical Design Recommendations

Conceptual geotechnical engineering evaluations have been made as they relate to the proposed future development of the Sherwin-William's Facility in Emeryville, CA. In general, these evaluations have been based on the minimum requirements of the Unified Building Code (UBC) 1997. In addition, recommended design criteria are based on performance tolerances, such as allowable settlement, as understood to relate to similar structures.

Low and Mid Rise Buildings – Conceptual Foundation Design

The proposed low-rise and some of the mid-rise buildings can be supported on spread footings or on mat foundations bearing on suitable foundation bearing soils. Suitable foundation layers consist of Layers 3, 4, or 5 or on structural fill placed after the excavation of unsuitable soils. Unsuitable soils include all of existing Layers 1 and 2 and any loose or disturbed soils present at the subgrade level. As presently understood, no below grade space is anticipated for the proposed buildings, therefore, normal foundation level for the structures will not likely extend into the suitable bearing materials and over excavation and removal of unsuitable soils will be required. Over excavated areas should be backfilled with compacted fill.

Foundations should be designed for maximum net allowable bearing pressures of no more than 5,000 pounds per square foot (psf) for both dead and live loads bearing directly on the existing naturally deposited clayey sand/silty sand, sandy clay, or silty

gravel/gravel and silt stratum soils or on compacted fill placed after the removal of all unsuitable soils. An ultimate bearing pressure for the suitable bearing Layer at the site should be assumed to be no more than 10,000 psf.

All foundations should bear at least 3 feet below any adjacent lowest ground surface. Settlement of these structure, under the anticipated loads and designed as recommended above, is expected to be less than 2 inches with no more than 1 inch of differential settlement across the width of the structure.

Due to the depth of suitable bearing bearings soils, in some areas it may not be economical to support some low and mid-rise structures on shallow spread footings or mat foundations. In these areas it may be more economical to support these structures on deep foundations as described below for high-rise structures.

High Rise Buildings – Conceptual Foundation Design

The proposed high-rise buildings or mid-rise buildings with heavy loads should be supported on deep foundations bearing in the underlying Layer 3, 4 and/or 5 stratums. End driven piles or deep-drilled shafts can be used.

Driven piles consisting of precast prestressed concrete piles are likely to be the most economical pile type. Pile capacities of 100 and 125 tons for 12 and 14-inch square piles, respectively, can be achieved. Piles will develop capacity in both skin friction and end bearing. Piles should be driven to a minimum tip elevation and/or final driving resistance as required to reach the design capacity. Pile lengths should be expected to be about 80 to 100 feet and a load test will be required. Little spoil should be produced during installation of driven piles, thus disposal costs for contaminated soils should be limited. Care should be used when piles are driven in close proximity to adjacent structures or sensitive utilities as excess vibrations may cause damage.

Deep-drilled shafts, bearing in the underlying Layers 3, 4, and 5, can also be used. Drilled shafts will develop capacity in both skin friction and end bearing. Drilled shaft capacities of up to approximately 200 tons can be achieved. Shaft diameters should be expected to range from 2 to 4 feet. Shaft lengths of 80 to 100 feet would be required as shorter shaft lengths will result in less capacity. For conceptual design purposes a 60 foot long, 2-foot diameter shaft should be expected to result in a design capacity of about 80 tons and a 100 foot long, 3-foot diameter shaft should expected to result in a design capacity of 200 tons. Shafts may encounter layers of granular soils (sand and/or gravel) and steel casing or drilling mud may be required to maintain the shaft opening during construction. A significant amount of spoil will result from the drilled shaft construction. Spoils from the upper contaminated layers will require proper disposal. Drilled shafts may be installed adjacent to existing structures. Provided proper construction techniques are used, damage to adjacent structures and/or utilities can be minimized.

Alternatively, it may be feasible and more economic able to support some high-rise structures on an intermediate pile-raft foundation system. Intermediate length piles and a raft, i.e., mat, foundation system can be designed as a composite system to carry

foundation loads. This approach allows for the use of shorter piles since some of the foundation load is carried by the mat/raft. It is unlikely that structures with very high column loads can be supported on a pile raft foundation system, however, structures with 6 to 10 stories may be appropriate.

Lowest Level Floor Slab

The lowest level floor slab may be designed as slabs-on-grade bearing on a minimum of 18-inches of compacted, non-expansive fill. Any existing fill, disturbed, or otherwise unsuitable soils present below the slab level should be removed and replaced with compacted, non-expansive fill. A moisture-proof membrane should be installed below the slab and a 2-inch layer of sand placed between the membrane and the underside of the slab to protect the membrane from damage during construction.

Seismic Design Considerations

For purposes of determining design earthquake forces in accordance with the 1997 Uniform Building Code (UBC), the site may be considered as a "Zone 4" soil site as determined by Figure 16-2 of the UBC 1997. Therefore, in accordance with Table 16-I of the UBC, a Seismic Zone Factor equal to 0.4 should be used. Based on the type of soil encountered in our borings and our recommendations, the site may be considered S_D-Stiff, per Table 16-J of UBC 1997. The site is approximately 3 miles from the Hayward Fault, which is a Type A fault per Table 16-U of UBC 1997. Per Table 16-S and 16-T of the UBC, the near source acceleration (N_a) and velocity (N_v) with respect to the subject site is 1.2 and 1.6, respectively. Per Tables 16-Q and 16-R, the site seismic coefficient of acceleration (C_a) and velocity (C_v) is 0.44 N_a and 0.64 N_v, respectively.

Construction Considerations

Deep Foundation Construction

Installation of deep foundations should be conducted to address the following issues:

- **Potential for contaminant migration during installation of deep foundations through contaminated soils:** Use of precast prestressed piles (e.g., displacement piles) should not require the installation of a casing in areas of shallow impacted soils or groundwater as the piles will displace the surrounding soft plastic ductile soils during driving thus preventing pathways for migration. Flow path development at the pile/soil interface is unlikely because of the resultant relatively high soil/pile interface shear stresses that are induced during driving. In addition, the surface of the piles tend to be relatively smooth and tend not to smear the soil along the pile surface during driving, which in turn reduces "drag down" of soil contamination. Furthermore, the potential for down drag of shallow contaminated soils during installation should be insignificant as the planned remedial action to stabilize these materials in-place will be completed prior to pile installation.

  Displacement piles have been installed at numerous locations throughout the San Francisco Bay Area, through areas of documented soil impacts. Representative

major-construction projects that installed displacement piles through impacted soil include the San Francisco Bay Area Rapid Transit SFO extension and the nearby Shellmound/Bay Street development. These local projects with similar site and soil/groundwater contaminant conditions support this choice of using displacement piles.

In the event that drilled piles are used, then the use of double-cased pile should be evaluated. However, CDM recommends using displacement piles such as prestressed precast concrete piles to prevent the need for casing or other special construction methods. As previously stated, displacement piles also provides the most cost beneficial foundation support for structures requiring deep foundation systems.

- **Driving piles through stabilized soils:** It is our experience that driving piles directly though stabilized soils without pre-drilling can result in damage to the piles, particularly concrete piles. Pre-drilling through stabilized soils using a small caisson drill rig may be required prior to pile driving.

Excavation Support

Removal of contaminated soil located to the north of the existing Building No. 31 and within the area of the raised cap will require an excavation support system due to the proximity of the excavation to adjacent structures and the property limits. As stated previously, excavation and/or in-situ treatment depths of up to 20 feet may be required. Excavation support systems consisting of continuous steel sheeting, soldier piles and lagging, seacant pile walls, or soil-mix walls are considered suitable excavation support systems. In addition, bracing and/or tiebacks may be required. The following is a brief summary of some of the key issues associated with each support system:

- **Continuous Sheeting:** The use of continuous steel sheeting will likely require pre-excavation along the wall alignment to remove obstructions. A vibratory hammer will be used to install the sheeting. Vibrations from a vibratory hammer are not expected to cause damage to adjacent structures but may be a temporary nuisance to adjacent residences/businesses. A steel sheet piling wall will be relatively water tight and thus, reduce site dewatering requirements.

- **Soldier Piles:** Soldier piles can be drilled, or installed into pre-drilled holes. Driven soldier piles can be installed with a vibratory hammer; however, installation using an impact hammer is more common. Provided proper construction methods are used vibrations from an impact hammer are not expected to cause damage to adjacent structures but will likely be a temporary nuisance to adjacent residences/businesses. Soldier piles installed in pre-drilled holes are not expected to result in significant vibrations. The lower portion of the drilled hole should be filled with concrete and the portion of the drilled hole above the lowest excavation level may be backfilled with soil. Some pre-excavation should be expected to remove underground obstructions prior to soldier pile installation. Timber lagging

is typically installed between the soldier piles, however, steel plates may be also be used. A soldier pile and lagging wall system is not considered to be a watertight wall system. Soldier piles that are driven in-place may be extracted once the site has been backfilled. Soldier piles concreted into pre-drilled holes will need to be cut-off and abandoned in place.

- **Seacant Pile Wall:** Seacant pile walls consist of concrete filled, overlapping drilled shafts. A steel section is installed in every other drilled shaft in order to provide sufficient strength to the wall system. Construction of a seacant pile wall system is not expected to result in significant vibrations. Pre-excavation should be expected to remove obstruction located along the wall alignment. A seacant pile wall system is considered to be a watertight wall system. In addition, the top of the wall will need to be cut-off and abandoned in place once the site is backfilled.

- **Soil-Mix Wall:** Soil-mix walls consist of overlapping soil-cement mix columns with a steel section is installed in each or every other column in order to provide sufficient strength to the wall system. Construction of a soil-mix wall system is not expected to result in significant vibrations. Pre-excavation should be expected to remove obstruction located along the wall alignment. A soil-mix wall system is considered to be a watertight wall system. In addition, the top of the wall will need to be cut-off and abandoned in place once the site is backfilled.

- **Bracing/Tiebacks:** Internal bracing and/or tiebacks should be expected to be required for excavation depths over about 15 feet. The actual depth that the excavation can extend without installing bracing will depend on the wall system used. It is not clear at this time if installation of tiebacks below city streets and railroad tracks will be permitted. In addition, installation of tiebacks may be hindered by unknown buried site obstructions. The presence of internal bracing inside the excavation will likely hamper excavation efforts whereas tiebacks allow for a wide-open excavation area.

Compacted Fill

All imported structural fills and backfills shall be predominantly granular, less than 3 inches in any dimensions, free of organic and inorganic debris and other deleterious materials, with less than 35 percent passing the No. 200 sieve. All fill and backfill materials should be observed and tested by the geotechnical engineer prior to their use in order to evaluate the suitability.

Granular structural fill should be placed in layers no thicker than 8 inches, as placed, and compacted with a self-propelled vibratory roller. Each layer of fill should be compacted to at least 95 percent of the maximum dry density as determined by ASTM-D1557. Lift thicknesses should be reduced to 4 inches in confined areas accessible only to hand guided compaction equipment.

Structural fill placed below foundations should extend at least 3 feet beyond the edge of foundations, then outward and downward at a slope of 1 horizontal to 1 vertical (1H:1V).

Closure

The recommendations contained herein are considered suitable for conceptual design level development evaluations associated with the proposed future development of the Sherwin-William's facility in Emeryville, CA as understood at this time and described herein. These recommendations have been prepared in accordance with generally accepted engineering practices. No other warranty, expressed or implied, is made. In the event that changes in the design or location of the structures occur, the conclusions and recommendations contained herein should not be considered valid unless verified in writing by CDM.

References

Abrahamson, N.H. and W.J, Silva, 1997. *Empirical Response Spectral Attenuation Relations for Shallow Crustal Earthquakes, Seismology Research Letter.* Volume 68, No.1.

California Geological Survey, 2003. *Seismic Hazard Zone Report for the West Oakland 7.5 Minute, Alameda County, Report 081 CA 2003.*

EQFAULT User's Manual. April 2000.

Jenning C.W., 1992. *Preliminary Fault Activity Map of California. California Division of Mines and Geology Open-File Report 92-3, Scale 1:750:000.*

ROMA Design Group, 2004. , Parcelization Map. ROMA Design Group in association with BKF Engineering for SRM Associates. May 17, 2004.

Uniform Building Code, 1997. *International Conference of Building Officials.* 1997.

WGCEP, Working Group on Northern California Earthquake Probabilities. 1996 *Database of Potential Sources for Earthquakes Larger Than Magnitude 6 in Northern California,* U.S. Geological Survey, Open File Report 96-705.

Attachments:

Figure 1 -	Site Location Map
Figure 2 -	Site Map
Figure 3 -	Isopach Map – Base of Layers 1 or 2
Table 1 –	Summary of Subsurface Explorations
Table 2 -	Summary of Geotechnical Laboratory Results
Appendix A -	Boring Logs
Appendix B -	Cone Penetrometer Test Results
Appendix C -	Geotechnical Laboratory Test Results
Appendix D -	EQFAULT Summary

Tables

Sherwin-Williams
1450 Sherwin Avenue
Emeryville, California

Table 1
SUMMARY OF SUBSURFACE EXPLORATIONS

Test Boring Number	Approximate Ground Surface EL [1]	Total Drilling Depth (ft)	Layer Thickness (ft)					Approximate Depth to Groundwater (ft) [2]
			Layer 1	Layer 2	Layer 3	Layer 4	Layer 5	
CDMSB-11		101.5	16	11	5 / 10	20 / 20 / >6.5	5 / 5	10
CDMSB-12		101.5	6	21	4 / 5 / >15.5	11/15/2011	13	10
B11		98	7	NE	7 / 2.5 / 4	3 / 8 / 3.5 / 26 / >34	3	NR
B12		81.5	10.5	NE	9	10.5 / >51.5	NE	13
B13		81	4	NE	4 / 11 / >7	8/21/2014	12	14
CPT-1 [3]		100.1	15	12	4 / 7	27 / 26 / >10	3	NR
CPT-2 [3]		100.1	22	10	8 / >24	11 / 19	6	NR
CPT-4 [3]		100.1	20	14	5 / 15	10 / 13 / >15	8	NR
CPT-5 [3]		100.1	5	27	1 / 2 / 9	12 / 21 / >8	4	NR
CPT-6 [3]		100.1	10	33	2 / 6	21 / >28	NE	NR
CPT-7 [3]		100.1	5	14	4 / 5 / 10 / >8	23 / 10 / 6 / 15	NE	NR

Notes:
1. Elevations based on Mean Sea Level (MSL) and are reported in feet.
2. Depth to groundwater is reported at the time of drilling.
3. CPT is an indirect means of investigation. Classification of Layer might be different.

Abbreviations:

NE	Not Encountered
NR	Not Recorded
>	Indicates Layer not fully penetrated
/	Indicates Layer is discontinuous. See test boring logs (Appendix A) for additional information.

Sherwin-Williams
1450 Sherwin Avenue
Emeryville, California

Table 2
SUMMARY OF LABORATORY TEST RESULTS

Test Boring Number	Sample Depth (ft)	Layer No.	Grain Size Analysis [1]			Atterberg Limits [2]			USCS Classification [3]
			Gravel %	Sand %	Fines %	LL (%)	PL (%)	PI (%)	
SB-12	15	2				31	15	16	CL
SB-11	18.5	2				34	15	19	
SB-11	21	2	26.8	52.3	20.9				SM
SB-11	25	2							
SB-12	25	2				46	13	33	
SB-11	27	5				30	14	16	
SB-11	30	5	27.7	61.2	11.1				SP-SM
SB-12	30	5				49	22	27	CL
SB-11	35	4							
SB-12	35	5	43.5	47.0	9.5				SW-SM
SB-11	40	4				36	16	20	
SB-12	40	4							
SB-11	45	4				33	15	18	
SB-12	45	4				33	15	18	
SB-11	55	5							
SB-12	60	4				70	16	54	
SB-11	65	4				39	20	19	CL
SB-12	65	4				47	16	31	
SB-12	70	3							

Notes:

1 Grain size analysis tests were conducted in accordance with ASTM D422.
2 Atterberg Limit tests were performed in accordance with ASTM D4318.
3 USCS classifications were performed in accordance with ASTM D2488.

Abbreviations:

LL Liquid Limit
PL Plastic Limit
PI Plasticity Index
CL Clay
SM Silty Sand
SP Poorly Graded Sand
SW Well Graded Sand

Sherwin-Williams
1450 Sherwin Avenue
Emeryville, California

Table 2
SUMMARY OF LABORATORY TEST RESULTS (continued)

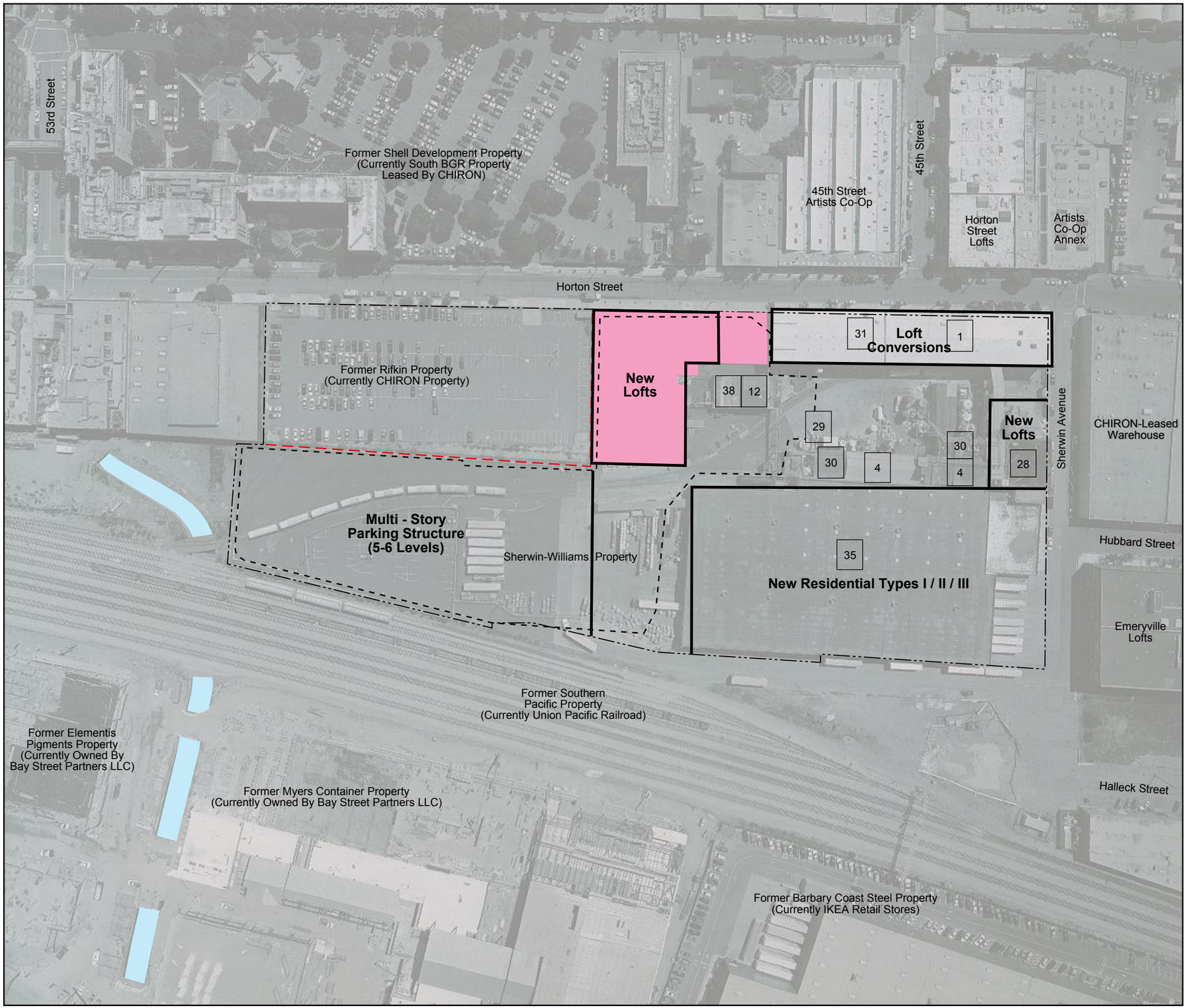
Test Boring Number	Sample Depth (ft)	Layer No.	Moisture Content (%)	Dry Unit Weight (pcf)	Total Unit Weight (pcf)	Consolidation Test [1]			Direct Shear Test [2]	
						PP (ksf)	CC (-)	CR (-)	Phi (deg)	C (psf)
SB-12	15	2							27.7	388
SB-11	18.5	2							23.5	303
SB-11	21	2								
SB-11	25	2	25.0	97.6	122.0					
SB-12	25	2				0.69	0.145	0.020		
SB-11	27	5							30.3	204
SB-11	30	5								
SB-12	30	5							26.0	859
SB-11	35	4	24.2	102.6	127.4	2.0	0.086	0.017		
SB-12	35	5								
SB-11	40	4								
SB-12	40	4	18.5	111.0	131.5	5.0	0.100	0.021		
SB-11	45	4	18.0	113.3	133.7				29.8	298
SB-12	45	4								
SB-11	55	5	16.2	118.9	138.2					
SB-12	60	4	25.8	99.8	125.5					
SB-11	65	4				4.5	0.089	0.021		
SB-12	65	4								
SB-12	70	3	17.5	114.3	134.3					

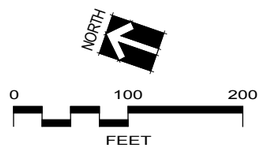
Notes:

1 Consolidation tests were performed in accordance with ASTM D2435
2 Direct shear tests were performed in accordance with ASTM D3080
3 Using CC = cc/(1+e0) with approximation cc = 0.007*(LL-10%)
4 Using approximation CR = 0.2*CC

Abbreviations:

PP Maximum past pressure.
CC Compression Ratio, (C_c/1+e_o)
CR Recompression Ratio, (C_r/1+eo)
Phi Friction Angle.
C Cohesion.





Legend

- Site Boundary
- Approximate Location of Slurry Wall
- Boundary Between S-W and Former Rifkin Property
- 1 — Building Number
- Raised Cap
- Temescal Creek

Figure 1
Conceptual Site Development Plan
Sherwin-Williams Company
Emeryville, California

CDM

N E S W

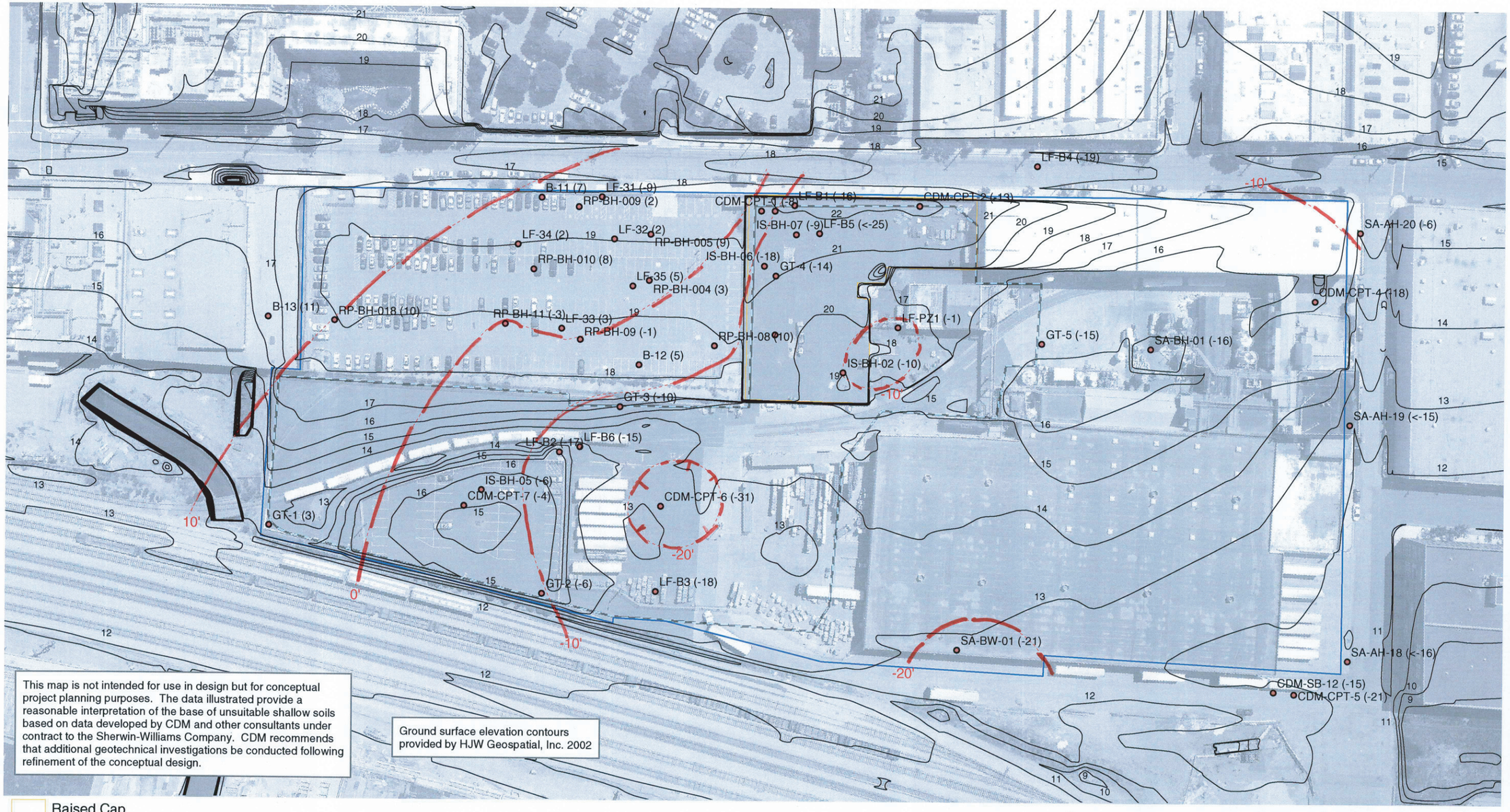
0 25 50 100 150 200 Feet

NAD83 California Stateplane III

Legend

- Extraction Well
- Approx Location Soil Boring By Others
- Approx Location Cone Penetromer Sounding (CDM, 2003)
- Approx Location Mud Rotary Boring (CDM, 2003)
- Temescal Creek
- Raised Cap
- Railroad Track
- Slurry Wall
- Boundary Between S-W and Former Rifkin Property

Figure 2
Boring Location Map
Sherwin-Williams Company
Emeryville, California



Raised Cap
Property Boundary
Slurry Wall
Inferred Elevation of Layers 1 and 2 (Contour Interval 10 Feet)
Ground Surface Elevation Contours (Ft. msl)
GT-1 (2.5)
Selected Soil Borings (Inferred Elev. of the Base of Layer 1 or Layer 2)

100 50 0 100 Feet
NAD83 California Stateplane III

N E S W

Figure 3
Isopach Map - Base of Layers 1 or 2
Sherwin-Williams Company
Emeryville, California

C:\arcgis\Projects\32581_Emeryville\contour_020504.mxd

Appendix A
Boring Logs

Boring Log CDMSB-11

Other Tests	Sample No.	Moisture Content (%)	Dry Density	PID (ppm)	Penetration Resistance (blows / 6 in.)	Depth (feet)	Sample	USCS	Symbol	DESCRIPTION	Elev. (feet)
	SB11-BULK							ML		Asphalt - 2 inches. SANDY SILT WITH GRAVEL, dark brown (10YR3/3), moist, 70% fine grained sand and silt, 25% gravel to 20 cm, and 5% dark gray-brown clay.	
	SB11-5			0.0	6 9 12			ML		SILT, dark brown (10YR3/3), moist, medium stiff, non-plastic, trace gravel to 0.5 cm, minor decayed vegetation.	
				0.0	3 6 6	10				SILTY SAND, dark yellowish-brown (10YR4/4), wet, medium dense, fine grained, 60% sand, 40% silt, some gravel, trace biotite, some gravel slough.	
	SB11-11			0.0	2 5 12			SM			
	SB11-15			0.0	3 3 3			GC		CLAYEY GRAVEL, very dark gray (10YR3/1), wet, 0.5 to 1 cm well rounded clasts.	
	SB11-18.5			0.0	400 lb			CH		CLAY, dark grayish-brown (10YR4/3), wet, mottled with orange-brown, medium to high plasticity.	
	SB11-21			0.0	5 8 8	20		SP		POORLY GRADED SAND WITH GRAVEL, very dark gray (10YR3/1), wet, medium dense, medium to coarse grained sand, 20% fine gravel to 0.5 cm, subangular to angular grains.	
	SB11-25			0.0	2 4 6			CL		CLAY, black (10YR2/1), wet, soft, medium to high plasticity, some gravel slough.	
	SB11-27			0.0	1500 lb			CL SP		GRAVELLY CLAY, dark yellowish-brown (10YR4/4), wet, gravel up to 1 cm.	
	SB11-30			0.0	6 10 9	30		SW		POORLY GRADED SAND WITH GRAVEL, very dark grayish-brown (10YR3/2), wet, medium dense, medium to coarse grained sand, trace gravel, some clay. WELL GRADED SAND, very dark grayish-brown (10YR3/2), wet, medium dense, coarse to medium grained, trace gravel.	
	SB11-35			0.0	4 7 11			CH		CLAY, grayish-brown (2.5YR5/2), moist, medium stiff, low to medium plasticity, medium toughness, stratified layers of brown (7.5YR4/4) oxidized clay, trace black organics, 3 inches of clayey gravel slough at 36.5 feet bgs.	
	SB11-40			0.0	2 3 6	40		CH		As above, medium stiff, no organics, no slough.	
	SB11-45			0.0	13 18 18			CL		GRAVELLY CLAY, gray (2.5Y5/1), moist, stiff, low plasticity, 15% well rounded gravel (chert and siltstone clasts) to 0.5 cm, abundant dark brown oxidation around edges of gravel clasts.	
	SB11-50			0.0	4 5 7	50		CH		CLAY, light olive-brown (2.5Y5/6), moist, medium stiff, medium plasticity, medium toughness, low dilatency.	
	SB11-55			0.0	14 39 38			SP SW		POORLY GRADED SAND, light yellowish-brown (2.5YR6/3), wet, fine to medium grained. WELL GRADED SAND WITH GRAVEL, dark yellowish-brown (10YR4/6), wet, very dense, medium to	

Location: Sherwin-Williams Emeryville
Surface Elevation:
Logged By: H. Young

Drill Rig: D-21
Equipment/Hammer: Mud Rotary/140 lb
Date Completed: 1-28-03

CDM

Sherwin-Williams
Sherwin-Williams Geotechnical Investigation
Emeryville, California

Boring Log CDMSB-11
Project No:

Figure:
1 of 2

BORING LOG SWGEOT.GPJ CDM_BLL.V.GDT 4/23/03 REV. 5

Boring Log CDMSB-11

Other Tests	Sample No.	Moisture Content (%)	Dry Density	PID (ppm)	Penetration Resistance (blows / 6 in.)	Depth (feet)	Sample	USCS	Symbol	DESCRIPTION	Elev. (feet)
	SB11-60			0.0	7 11 12			GC		coarse grained, 20% fine gravel (subrounded) to 0.5 cm, subangular grains, quartz and red chert composition. CLAYEY GRAVEL, light yellowish-brown (2.5Y6/3), wet, medium dense, 50% subanular gravel to 4 mm, clay is highly plastic.	
	SB11-65			0.0	7 9 14			CH		CLAY, grayish-brown (2.5Y5/2), moist, medium stiff, medium plasticity, low to medium toughness, mottled with brown (7.5YR4/4) clay, dark brown rootlets to 3 mm.	
	SB11-70			0.0	6 9 11	70		CH		CLAY, as above, moist, stiff, medium plasticity, 5% fine gravel (well rounded, red, light gray, and gray clasts) to 1 cm, dark brown rootlets.	
	SB11-75			0.0	16 24 32			CH		CLAY, light olive brown (2.5Y5/4), moist, very stiff, medium plasticity and toughness, slow dilatency, abundant dark brown rootlets.	
	SB11-80			0.0	4 5 8	80		CL		CLAY, as above, mottled pale olive (5Y6/3) and light olive-brown (2.5Y5/4), moist, stiff, low to medium plasticity, trace fine grained sand, trace white shell fragments.	
	SB11-85			0.0	24 29 35			SC		CLAYEY SAND WITH GRAVEL, dark yellowish-brown (10YR4/6), wet, medium dense, 40% sand, 30% clay, 30% gravel, sand is coarse grained to 3 mm, poorly graded, gravel is well rounded, 0.5 to 3 cm, spherical to oblate clasts, black, light gray, gray, and red.	
	SB11-90			0.0	18 22 24	90		SC		As above, dense, less gravel (15%).	
	SB11-95			0.0	11 15 24			CH		CLAY, light olive-brown (2.5Y5/4), moist, stiff, medium to high plasticity, medium toughness, trace black well rounded gravel to 0.5 cm.	
	SB11-100			0.0	6 12 14	100		CH		As above, very stiff.	
										Total depth 101.5 feet bgs. Borehole abandoned with Portland cement (10-94 lb bags Type I/II cement and 60 gallons of potable water) pumped through a 1-inch tremmie pipe to 100 feet bgs. Bentonite drilling mud and soil cuttings containerized in 55-gallon drums for characterization and disposal.	
						110					

Location: Sherwin-Williams Emeryville
Surface Elevation:
Logged By: H. Young

Drill Rig: D-21
Equipment/Hammer: Mud Rotary/140 lb
Date Completed: 1-28-03

CDM

Sherwin-Williams
Sherwin-Williams Geotechnical Investigation
Emeryville, California

Boring Log CDMSB-11
Project No:

Figure:
2 of 2

BORING LOG SWGEOT.GPJ CDM_BLLV.GDT 4/23/03 REV. 5

Boring Log CDMSB-12

Other Tests	Sample No.	Moisture Content (%)	Dry Density	PID (ppm)	Penetration Resistance (blows / 6 in.)	Depth (feet)	Sample	USCS	Symbol	DESCRIPTION	Elev. (feet)
								GP		Asphalt/concrete-5-inches.	
										GRAVEL, dark yellowish-brown (10YR4/4), moist, loose, angular to subangular clasts to 5 cm, some asphalt.	
	SB12-2.5			0.0			G	CL		CLAY, black (10YR2/1), moist, medium to low plasticity, slight organic odor.	
	SB12-5			0.0	4 3 4			GP		GRAVEL, gray, moist, loose, angular to subangular clasts to 4 cm, 20% clay.	
										CLAY, very dark gray (10YR3/1), moist, soft, high plasticity, high toughness, trace gravel to 0.5 cm, odor like decayed vegetation.	
	SB12-10			0.0	1 1 1	10		CH			
	SB12-15			0.0	1 4 5			CH		CLAY, very dark grayish-brown (10YR3/2), moist, soft, high plasticity and toughness, trace decayed rootlets to 1 cm, strong odor like decayed vegetation.	
	SB12-20			0.0	2 4 6	20		CH		SILTY CLAY, dark gray (10YR4/1), moist, medium stiff, high plasticity, high toughness, mottled with orange-brown clay, trace gravel to 4 mm, well rounded, white and gray clasts.	
	SB12-25			0.0	300 lb			CH		CLAY, grayish-brown (2.5Y5/2), wet, firm, high plasticity, high toughness, trace fine sand.	
								SP		GRAVELLY SAND, dark grayish-brown (2.5Y4/2), wet, medium dense, fine to medium grained, 10% fine gravel to 0.5 cm, subangular to subrounded grains, gray, white, and red clasts.	
	SB12-30			0.0	12 15 17	30		CH		CLAY, grayish-brown (2.5Y5/2) mottled with light olive-brown (2.5Y5/6), moist, stiff, high plasticity, stratified, minor dark brown organics.	
								GM		SILTY GRAVEL, dark yellowish-brown (10YR4/4), wet, medium dense, medium grained sand to medium gravel, 20% silt, well rounded gravel clasts to 2 cm, gray and white clasts, some stratification of clasts, gravel contact at 32.5 feet bgs infered by drill rig chatter.	
	SB12-35			0.0	7 9 16			GM		As above, medium dense.	
	SB12-40			0.0	6 11 13	40		CH		CLAY, light olive-brown (2.5Y5/3), wet, stiff, high plasticity, high toughness, some mottling, 6 inches of gravel slough.	
	SB12-45			0.0	3 5 7			CH		SILTY CLAY, light olive-brown (2.5Y5/3) with stratified layers of yellowish-brown (10YR5/6) clay, moist, medium stiff, medium plasticity low to medium toughness.	
	SB12-50			0.0	6 8 11	50		CH		50 - 50.5 feet bgs: yellow-brown stratification of 2 mm fine grained sand layers.	
								SC		50.5 - 51 feet bgs: trace 3 mm white gravel and shell fragments.	
	SB12-55			0.0	3 4 4			CH		CLAYEY SAND, light olive-brown (2.5Y5/4), wet, loose, fine to coarse grained, trace fine gravel and shell fragments to 0.5 cm, angular to subrounded grains.	
										CLAY, light olive-gray (5Y6/2), moist, medium stiff, high plasticity, medium toughness.	
										55.5 feet bgs: 2-inch clayey sand layer, stratified.	

Location: Sherwin-Williams Emeryville
Surface Elevation:
Logged By: H. Young

Drill Rig: D-21
Equipment/Hammer: Mud Rotary/140 lb
Date Completed: 1-29-03

CDM

Sherwin-Williams
Sherwin-Williams Geotechnical Investigation
Emeryville, California

Boring Log CDMSB-12
Project No:

Figure:
1 of 2

BORING LOG SWGEOT.GPJ CDM_BLLV.GDT 4/23/03 REV. 5

Boring Log CDMSB-12

Other Tests	Sample No.	Moisture Content (%)	Dry Density	PID (ppm)	Penetration Resistance (blows / 6 in.)	Depth (feet)	Sample	USCS	Symbol	DESCRIPTION	Elev. (feet)
	SB12-60			0.0	7 10 12			CH		56 feet bgs: color changes to dark greenish gray (1 FOR GLEY4/1). CLAY, light olive-gray (5Y6/2), wet, medium stiff, high plasticity and toughness, 2% of sample comprises 1-2 mm, black (10YR2/1) round voids and organic fragments.	
	SB12-65			0.0	4 8 9			CH		At 60 - 60.5 feet bgs, trace coarse sand to 4 mm, well rounded, red and white. CLAY, pale olive (5Y6/3), wet, stiff, high plasticity, abundant black (10YR2/2) sand grains to 2 mm, trace gravel to 2 cm, light gray with dark brown and black iron oxide coating, well rounded, siltstone composition.	
	SB12-70			0.0	50 50/4"	70		GC		CLAYEY GRAVEL, yellowish-brown (10YR5/6), wet, very dense, 70% gravel, red and black clasts, 0.5 to 3 cm, well rounded, siltstone composition, high plasticity clay matrix.	
	SB12-75			0.0	8 12 12					SANDY CLAY WITH GRAVEL, moist, very stiff, medium plasticity, 15% fine grained sand, 5% fine gravel to 0.5 cm, gravel is white, light gray, and red chert, well rounded, trace white shell material to 3 mm, thin and soft.	
	NR				27 29 33	80		CH			
	SB12-85A SB12-85B			0.0	29 45 42			CH		CLAY, grayish-brown (2.5Y5/2), wet, firm, high plasticity, minor dark brownish-gray mottling, firm.	
								SC		CLAYEY SAND WITH GRAVEL, grayish-brown (10YR5/2), wet, medium dense, 60% sand, 30% clay/silt, 10% gravel, sand is fine to coarse grained, gravel up to 1 cm, subrounded clasts, black, red, and light gray.	
	SB12-90			0.0	6 8 14	90		ML		SILT, yellowish-brown (10YR5/4), wet, firm, low to medium plasticity, trace fine sand, trace rootlets, <2 mm.	
								SC		CLAYEY SAND, yellowish-brown (10YR5/4), wet, medium dense, fine to medium grained.	
	NR				16 19 24						
	SB12-96.5			0.0	16 27 29			CL		GRAVELLY CLAY, pale olive (5Y6/3), moist, low to medium plasticity, 15% gravel to 0.5 cm, well rounded, black iron oxide around edges.	
								SC		CLAYEY SAND WITH GRAVEL, yellowish brown (10YR5/4), wet, medium dense, 50% fine to coarse grained sand, 30% clay, 20% well rounded gravel to 1 cm, black and gray clasts, abundant black iron oxide around grains.	
	SB12-100			0.0	12 16 22	100		CL		GRAVELLY CLAY, yellowish-brown (10YR5/8), wet, very stiff, low plasticity, gravel to 0.5 cm, white shell fragments.	
										Total depth 101.5 feet bgs. Borehole abandoned with Portland cement (10-94 lb bags Type I/II cement and 60 gallons of potable water) pumped through a 1-inch tremmie pipe to 100 feet bgs. Bentonite drilling mud and soil cuttings containerized in 55-gallon drums for characterization and disposal.	
						110					

Location: Sherwin-Williams Emeryville
Surface Elevation:
Logged By: H. Young

Drill Rig: D-21
Equipment/Hammer: Mud Rotary/140 lb
Date Completed: 1-29-03

Sherwin-Williams
Sherwin-Williams Geotechnical Investigation
Emeryville, California

CDM

Boring Log CDMSB-12
Project No:

Figure:
2 of 2

BORING LOG SWGEOT.GPJ CDM_BLLV.GDT 4/23/03 REV. 5

Boring Logs – Chiron, Geomatrix (1994)

PROJECT: CHIRON CAMPUS EXPANSION PROJECT
Emeryville, California

Log of Boring No. B11

BORING LOCATION: 490799.5N, 1483583.7E

DATE STARTED: 9/29/94 | DATE FINISHED: 9/29/94

DRILLING METHOD: Hollow stem auger/rotary wash

HAMMER WEIGHT: 140 lbs | DROP: 30 inches

SAMPLER: See Explanation, Figure A-1

NOTES:
Logged by: E. Chase
Drilling Equipment: Mobile B-53
Drilling Contractor: RNL Enterprises

Surface Elevation: +14.2 feet

DEPTH (feet)	Sample No.	Sample	Blows/ Foot	MATERIAL DESCRIPTION	Moisture Content (%)	Dry Density (pcf)	Unconf. Comp. Str. (psf)
0				2 inches ASPHALT CONCRETE over 5.5 inches CONCRETE			
1-3	1		26	SILTY SAND (SM) Medium dense, dark yellowish brown, dry, fine to medium gravel, some clay [FILL] GMTX-11A PID = 0 ppm -#200 = 16%	---	---	---
4-6	2		22	SANDY CLAY (CL) Stiff, dark brown to black with red [FILL] GMTX-11B PID = 0 ppm	25	93	---
7-9				SANDY CLAY (CL) Stiff, brown			
10-12	3		13	CLAYEY GRAVEL with SAND (GC) Medium dense, dark olive brown, moist, fine to coarse sand Loose, olive green, hydrocarbon odor	---	---	---
13-19	4		2	SANDY CLAY with SILT (CL) Very soft, dark gray, wet	---	---	---
20	5	Shelby	25 - 200 psi		25	102	200
21-24				SILTY SAND (SM) Stiff, olive brown, fine to medium			
25-27	6		44	CLAYEY SAND with GRAVEL (SC) Dense, olive green, fine to coarse	---	---	---
28-30				SANDY CLAY (CL) Medium stiff to stiff, olive green, fine sand			

DRAFT

gt-1-88

Project No. 2803 | Geomatrix Consultants | Figure A-12

PROJECT: CHIRON CAMPUS EXPANSION PROJECT
Emeryville, California

Log of Boring No. B11 (cont'd.)

DEPTH (feet)	SAMPLES Sample No.	SAMPLES Sample	SAMPLES Blows/Foot	MATERIAL DESCRIPTION	LABORATORY TESTS Moisture Content (%)	LABORATORY TESTS Dry Density (pcf)	LABORATORY TESTS Unconf. Comp. Str. (psf)
31	7		41	SANDY CLAY (CL) (continued)	---	---	---
32				CLAYEY SAND with GRAVEL (SC) Dense, mottled yellowish brown, olive brown and light gray, fine to coarse sand, fine gravel			
34							
35	8		20	SANDY CLAY (CL) Stiff, mottled olive brown, gray, and yellowish brown, fine sand			
36				Fine to coarse sand, some gravel	29	95	3900
37							
38							
39							
40	9		19	SILTY CLAY with SAND (CL) Stiff to very stiff, mottled olive gray and rust brown, fine sand	20	105	---
42				SANDY CLAY (CH) Very stiff, light gray with black, fine sand			
44							
45				SANDY CLAY with GRAVEL (CL) Very stiff, mottled olive brown and yellowish brown, fine to coarse sand, fine gravel			
46							
47							
48							
49							
50	10		50				
51					16	118	3850
52				SANDY CLAY (CL) Stiff, dark yellowish brown, fine sand			
53							
54							
55							
56							
57							
58							
59							
60	11		60	CLAYEY SAND with GRAVEL (SC) Very dense, dark olive brown, fine to coarse sand, fine gravel	---	---	---
62							
63							
64							

DRAFT

gt-2-88

Emeryville, California

Log of Boring No. B11 (cont'd.)

DEPTH (feet)	SAMPLES Sample No.	SAMPLES Sample	SAMPLES Blows/Foot	MATERIAL DESCRIPTION	LABORATORY TESTS Moisture Content (%)	LABORATORY TESTS Dry Density (pcf)	LABORATORY TESTS Unconf. Comp. Str. (psf)
65				SILTY CLAY (CL) Very stiff, light olive, some fine sand			
66							
67							
68				Gravel and sand			
69							
70							
71	12		31		28	96	5300
72							
73							
74							
75				SANDY CLAY (CL) Very stiff, mottled olive brown and yellowish brown, fine to coarse sand			
76							
77							
78							
79							
80	13		20	Mottled light olive and olive brown, some gravel	17	115	---
81							
82							
83							
84							
85							
86							
87							
88							
89							
90							
91	14		44	Olive brown	---	---	---
92				Fine sand, no gravel			
93				SANDY CLAY with GRAVEL (CL) Very dense, olive brown			
94							
95				Bottom of boring at 98.0 feet. Boring drilled using hollow stem augers to 36 feet; approximately 20 gallons of groundwater pumped from hollow stem augers; boring advanced to bottom using rotary wash drilling. Boring backfilled with cement bentonite grout.			
96							
97	15		50/6"		---	---	---
98							

DRAFT

gt-2-88

PROJECT: CHIRON CAMPUS EXPANSION PROJECT
Emeryville, California

Log of Boring No. B12

BORING LOCATION: 490572.6N, 1483467.3E

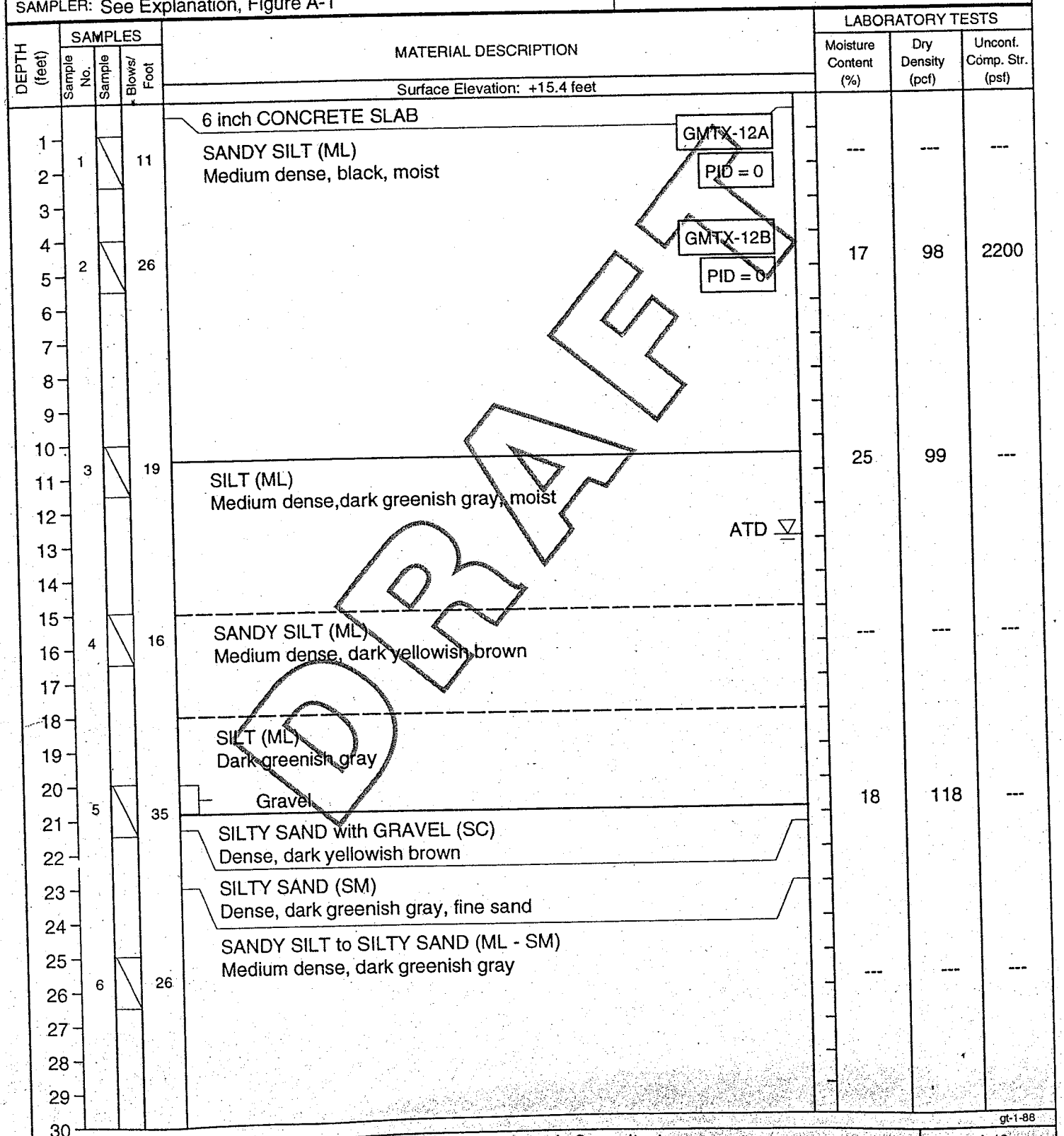
DATE STARTED: 9/17/94 | DATE FINISHED: 9/17/94

DRILLING METHOD: Hollow stem auger/rotary wash

HAMMER WEIGHT: 140 lbs | DROP: 30 inches

SAMPLER: See Explanation, Figure A-1

NOTES:
Logged by: J. Abitz
Drilling Equipment: CME 550
Drilling Contractor: RNL Enterprises



DRAFT

gt-1-88

Project No. 2803 | Geomatrix Consultants | Figure A-13

PROJECT: CHIRON CAMPUS EXPANSION PROJECT
Emeryville, California

Log of Boring No. B12 (cont'd.)

DEPTH (feet)	SAMPLES: Sample No.	SAMPLES: Sample	SAMPLES: Blows/Foot	MATERIAL DESCRIPTION	LABORATORY TESTS: Moisture Content (%)	LABORATORY TESTS: Dry Density (pcf)	LABORATORY TESTS: Unconf. Comp. Str. (psf)
31	7		52	SANDY CLAY (CL) Very stiff to hard, dark greenish gray	20	110	4900
32							
33							
34							
35				With gravel, dark yellowish brown			
36							
37							
38							
39							
40	8		45		24	101	---
41				SILTY CLAY (CL) Hard, dark greenish gray			
42							
43							
44							
45							
46							
47							
48							
49							
50	9		63		24	103	4400
51							
52							
53							
54							
55				GRAVELLY CLAY with SAND (CL) Hard, dark yellowish brown			
56							
57							
58							
59							
60	10		50/5"		---	---	---
61							
62							
63							
64							

DRAFT

gt-2-88

PROJECT: CHIRON CAMPUS EXPANSION PROJECT
Emeryville, California

Log of Boring No. B12 (cont'd.)

DEPTH (feet)	SAMPLES: Sample No.	SAMPLES: Sample	SAMPLES: Blows/Foot	MATERIAL DESCRIPTION	LABORATORY TESTS: Moisture Content (%)	LABORATORY TESTS: Dry Density (pcf)	LABORATORY TESTS: Unconf. Comp. Str. (psf)
65				GRAVELLY CLAY with SAND (CL) (continued)			
66							
67							
68							
69							
70							
71				SILTY CLAY (CL) Hard, light yellowish brown			
72							
73							
74							
75							
76							
77							
78							
79							
80	11		59		26	98	---
81							
82				Bottom of boring at 81.5 feet. Boring drilled using hollow stem augers to 25 feet; approximately 1 gallon of groundwater bailed from hollow stem augers; boring advanced to bottom using rotary wash drilling. Boring backfilled with cement bentonite grout.			
83							
84							
85							
86							
87							
88							
89							
90							
91							
92							
93							
94							
95							
96							
97							
98							

DRAFT

gt-2-88

PROJECT: CHIRON CAMPUS EXPANSION PROJECT
Emeryville, California

Log of Boring No. B13

BORING LOCATION: 490826.6N, 1483410.0E

DATE STARTED: 9/16/94 | DATE FINISHED: 9/16/94

DRILLING METHOD: Hollow stem auger/rotary wash

HAMMER WEIGHT: 140 lbs | DROP: 30 inches

SAMPLER: See Explanation, Figure A-1

NOTES:
Logged by: J. Abitz
Drilling Equipment: CME 550
Drilling Contractor: RNL Enterprises

Surface Elevation: +15.4 feet

DEPTH (feet)	Sample No.	Sample	Blows/ Foot	MATERIAL DESCRIPTION	Moisture Content (%)	Dry Density (pcf)	Unconf. Comp. Str. (psf)
0				12 inches CONCRETE SLAB			
1	1		28	CLAYEY SILT (ML) Medium dense, very dark brown, trace gravel GMTX-13A PID = 0	18	89	---
4	2		12	CLAYEY SAND (SC) Medium dense, olive brown, trace gravel, moist GMTX-13B PID = 0	---	---	---
8	3		7	CLAYEY SILT (ML - CL) Medium stiff, dark greenish gray ATD ▽	31	89	---
15	4	SHELBY	50-250 psi		---	---	---
16				GRAVELLY SILT (ML) Medium dense, black, grayish green, fine sand, trace calcareous deposits			
20	5	SHELBY	---		22	108	700
25	6		15		19	106	---
28				SANDY CLAY with GRAVEL (CL) Very stiff to hard, greenish gray with dark yellowish brown, fine sand			
30							

DRAFT

gt-1-88

PROJECT: CHIRON CAMPUS EXPANSION PROJECT
Emeryville, California

Log of Boring No. B13 (cont'd.)

DEPTH (feet)	SAMPLES Sample No.	SAMPLES Sample	SAMPLES Blows/Foot	MATERIAL DESCRIPTION	LABORATORY TESTS Moisture Content (%)	LABORATORY TESTS Dry Density (pcf)	LABORATORY TESTS Unconf. Comp. Str. (psf)
65–69				SANDY CLAY (CL) (continued)			
70–71	12		75		---	---	---
72–74							
74–81				CLAYEY SAND with GRAVEL (SC) Very dense, dark yellowish brown			
80	13		50/4"		---	---	---
81				Bottom of boring at 81.0 feet. Boring drilled using hollow stem augers to 25 feet; approximately 15 gallons of groundwater bailed from hollow stem augers; boring advanced to bottom using rotary wash drilling. Boring backfilled with cement bentonite grout.			
82–98							

DRAFT

gt-2-88

Project No. 2803 | Geomatrix Consultants | Figure A-14 (cont.)

Appendix B
Cone Penetration Test Results

PRESENTATION OF CONE PENETRATION TEST DATA

SHERWIN WILLIAMS

1450 SHERWIN AVENUE
EMERYVILLE, CALIFORNIA

Prepared for:

CDM

Prepared by:

GREGG IN SITU, INC.
Martinez, California
03-027ma

Prepared on:

February 4, 2003

TABLE OF CONTENTS

1.0 INTRODUCTION

2.0 FIELD EQUIPMENT & PROCEDURES

3.0 CONE PENETRATION TEST DATA & INTERPRETATION

3.1 CPT PLOTS
3.2 INTERPRETED OUTPUT
3.3 PORE PRESSURE DISSIPATION PLOTS

APPENDIX

- Figure 1 Piezocone Figure
- Figure 2 PPDT Correlation Figure
- Figure 3 Soil Classification Chart
- References

ATTACHMENTS

- Interpretation Method
- Computer Diskette with ASCII Files

PRESENTATION OF CONE PENETRATION TEST DATA

1.0 INTRODUCTION

This report presents the results of a Cone Penetration Testing (CPT) program carried out at the Sherwin Williams site located in Emeryville, CA. The work was performed on January 29th, 2003. The scope of work was performed as directed by CDM personnel.

2.0 FIELD EQUIPMENT & PROCEDURES

The Cone Penetration Tests (CPT) were carried out by GREGG IN SITU, INC. of Martinez, CA using an integrated electronic cone system. The CPT soundings were performed in accordance with ASTM standards (D 5778-95). A 20 ton capacity cone was used for all of the soundings (figure 1). This cone has a tip area of 15 cm^2 and friction sleeve area of 225 cm^2. The cone is designed with an equal end area friction sleeve and a tip end area ratio of 0.85.

The cones used during the program recorded the following parameters at 5 cm depth intervals:

- Tip Resistance (qc)
- Sleeve Friction (fs)
- Dynamic Pore Pressure (U)

The above parameters were printed simultaneously on a printer and stored on a computer diskette for future analysis and reference.

The pore water pressure element was located directly behind the cone tip. The pore water pressure element was 5.0 mm thick and consisted of porous plastic. Each of the elements were saturated in silicon oil under vacuum pressure prior to penetration. Pore pressure dissipations were recorded at 5 second intervals when appropriate during pauses in the penetration.

A complete set of baseline readings was taken prior to each sounding to determine temperature shifts and any zero load offsets. Monitoring base line readings ensures that the cone electronics are operating properly.

The cones were pushed using GREGG IN SITU's CPT rig, having a down pressure capacity of approximately 20 tons. Six CPT soundings were performed. The penetration tests were carried to depths of approximately 100 feet below ground surface. Test locations and depths were determined in the field by CDM personnel.

3.0 CONE PENETRATION TEST DATA & INTERPRETATION

The cone penetration test data is presented in graphical form. Penetration depths are referenced to existing ground surface. This data includes CPT logs of measured soil parameters and a computer tabulation of interpreted soil types along with additional geotechnical parameters and pore pressure dissipation data.

The stratigraphic interpretation is based on relationships between cone bearing (qc), sleeve friction (fs), and penetration pore pressure (U). The friction ratio (Rf), which is sleeve friction divided by cone bearing, is a calculated parameter which is used to infer soil behavior type. Generally, cohesive soils (clays) have high friction ratios, low cone bearing and generate large excess pore water pressures. Cohesionless soils (sands) have lower friction ratios, high cone bearing and generate little in the way of excess pore water pressures.

Pore Pressure Dissipation Tests (PPDT's) were taken at various intervals in order to measure hydrostatic water pressures and approximate depth to groundwater table. In addition, the PPDT data can be used to estimate the horizontal permeability (k_h) of the soil. The correlation to permeability is based on the time required for 50 percent of the measured dynamic pore pressure to dissipate (t_{50}). The PPDT correlation figure (figure 2) is provided in the Appendix.

The interpretation of soils encountered on this project was carried out using recent correlations developed by Robertson et al, 1990. It should be noted that it is not always possible to clearly identify a soil type based on qc, fs and U. In these situations, experience and judgement and an assessment of the pore pressure dissipation data should be used to infer the soil behavior type. The soil classification chart (figure 3) used to interpret soil types based on qc and Rf is provided in the Appendix.

Interpreted output requires that depth of water be entered for calculation purposes, where depth to water is unknown an arbitrary depth in excess of 10 feet of the deepest sounding is entered as the groundwater depth.

GREGG IN SITU, INC.
February 4, 2003
03-027ma

CDM
Sherwin Williams
Emeryville, Ca.

We hope the information presented is sufficient for your purposes. We recommend that all data be carefully reviewed by qualified personnel to verify the data and make appropriate recommendations. If you have any questions, please do not hesitate to contact our office at (925) 313-5800.

Sincerely,
GREGG IN SITU, INC.

Mary Walden
Operations Manager

APPENDIX

ELECTRICAL PIEZOCONE

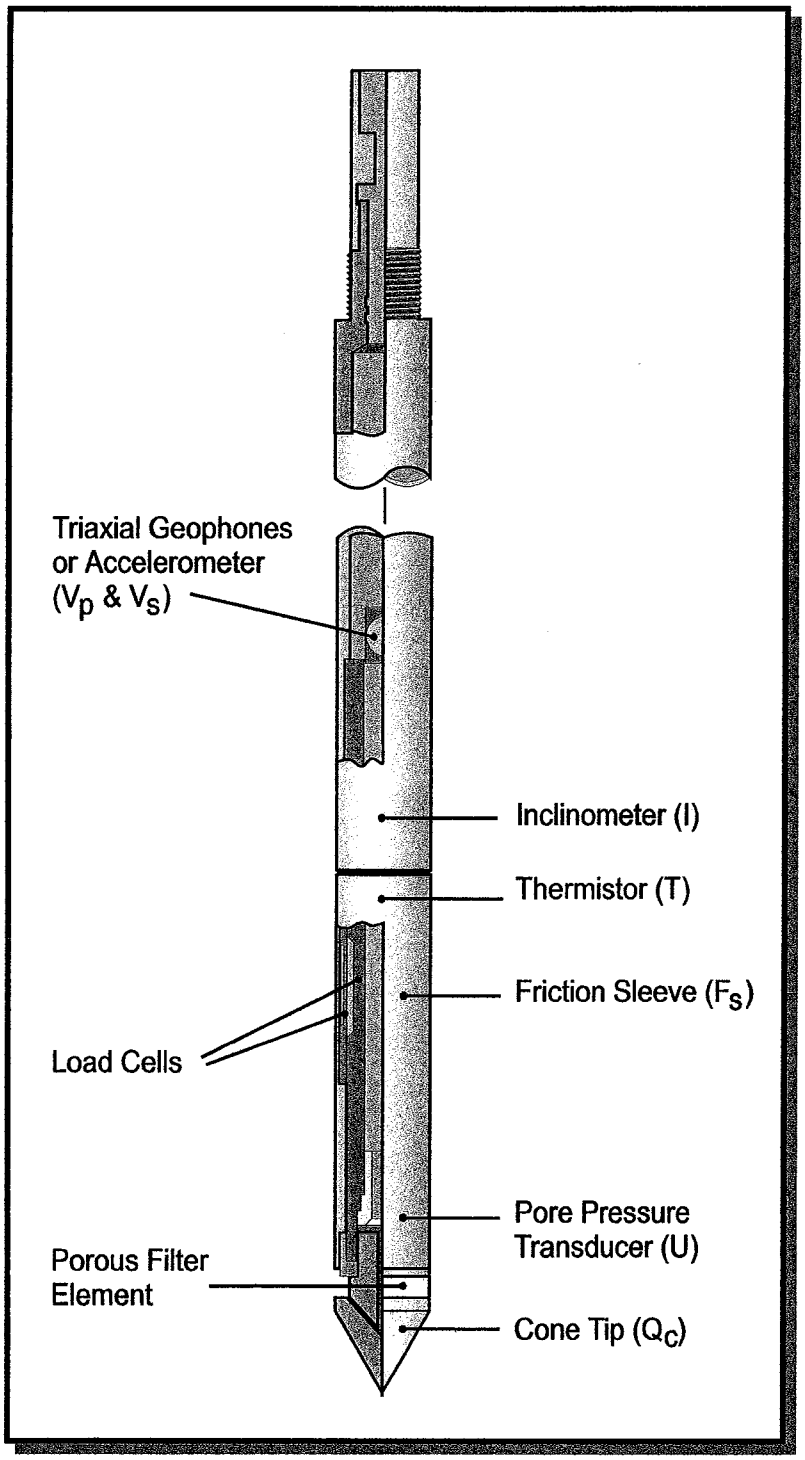
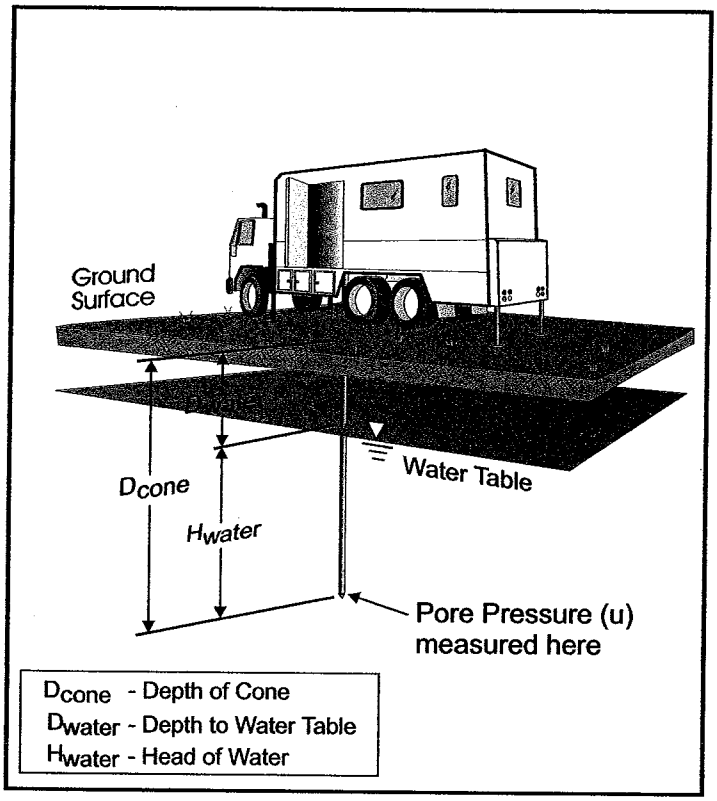
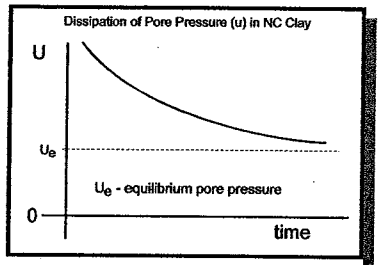
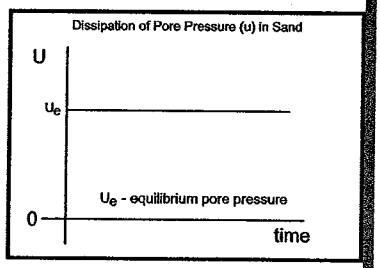


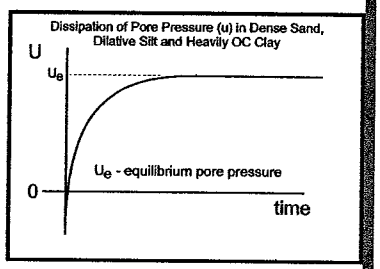
Figure 1

INTERPRETATION PORE PRESSUE DATA AND DISSIPATIONS









Water Table Calculation

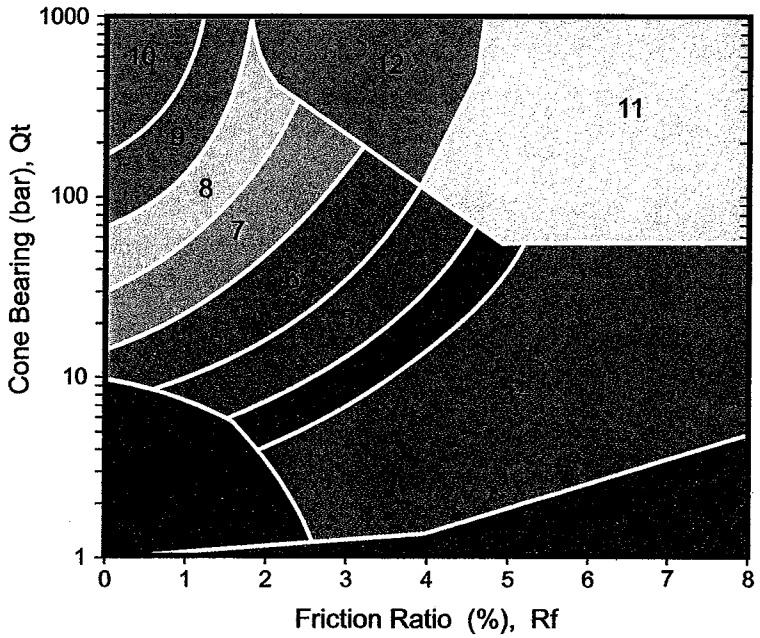
$$D_{water} = D_{cone} - H_{water}$$

where $H_{water} = U_e$ (depth units)

Useful Conversion Factors: 1psi = 0.704m = 2.31 feet (water)
1tsf = 0.958 bar = 13.9 psi
1m = 3.28 feet

Figure 2

SOIL BEHAVIOR TYPE



Zone	Q_t / N	Soil Behaviour Type
1	2	sensitive fine grained
2	1	organic material
3	1	clay
4	1.5	silty clay to clay
5	2	clayey silt to silty clay
6	2.5	sandy silt to clayey silt
7	3	silty sand to sandy silt
8	4	sand to silty sand
9	5	sand
10	6	gravelly sand to sand
11	1	very stiff fine grained *
12	2	sand to clayey sand *

* overconsolidated or cemented

Robertson (1990)

Figure 3

REFERENCES

Robertson, P.K. and Campanella, R.G. and Wightman, A., 1983 "SPT-CPT Correlations", Journal of the Geotechnical Division, ASCE, Vol. 109, No. GT11, Nov., pp. 1449-1460.

Robertson, P.K. and Wride C.E., 1998 "Evaluating Cyclic Liquefaction Potential Using The Cone Penetration Test", Journal of Geotechnical Division, Mar. 1998, pp. 442-459.

Robertson, P.K. and Campanella, R.G., Gillespie, D. and Greig, J., 1986, "Use of Piezometer Cone Data", Proceedings of In Situ 86, ASCE Specialty Conference, Blacksburg, Virginia.

Robertson, P.K. and Campanella, R.G., 1988, "Guidelines for Use, Interpretation and Application of the CPT and CPTU", UBC, Soil Mechanics Series No. 105, Civil Eng. Dept., Vancouver, B.C., V6T 1W5, Canada.

Robertson, P.K., Campanella, R.G., Gillespie, D. and Rice, A., 1986, "Seismic CPT to Measure In Situ Shear Wave Velocity", Journal of Geotechnical Engineering, ASCE, Vol. 112, No. 8, pp. 791-803.

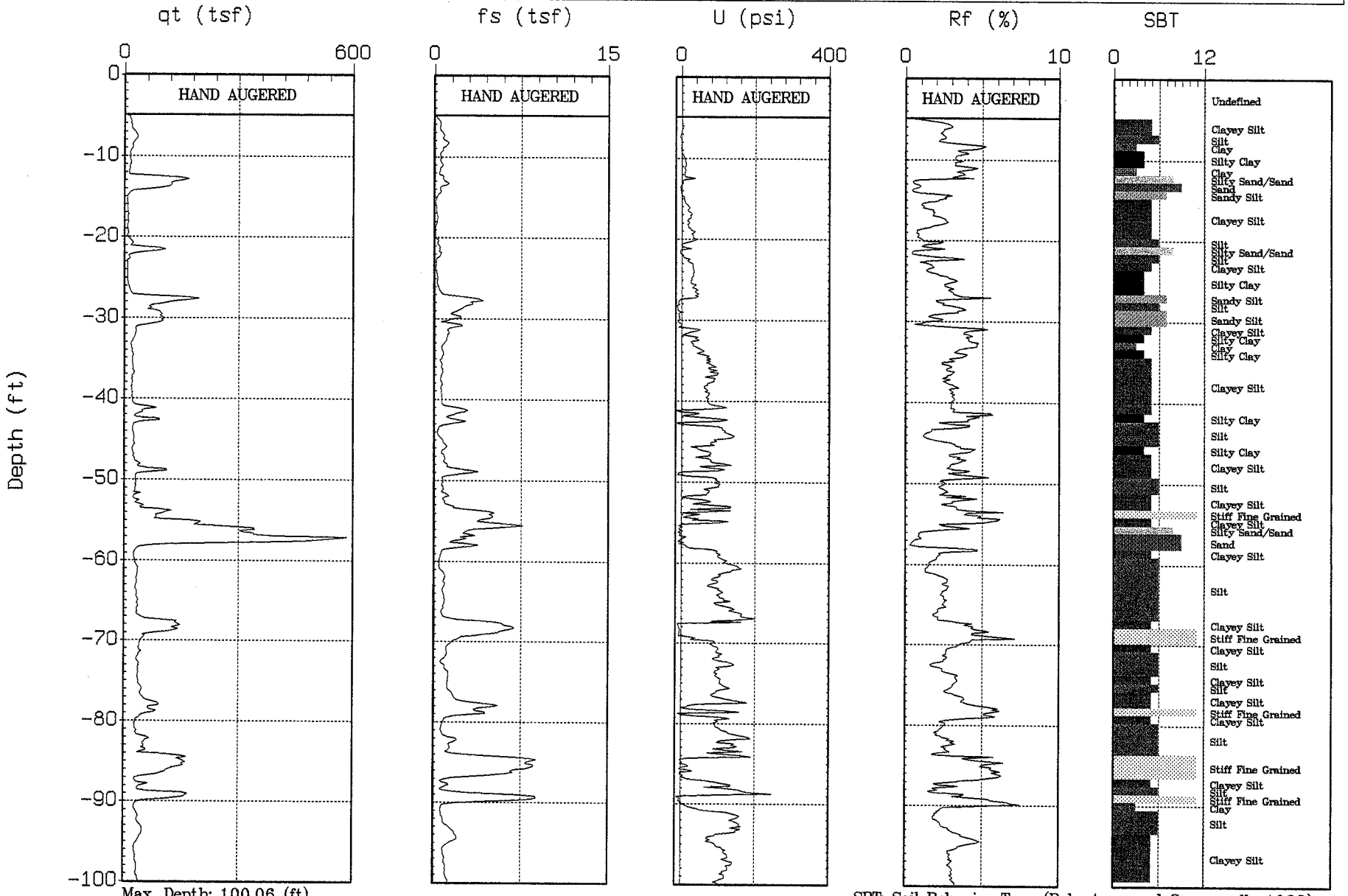
3.1 CPT PLOTS

GREGG

CDM

Site : SHERWIN WILLIAMS
Location : CPT-01

Engineer : H. YOUNG
Date : 01:29:03 11:54



Max. Depth: 100.06 (ft)

Depth Inc.: 0.164 (ft)

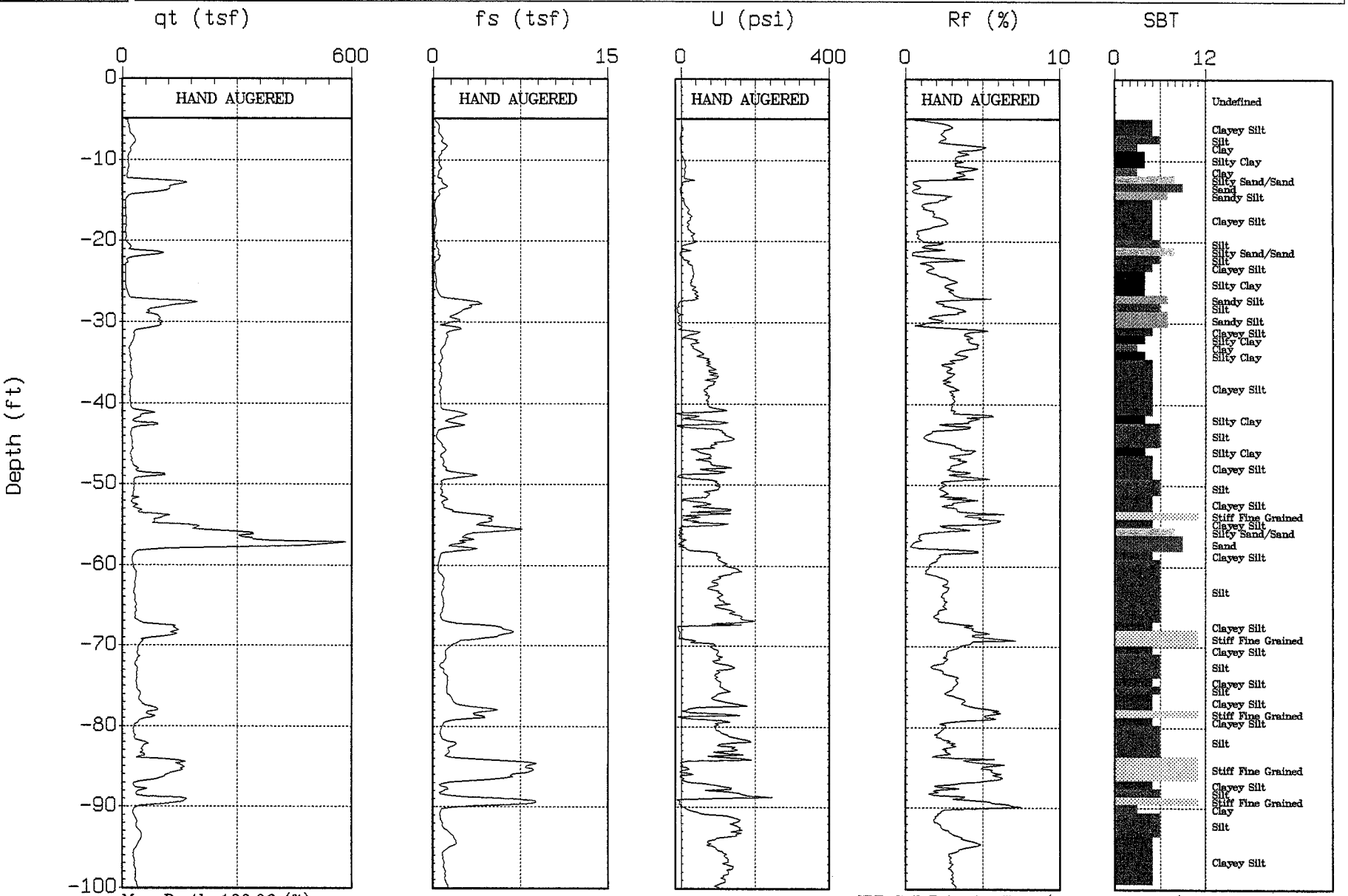
SBT: Soil Behavior Type (Robertson and Campanella 1988)

GREGG

CDM

Site : SHERWIN WILLIAMS
Location : CPT-01

Engineer : H. YOUNG
Date : 01:29:03 11:54



Max. Depth: 100.06 (ft)

Depth Inc.: 0.164 (ft)

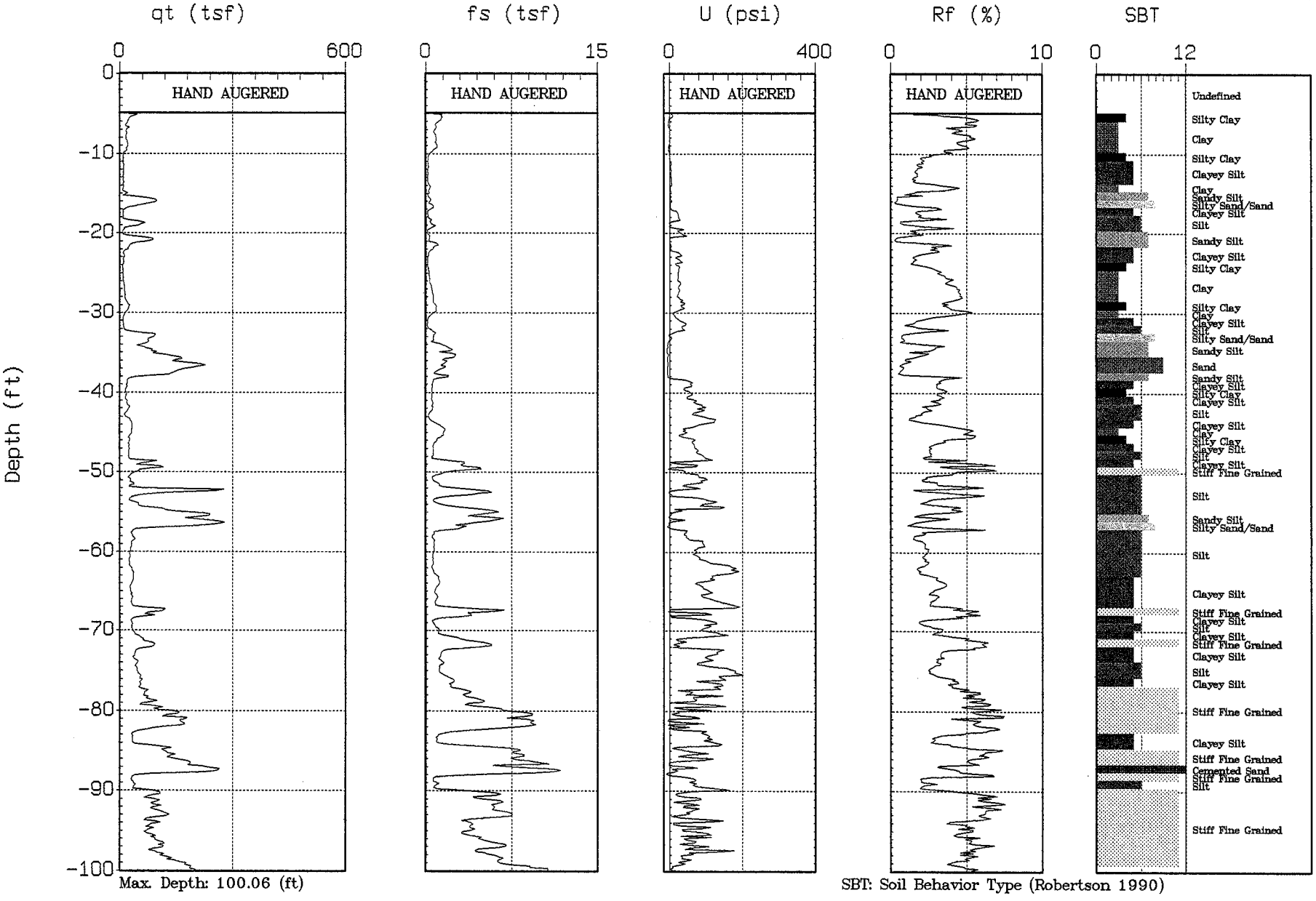
SBT: Soil Behavior Type (Robertson 1990)

GREGG

CDM

Site : SHERWIN WILLIAMS
Location : CPT-02

Engineer : H. YOUNG
Date : 01:29:03 09:33



Max. Depth: 100.06 (ft)

Depth Inc.: 0.164 (ft)

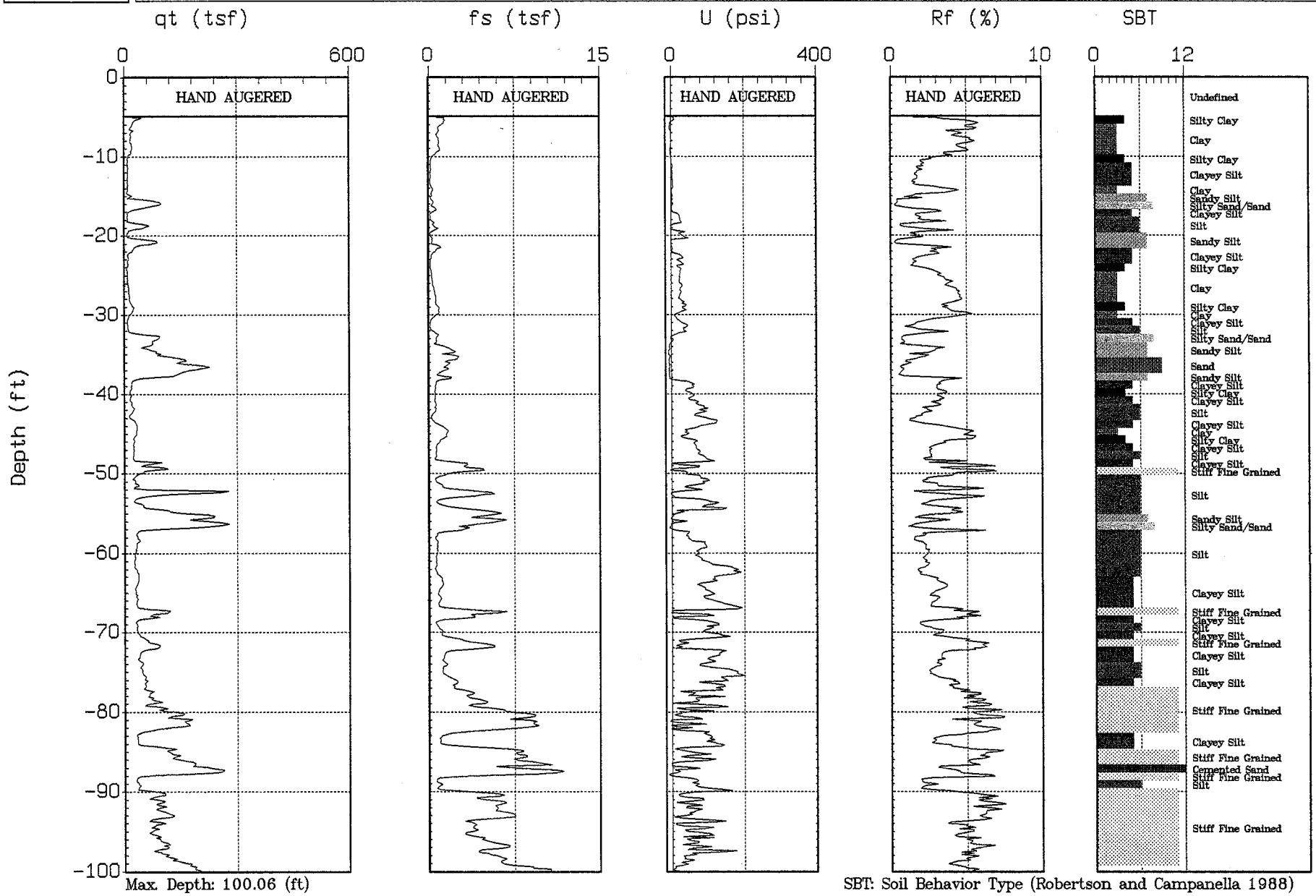
SBT: Soil Behavior Type (Robertson 1990)

GREGG

CDM

Site : SHERWIN WILLIAMS
Location : CPT-02

Engineer : H. YOUNG
Date : 01:29:03 09:33



Max. Depth: 100.06 (ft)

Depth Inc.: 0.164 (ft)

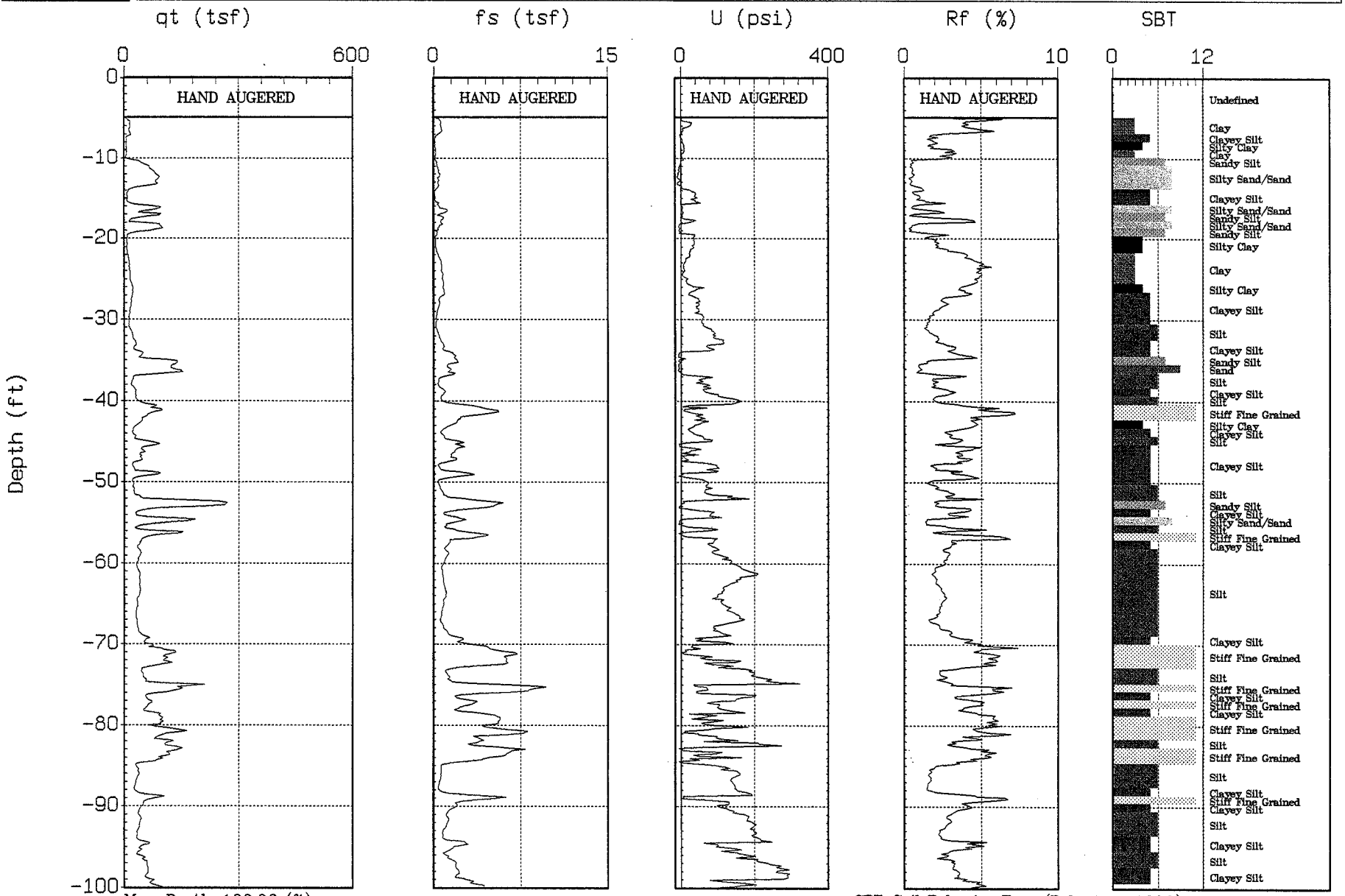
SBT: Soil Behavior Type (Robertson and Campanella 1988)

GREGG

CDM

Site : SHERWIN WILLIAMS
Location : CPT-04

Engineer : H. YOUNG
Date : 01:28:03 08:29



Max. Depth: 100.06 (ft)

Depth Inc.: 0.164 (ft)

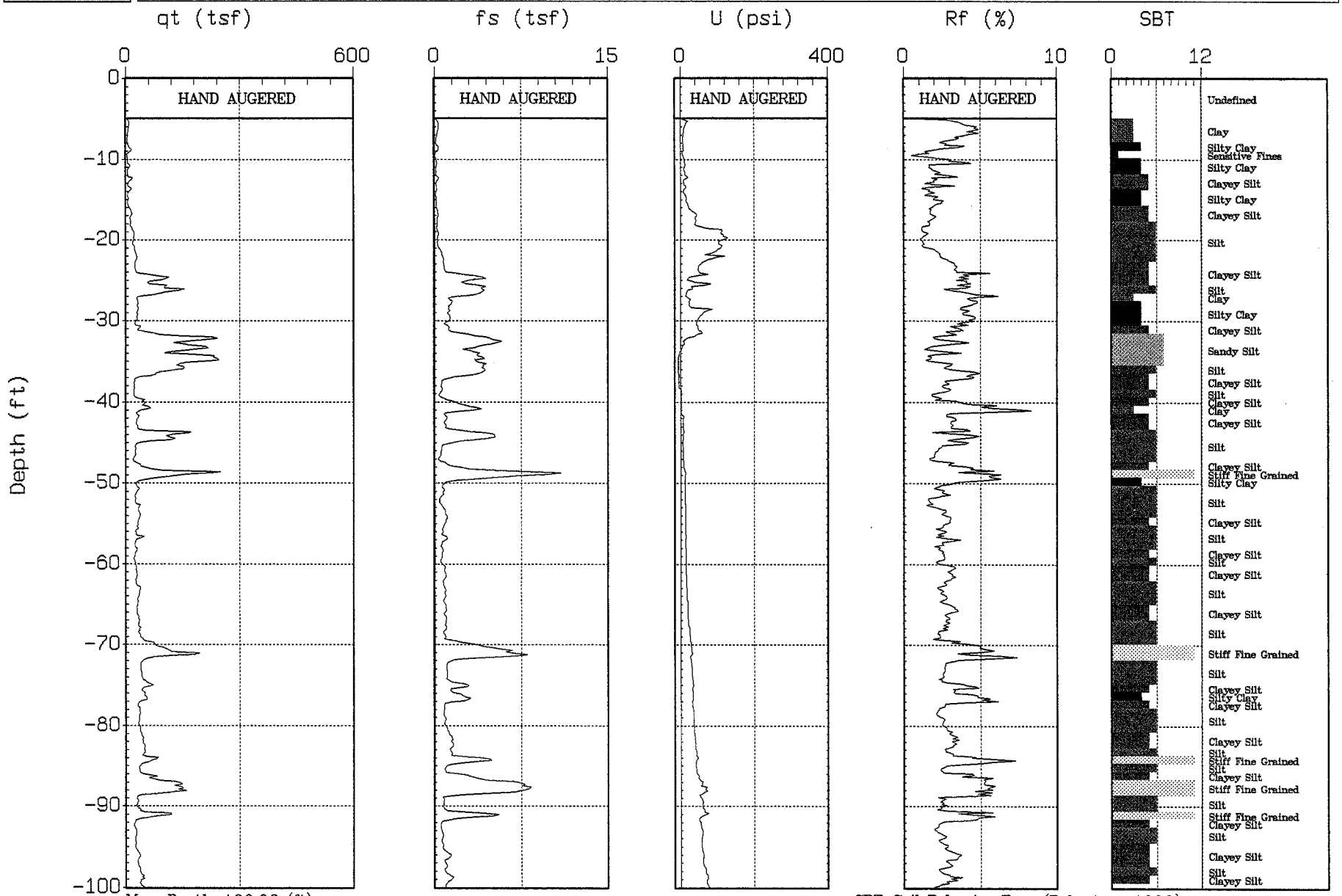
SBT: Soil Behavior Type (Robertson 1990)

GREGG

CDM

Site : SHERWIN WILLIAMS
Location : CPT-05

Engineer : H. YOUNG
Date : 01:28:03 10:52



Max. Depth: 100.06 (ft)

Depth Inc.: 0.164 (ft)

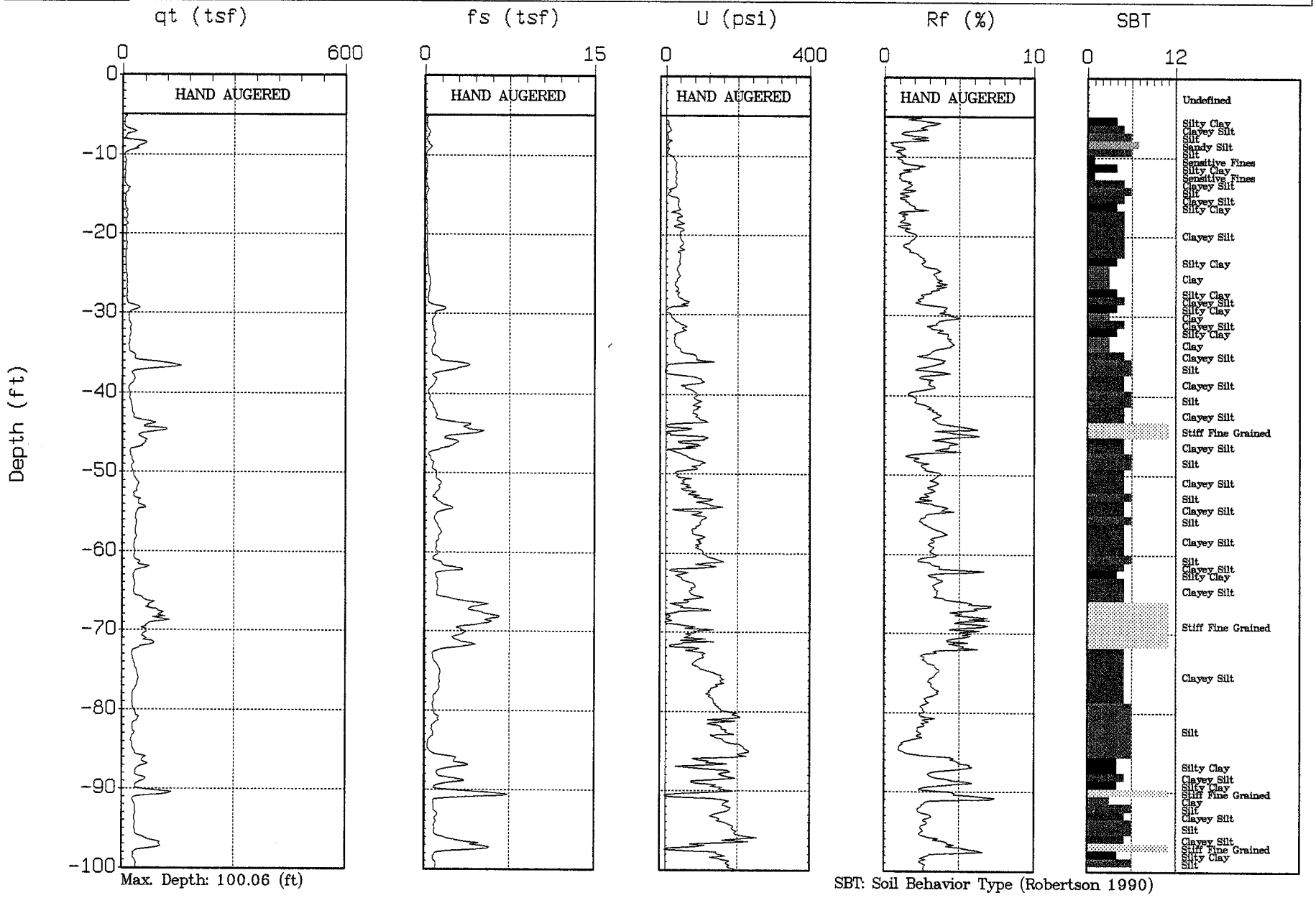
SBT: Soil Behavior Type (Robertson 1990)

GREGG

CDM

Site : SHERWIN WILLIAMS
Location : CPT-06

Engineer : H. YOUNG
Date : 01:28:03 12:49



Max. Depth: 100.06 (ft)

Depth Inc.: 0.164 (ft)

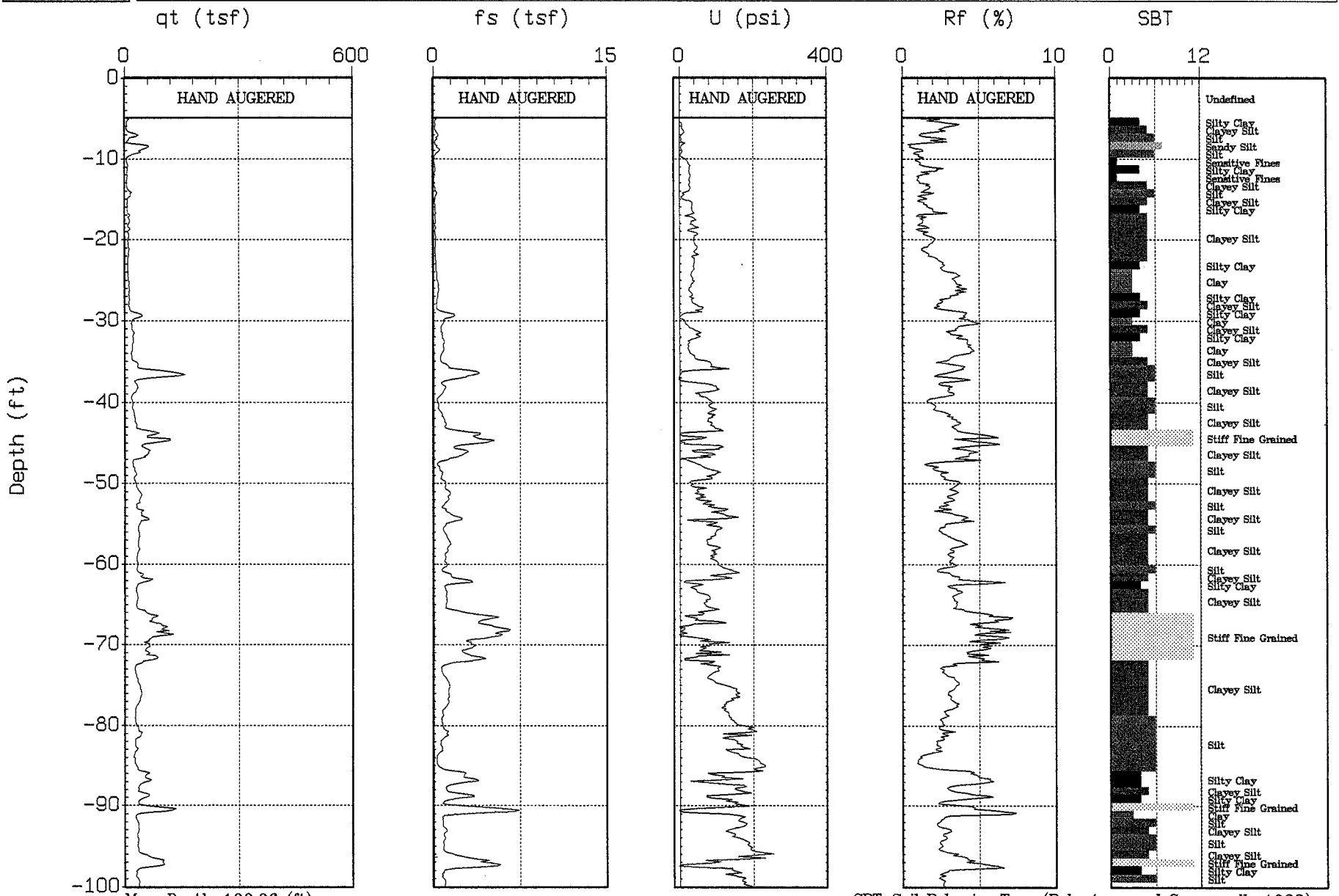
SBT: Soil Behavior Type (Robertson 1990)

GREGG

CDM

Site : SHERWIN WILLIAMS
Location : CPT-06

Engineer : H. YOUNG
Date : 01:28:03 12:49



Max. Depth: 100.06 (ft)

Depth Inc.: 0.164 (ft)

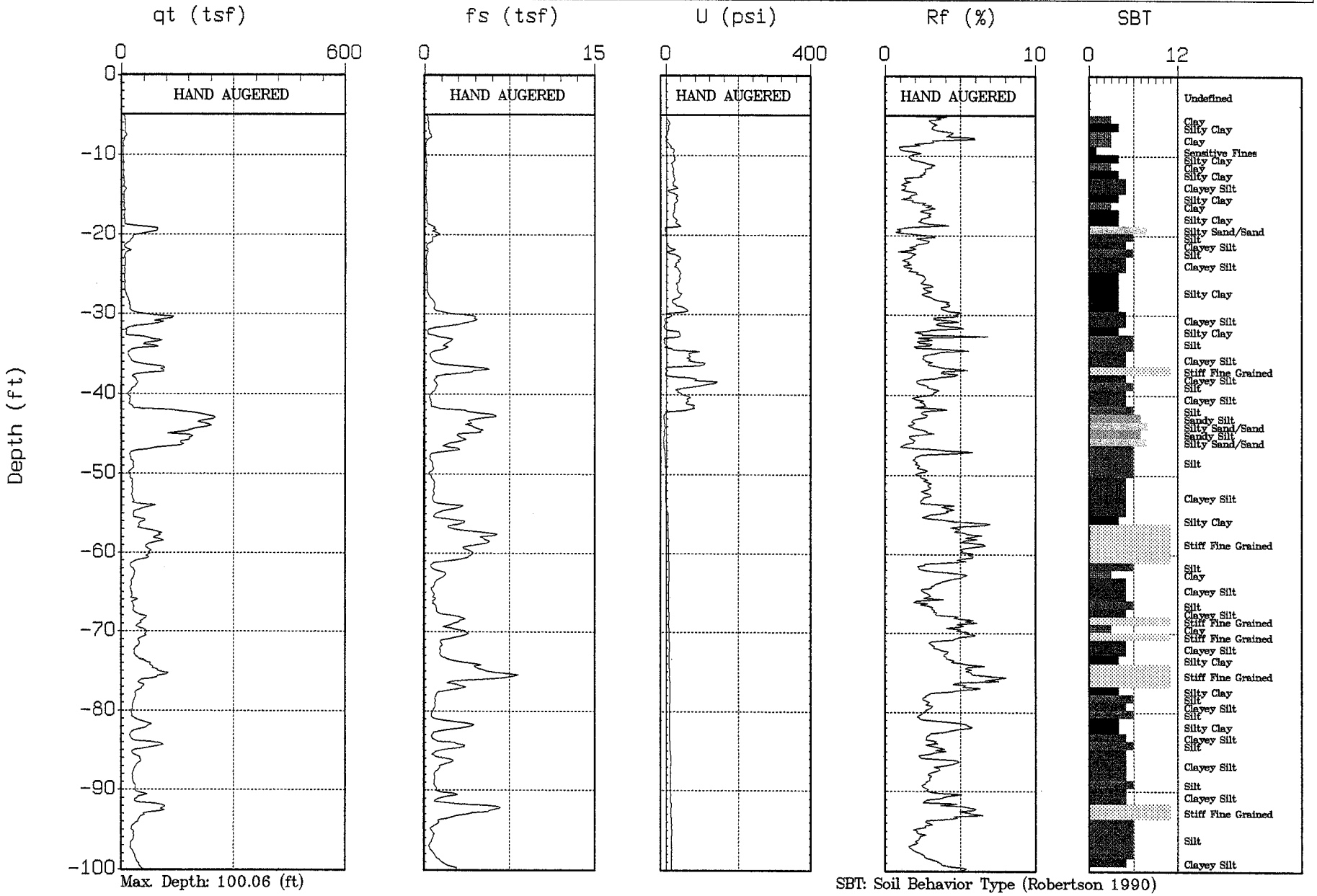
SBT: Soil Behavior Type (Robertson and Campanella 1988)

GREGG

CDM

Site : SHERWIN WILLIAMS
Location : CPT-07

Engineer : H. YOUNG
Date : 01:28:03 14:52



Max. Depth: 100.06 (ft)

Depth Inc.: 0.164 (ft)

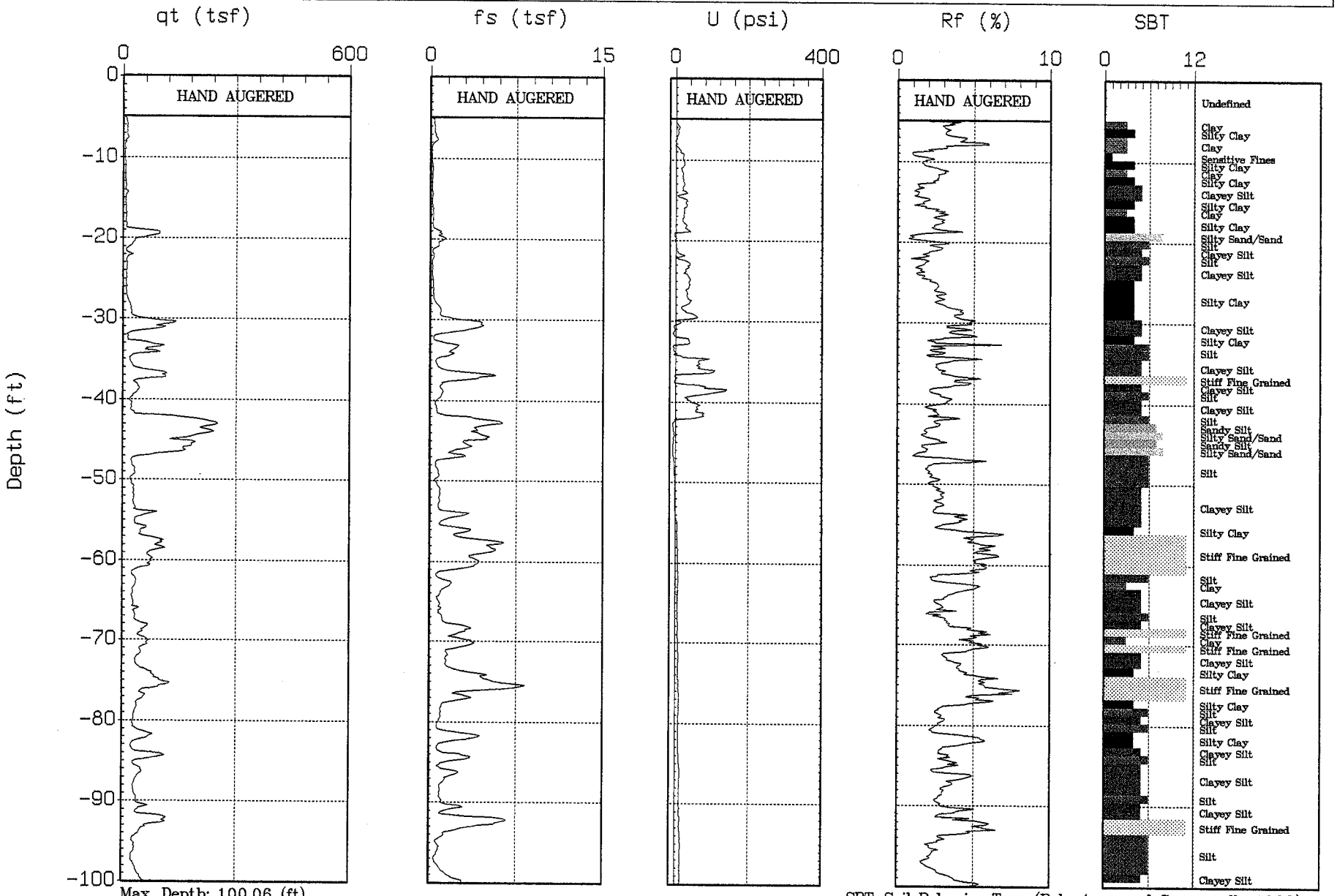
SBT: Soil Behavior Type (Robertson 1990)

GREGG

CDM

Site : SHERWIN WILLIAMS
Location : CPT-07

Engineer : H. YOUNG
Date : 01:28:03 14:52



Max. Depth: 100.06 (ft)

Depth Inc.: 0.164 (ft)

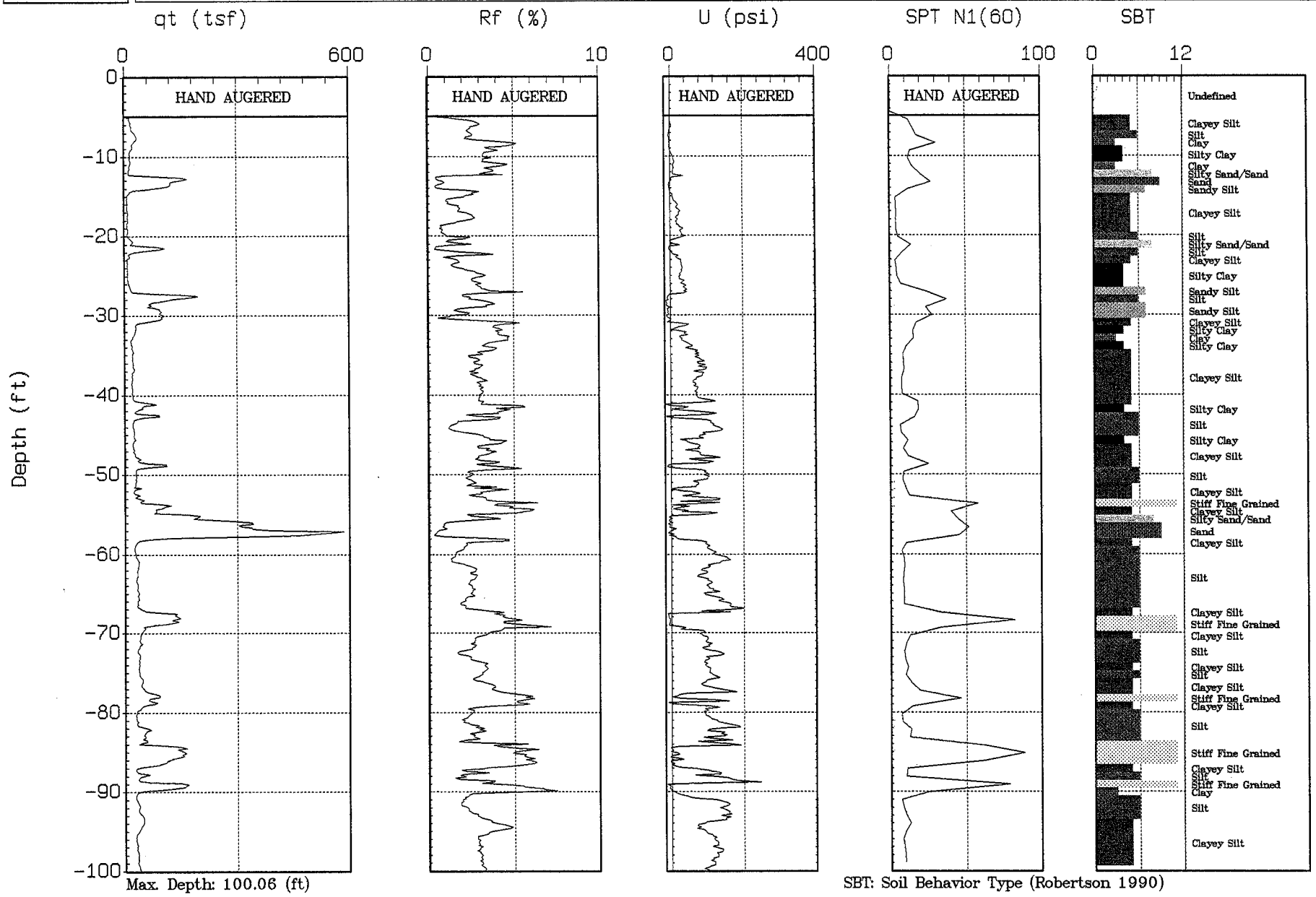
SBT: Soil Behavior Type (Robertson and Campanella 1988)

GREGG

CDM

Site : SHERWIN WILLIAMS
Location : CPT-01

Engineer : H. YOUNG
Date : 01:29:03 11:54



Max. Depth: 100.06 (ft)

Depth Inc.: 0.164 (ft)

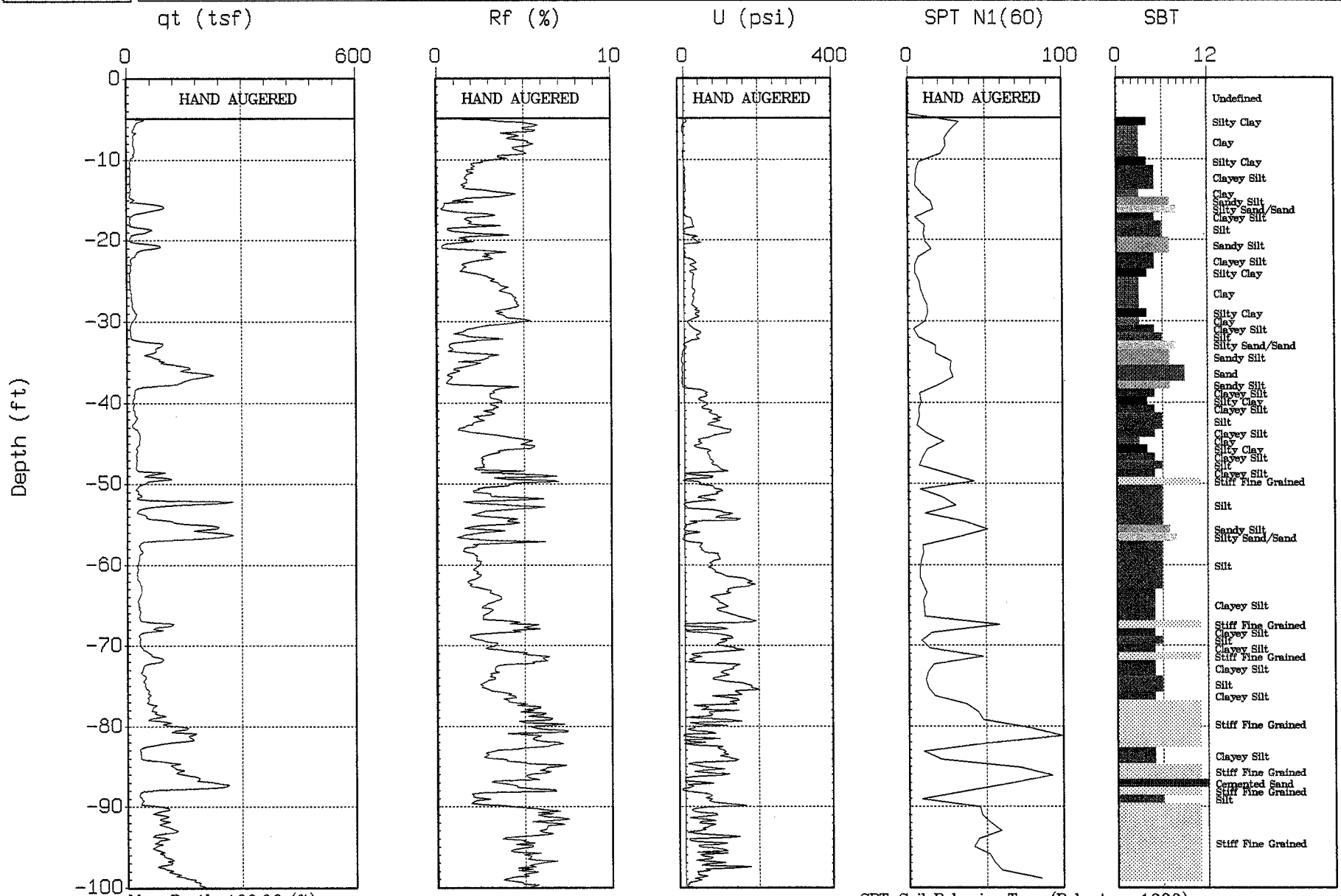
SBT: Soil Behavior Type (Robertson 1990)

GREGG

CDM

Site : SHERWIN WILLIAMS
Location : CPT-02

Engineer : H. YOUNG
Date : 01:29:03 09:33



Max. Depth: 100.06 (ft)

Depth Inc.: 0.164 (ft)

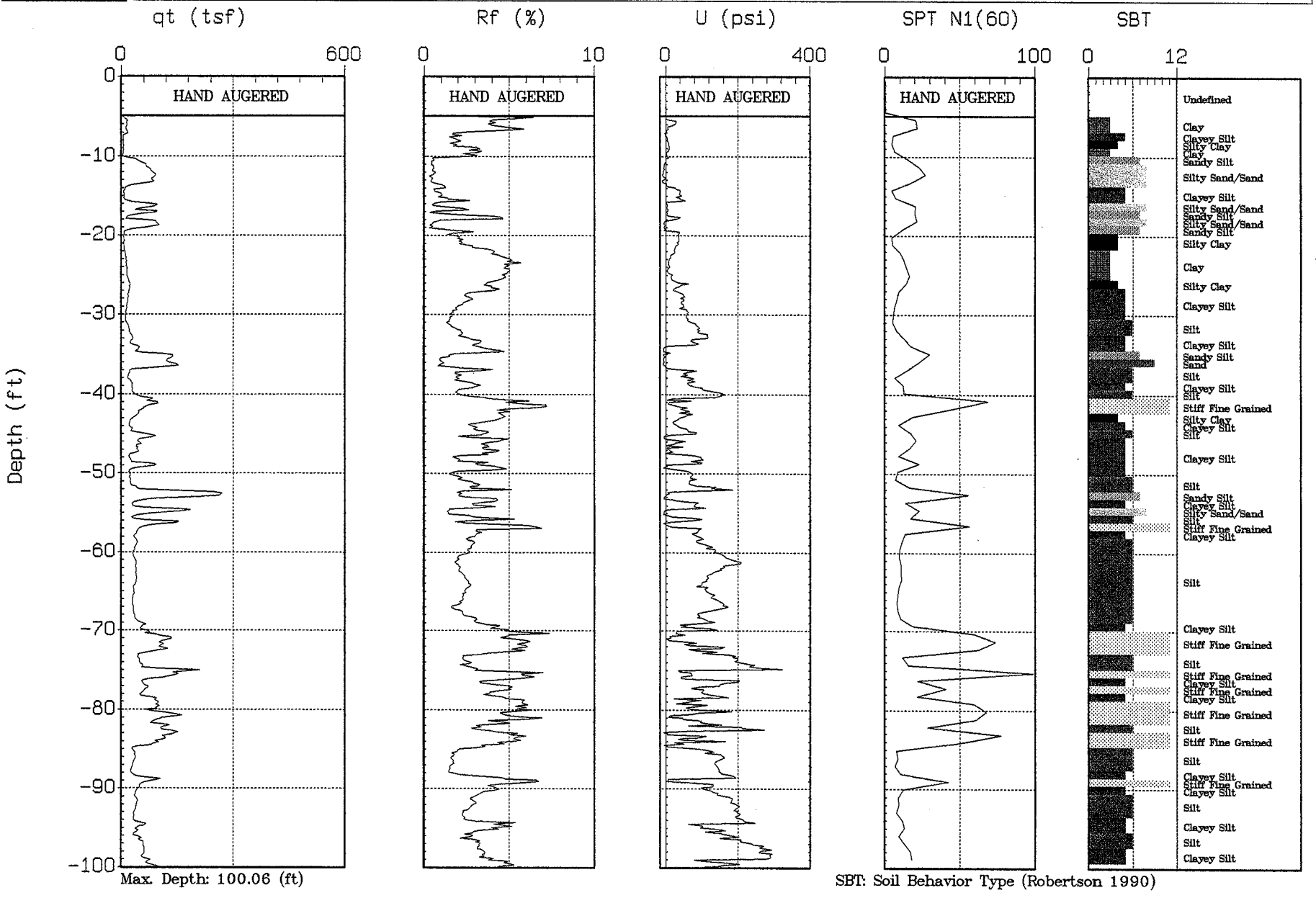
SBT: Soil Behavior Type (Robertson 1990)

GREGG

CDM

Site : SHERWIN WILLIAMS
Location : CPT-04

Engineer : H. YOUNG
Date : 01:28:03 08:29



Max. Depth: 100.06 (ft)

Depth Inc.: 0.164 (ft)

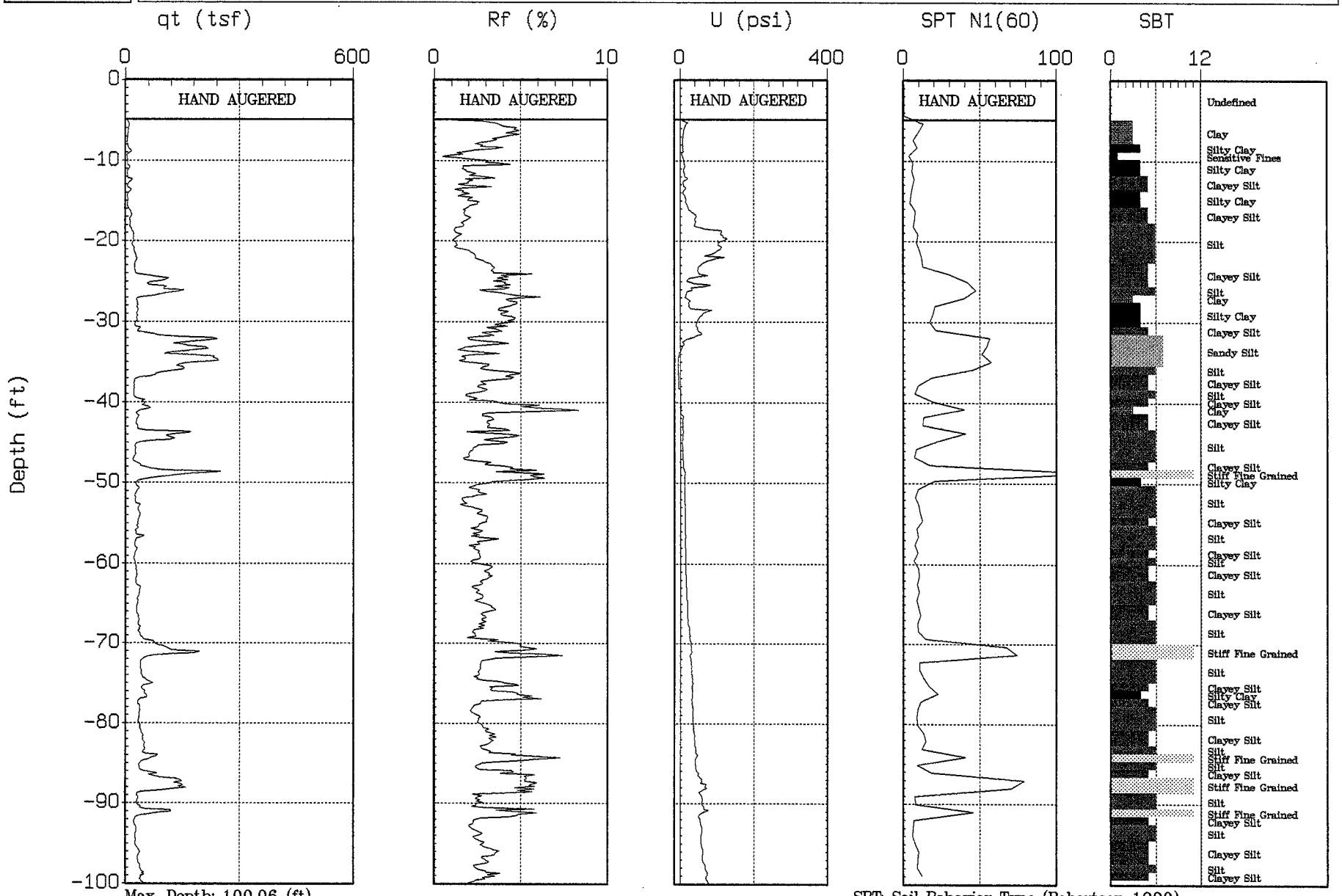
SBT: Soil Behavior Type (Robertson 1990)

GREGG

CDM

Site : SHERWIN WILLIAMS
Location : CPT-05

Engineer : H. YOUNG
Date : 01:28:03 10:52



Max. Depth: 100.06 (ft)

Depth Inc.: 0.164 (ft)

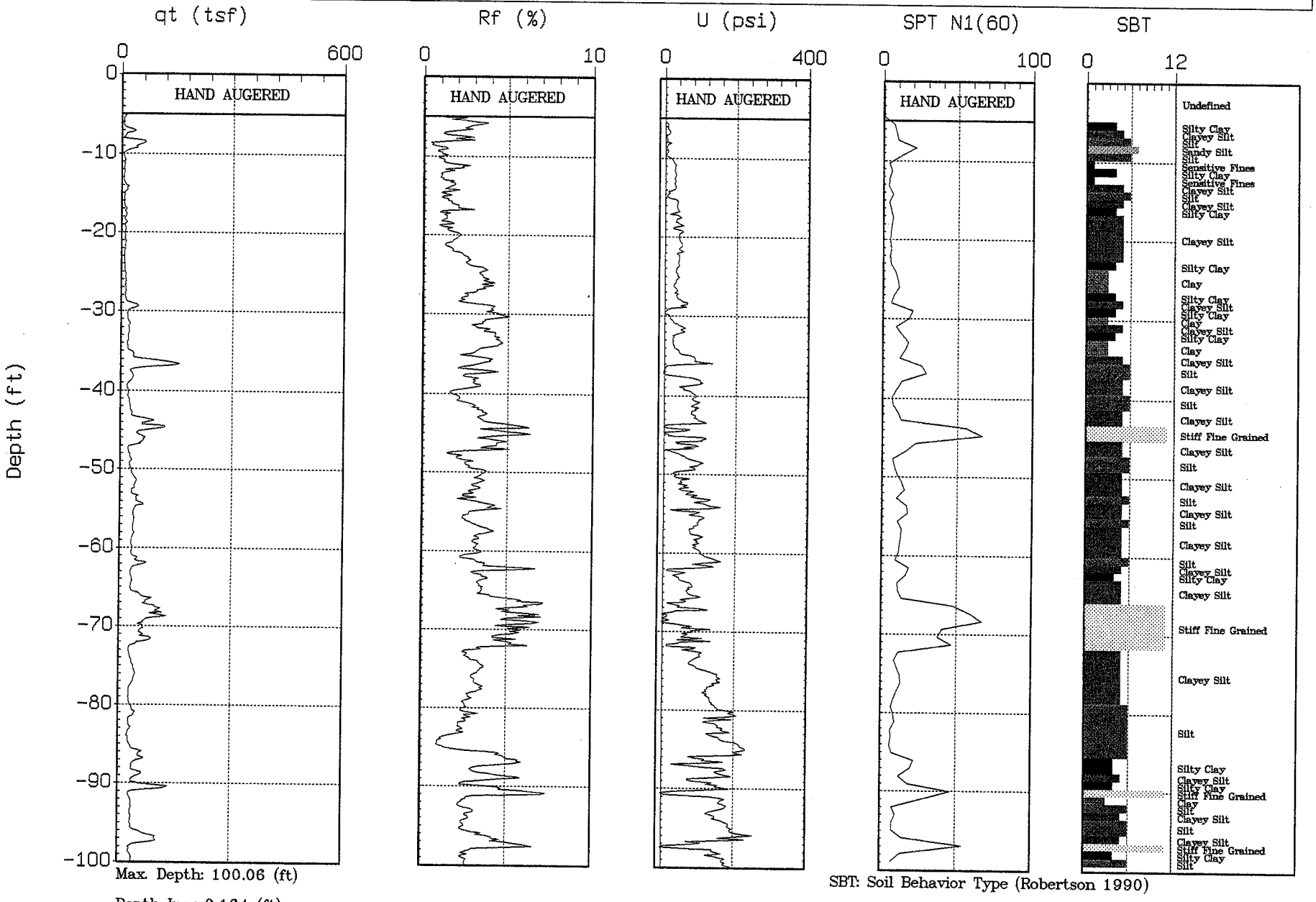
SBT: Soil Behavior Type (Robertson 1990)

GREGG

CDM

Site : SHERWIN WILLIAMS
Location : CPT-06

Engineer : H. YOUNG
Date : 01:28:03 12:49



Max. Depth: 100.06 (ft)

Depth Inc.: 0.164 (ft)

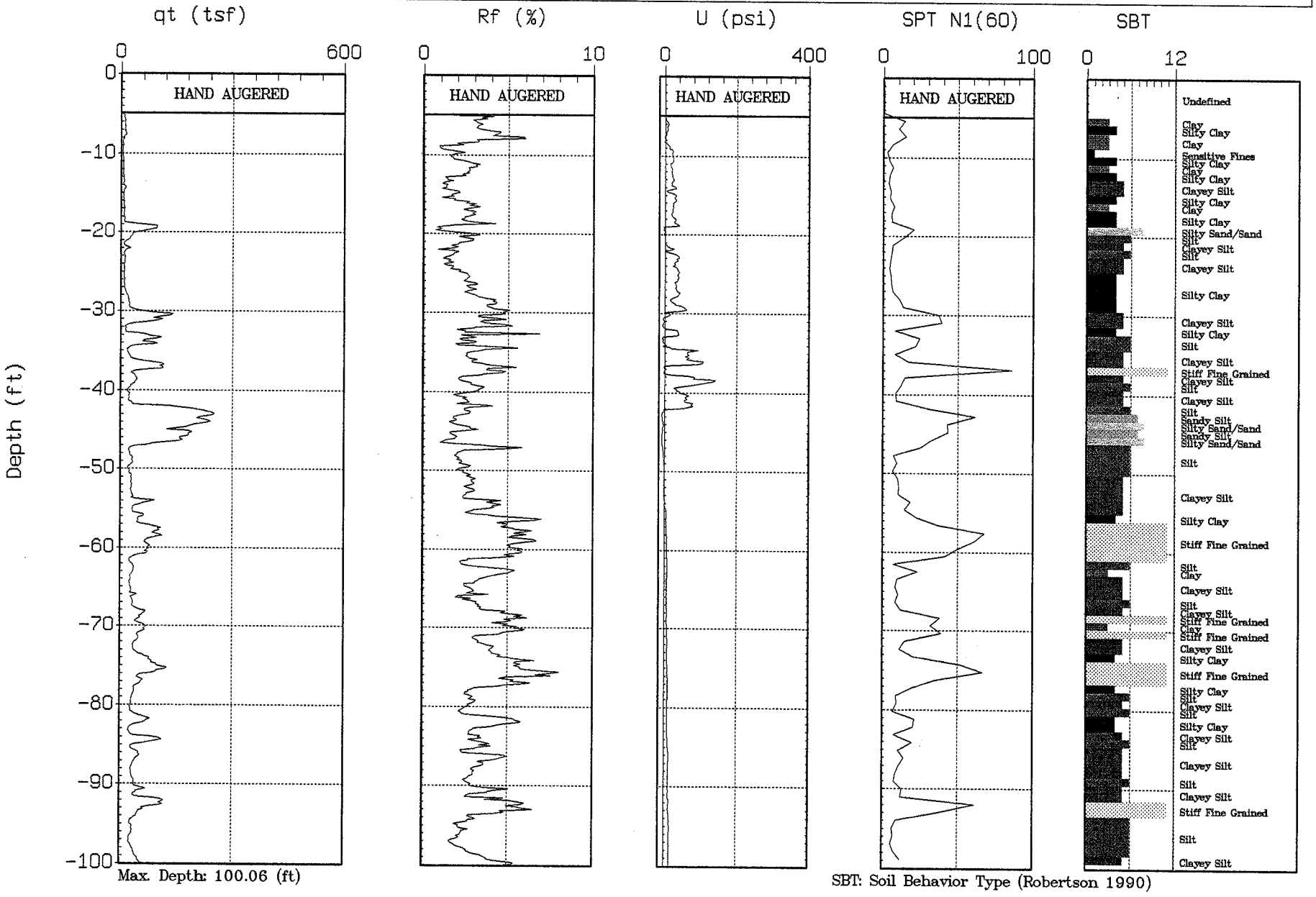
SBT: Soil Behavior Type (Robertson 1990)

GREGG

CDM

Site : SHERWIN WILLIAMS
Location : CPT-07

Engineer : H. YOUNG
Date : 01:28:03 14:52



Max. Depth: 100.06 (ft)

Depth Inc.: 0.164 (ft)

SBT: Soil Behavior Type (Robertson 1990)

3.2 INTERPRETED OUTPUT

Gregg In Situ, Inc.
Interpretation Output - Release 1.00.19e
Run No: 03-0203-1606-1781
Job No: 97-100
Client: CDM
Project: CPT SITE INVESTIGATION
Site: SHERWIN WILLIAMS
Location: CPT-07
Engineer: H. YOUNG
CPT Date: 03/28/01
CPT Time: 14:52
CPT File: 027C07.COR
Northing (m): 0.000
Easting (m): 0.000
Elevation (m): 0.000

Water Table (m): 3.35 (ft): 11.0
Su Nkt used: 12.50
Averaging Increment (m): 0.30
Phi Method : Robertson and Campanella, 1983
Dr Method : Jamiolkowski - All Sands
State Parameter M: 1.20
Used Unit Weights Assigned to Soil Zones
Values of 1.0E9 or UnDef are printed for parameters that are not valid for the material type (SBT)

Depth (ft)	AvgQt (tsf)	AvgFs (tsf)	AvgRf (%)	AvgUd (ft)	SBT	U.Wt. pcf	TStress (tsf)	EStress (tsf)	Ueq (tsf)	Cn	N60 (blows/ft)	(N1)60 (blows/ft)	Su (tsf)	CRR
0.49	0.0	0.00	0.00	0.0	UnDef	124.1	0.03	0.03	0.00	2.00	UnDef	UnDef	UnDef	0.00
1.48	0.0	0.00	0.00	0.0	UnDef	124.1	0.09	0.09	0.00	2.00	UnDef	UnDef	UnDef	0.00
2.46	0.0	0.00	0.00	0.0	UnDef	124.1	0.15	0.15	0.00	2.00	UnDef	UnDef	UnDef	0.00
3.44	0.0	0.00	0.00	0.0	UnDef	124.1	0.21	0.21	0.00	2.00	UnDef	UnDef	UnDef	0.00
4.43	0.0	0.00	0.00	0.0	UnDef	124.1	0.27	0.27	0.00	1.91	UnDef	UnDef	UnDef	0.00
5.41	8.5	0.28	3.33	9.3	3	111.4	0.33	0.33	0.00	1.73	8.2	14.1	0.65	0.12
6.40	9.9	0.33	3.31	15.2	4	114.6	0.39	0.39	0.00	1.60	6.3	10.2	0.76	0.12
7.30	10.8	0.50	4.57	3.4	3	111.4	0.44	0.44	0.00	1.51	10.4	15.7	0.83	0.00
8.20	5.0	0.18	3.55	7.1	3	111.4	0.49	0.49	0.00	1.43	4.8	6.8	0.36	0.00
9.19	3.9	0.05	1.32	39.7	1	79.6	0.54	0.54	0.00	1.37	1.9	2.6	0.27	0.00
10.17	4.2	0.08	1.80	50.1	1	79.6	0.58	0.58	0.00	1.32	2.0	2.6	0.29	0.00
11.15	5.2	0.15	2.90	38.3	3	111.4	0.62	0.62	0.00	1.27	5.0	6.4	0.37	0.00
12.14	4.8	0.12	2.54	44.0	3	111.4	0.68	0.64	0.04	1.25	4.6	5.7	0.33	0.00
13.21	6.1	0.08	1.34	47.5	5	114.6	0.74	0.67	0.07	1.22	2.9	3.6	0.43	0.08
14.27	8.4	0.12	1.47	41.9	5	114.6	0.80	0.70	0.10	1.20	4.0	4.8	0.61	0.09
15.26	5.8	0.09	1.61	67.5	4	114.6	0.86	0.72	0.13	1.18	3.7	4.4	0.40	0.08
16.24	6.5	0.18	2.82	52.8	3	111.4	0.91	0.75	0.16	1.16	6.2	7.2	0.45	0.00
17.22	7.3	0.20	2.74	45.6	4	114.6	0.97	0.77	0.19	1.14	4.7	5.3	0.51	0.09
18.21	7.8	0.22	2.80	66.6	4	114.6	1.02	0.80	0.23	1.12	5.0	5.5	0.54	0.00
19.19	78.7	0.82	1.05	11.7	8	120.9	1.08	0.83	0.26	1.10	18.8	20.7	UnDef	0.18
20.18	34.0	0.90	2.65	-1.4	6	114.6	1.14	0.85	0.29	1.08	13.0	14.1	2.63	0.24
21.16	12.5	0.29	2.33	9.2	5	114.6	1.20	0.88	0.32	1.07	6.0	6.4	0.90	0.11
22.15	14.1	0.21	1.51	41.3	6	114.6	1.25	0.90	0.35	1.05	5.4	5.7	1.03	0.12
23.13	9.3	0.13	1.44	76.0	5	114.6	1.31	0.93	0.38	1.04	4.4	4.6	0.64	0.09
24.11	8.4	0.13	1.58	70.9	5	114.6	1.36	0.96	0.41	1.02	4.0	4.1	0.56	0.09
25.10	7.8	0.19	2.47	85.3	4	114.6	1.42	0.98	0.44	1.01	5.0	5.0	0.51	0.00
26.08	8.3	0.22	2.65	72.4	4	114.6	1.48	1.01	0.47	1.00	5.3	5.3	0.55	0.00
27.07	10.0	0.27	2.70	79.7	4	114.6	1.53	1.03	0.50	0.98	6.4	6.3	0.68	0.09
28.05	17.4	0.63	3.62	54.6	4	114.6	1.59	1.06	0.53	0.97	11.1	10.8	1.26	0.00
29.04	21.8	0.87	4.01	101.7	4	114.6	1.65	1.08	0.56	0.96	13.9	13.3	1.61	0.00

Gregg In Situ, Inc.
Run No: 03-0203-1606-1781
CPT File: 027C07.COR

Depth (ft)	AvgQt (tsf)	AvgFs (tsf)	AvgRf (%)	AvgUd (ft)	SBT	U.Wt. pcf	TStress (tsf)	EStress (tsf)	Ueq (tsf)	Cn	N60 (blows/ft)	(N1)60	Su (tsf)	CRR
30.02	83.1	3.26	3.92	28.8	5	114.6	1.70	1.11	0.59	0.95	39.8	37.8	6.51	0.00
31.00	87.8	3.52	4.01	-9.4	5	114.6	1.76	1.13	0.62	0.94	42.0	39.5	6.88	0.00
31.99	13.5	0.43	3.21	39.9	4	114.6	1.82	1.16	0.66	0.93	8.6	8.0	0.94	0.00
32.97	69.7	1.81	2.60	18.3	6	114.6	1.87	1.19	0.69	0.92	26.7	24.5	5.43	0.32
33.96	62.1	1.76	2.83	9.4	6	114.6	1.93	1.21	0.72	0.91	23.8	21.6	4.82	0.37
34.94	18.7	0.54	2.92	155.8	5	114.6	1.98	1.24	0.75	0.90	8.9	8.0	1.34	0.13
35.92	40.3	1.22	3.04	193.6	5	114.6	2.04	1.26	0.78	0.89	19.3	17.2	3.06	0.00
36.91	102.9	4.45	4.33	-1.9	11	130.5	2.10	1.29	0.81	0.88	98.6	86.7	UnDef	0.00
37.89	35.0	1.03	2.94	146.2	5	114.6	2.16	1.32	0.84	0.87	16.8	14.6	2.63	0.39
38.88	36.5	1.01	2.78	192.5	6	114.6	2.22	1.35	0.87	0.86	14.0	12.0	2.74	0.42
39.86	20.6	0.57	2.79	105.7	5	114.6	2.27	1.37	0.90	0.85	9.9	8.4	1.47	0.14
40.85	21.4	0.52	2.45	140.5	5	114.6	2.33	1.40	0.93	0.85	10.2	8.7	1.52	0.14
41.83	95.9	2.53	2.64	102.0	6	114.6	2.39	1.42	0.96	0.84	36.7	30.8	7.48	0.45
42.81	233.7	5.30	2.27	-15.2	7	117.8	2.44	1.45	0.99	0.83	74.6	61.9	UnDef	0.00
43.80	221.0	4.14	1.88	-9.8	8	120.9	2.50	1.48	1.02	0.82	52.9	43.5	UnDef	0.00
44.78	168.7	3.95	2.34	-13.3	7	117.8	2.56	1.51	1.05	0.81	53.9	43.9	UnDef	0.00
45.77	171.7	2.89	1.68	-16.7	8	120.9	2.62	1.54	1.09	0.81	41.1	33.2	UnDef	0.00
46.75	82.5	2.18	2.64	-13.3	6	114.6	2.68	1.56	1.12	0.80	31.6	25.3	6.39	0.45
47.74	23.6	0.49	2.06	-7.8	6	114.6	2.74	1.59	1.15	0.79	9.0	7.2	1.67	0.15
48.72	31.2	0.68	2.19	-4.5	6	114.6	2.79	1.61	1.18	0.79	12.0	9.4	2.28	0.24
49.70	22.1	0.53	2.40	-3.3	6	114.6	2.85	1.64	1.21	0.78	8.5	6.6	1.54	0.14
50.69	26.9	0.75	2.77	-2.6	5	114.6	2.90	1.66	1.24	0.78	12.9	10.0	1.92	0.18
51.67	28.8	0.80	2.77	-2.0	5	114.6	2.96	1.69	1.27	0.77	13.8	10.6	2.06	0.20
52.66	28.1	0.76	2.71	-1.4	5	114.6	3.02	1.72	1.30	0.76	13.5	10.3	2.01	0.19
53.64	50.4	1.82	3.62	-0.3	5	114.6	3.07	1.74	1.33	0.76	24.1	18.3	3.79	0.00
54.63	40.3	1.56	3.87	6.9	5	114.6	3.13	1.77	1.36	0.75	19.3	14.5	2.98	0.00
.61	47.3	2.19	4.62	11.8	4	114.6	3.19	1.79	1.39	0.75	30.2	22.6	3.53	0.00
6.59	52.7	2.63	4.99	11.7	11	130.5	3.25	1.82	1.42	0.74	50.5	37.4	UnDef	0.00
57.58	97.0	5.57	5.75	12.3	11	130.5	3.31	1.86	1.45	0.73	92.9	68.2	UnDef	0.00
58.56	88.7	5.11	5.76	15.2	11	130.5	3.37	1.89	1.49	0.73	84.9	61.8	UnDef	0.00
59.55	73.0	3.86	5.29	15.7	11	130.5	3.44	1.92	1.52	0.72	69.9	50.4	UnDef	0.00
60.53	60.9	3.22	5.29	16.3	11	130.5	3.50	1.96	1.55	0.71	58.3	41.7	UnDef	0.00
61.52	26.4	0.64	2.42	18.0	6	114.6	3.56	1.99	1.58	0.71	10.1	7.2	1.82	0.15
62.42	34.7	1.62	4.68	18.3	3	111.4	3.61	2.01	1.61	0.71	33.3	23.5	2.49	0.00
63.32	29.3	1.20	4.11	16.9	4	114.6	3.67	2.03	1.63	0.70	18.7	13.1	2.05	0.00
64.30	25.6	0.72	2.80	15.6	5	114.6	3.72	2.06	1.66	0.70	12.3	8.6	1.75	0.14
65.29	27.5	0.82	2.99	15.5	5	114.6	3.78	2.08	1.70	0.69	13.1	9.1	1.89	0.15
66.27	33.4	0.83	2.48	16.2	6	114.6	3.83	2.11	1.73	0.69	12.8	8.8	2.37	0.21
67.26	34.3	1.14	3.31	16.5	5	114.6	3.89	2.13	1.76	0.68	16.4	11.3	2.44	0.00
68.24	58.4	3.09	5.29	16.8	11	130.5	3.95	2.16	1.79	0.68	56.0	38.0	UnDef	0.00
69.22	47.6	2.28	4.78	16.7	4	114.6	4.01	2.19	1.82	0.68	30.4	20.5	3.49	0.00
70.21	63.9	3.45	5.39	17.5	11	130.5	4.07	2.22	1.85	0.67	61.2	41.1	UnDef	0.00
71.19	47.2	1.57	3.32	18.8	5	114.6	4.13	2.25	1.88	0.67	22.6	15.1	3.44	0.42
72.18	36.7	1.39	3.78	19.6	5	114.6	4.19	2.28	1.91	0.66	17.6	11.6	2.60	0.00
73.16	43.5	1.84	4.23	19.2	5	114.6	4.25	2.30	1.94	0.66	20.8	13.7	3.14	0.00
74.15	77.6	4.39	5.65	19.4	11	130.5	4.31	2.33	1.97	0.65	74.3	48.6	UnDef	0.00
75.13	108.3	6.75	6.23	20.6	11	130.5	4.37	2.37	2.00	0.65	103.7	67.4	UnDef	0.00
76.11	62.7	3.96	6.33	22.1	11	130.5	4.43	2.40	2.03	0.65	60.0	38.7	UnDef	0.00
77.10	51.7	2.63	5.09	25.0	3	111.4	4.49	2.43	2.06	0.64	49.5	31.8	3.77	0.00
78.08	36.8	0.98	2.66	23.6	6	114.6	4.55	2.45	2.09	0.64	14.1	9.0	2.58	0.22
79.07	31.1	0.91	2.92	22.3	5	114.6	4.61	2.48	2.13	0.64	14.9	9.5	2.12	0.00
80.05	28.3	0.70	2.46	21.4	6	114.6	4.66	2.51	2.16	0.63	10.9	6.9	1.89	0.14

Depth (ft)	AvgQt (tsf)	AvgFs (tsf)	AvgRf (%)	AvgUd (ft)	SBT	U.Wt. pcf	TStress (tsf)	BStress (tsf)	Ueq (tsf)	Cn	N60 (blows/ft)	(N1)60 (blows/ft)	Su (tsf)	CRR
81.04	44.7	1.78	3.99	21.8	5	114.6	4.72	2.53	2.19	0.63	21.4	13.5	3.20	0.00
82.02	60.6	3.13	5.16	21.6	11	130.5	4.78	2.56	2.22	0.62	58.1	36.3	UnDef	0.00
83.00	24.6	0.70	2.83	21.5	5	114.6	4.84	2.59	2.25	0.62	11.8	7.3	1.58	0.00
83.99	76.2	2.44	3.20	23.5	6	114.6	4.90	2.62	2.28	0.62	29.2	18.1	5.71	0.00
84.97	42.3	1.45	3.43	25.7	5	114.6	4.95	2.64	2.31	0.62	20.3	12.5	2.99	0.00
85.96	47.4	1.81	3.81	29.6	5	114.6	5.01	2.67	2.34	0.61	22.7	13.9	3.39	0.00
86.94	38.6	1.43	3.70	28.2	5	114.6	5.06	2.69	2.37	0.61	18.5	11.3	2.68	0.00
87.93	30.3	0.90	2.97	26.0	5	114.6	5.12	2.72	2.40	0.61	14.5	8.8	2.01	0.00
88.91	32.5	0.86	2.64	25.8	6	114.6	5.18	2.74	2.43	0.60	12.4	7.5	2.18	0.16
89.89	39.9	1.36	3.42	26.7	5	114.6	5.23	2.77	2.46	0.60	19.1	11.5	2.77	0.00
90.88	46.7	1.61	3.44	27.7	5	114.6	5.29	2.80	2.49	0.60	22.3	13.4	3.31	0.00
91.86	95.4	5.01	5.26	31.0	11	130.5	5.35	2.83	2.52	0.59	91.3	54.3	UnDef	0.00
92.85	76.8	4.10	5.34	30.0	11	130.5	5.41	2.86	2.56	0.59	73.6	43.5	UnDef	0.00
93.83	42.9	1.31	3.06	33.3	5	114.6	5.47	2.89	2.59	0.59	20.5	12.1	2.99	0.26
94.82	29.0	0.63	2.17	34.4	6	114.6	5.53	2.91	2.62	0.59	11.1	6.5	1.88	0.13
95.80	32.1	0.74	2.30	34.0	6	114.6	5.59	2.94	2.65	0.58	12.3	7.2	2.12	0.15
96.78	25.0	0.45	1.81	33.2	6	114.6	5.64	2.97	2.68	0.58	9.6	5.6	1.54	0.11
97.77	31.3	0.73	2.33	33.5	6	114.6	5.70	2.99	2.71	0.58	12.0	6.9	2.04	0.14
98.75	40.5	1.39	3.42	33.0	5	114.6	5.76	3.02	2.74	0.58	19.4	11.2	2.78	0.00

Gregg In Situ, Inc.
Interpretation Output - Release 1.00.19e
Run No: 03-0203-1606-1781
Job No: 97-100
Client: CDM
Project: CPT SITE INVESTIGATION
Site: SHERWIN WILLIAMS
Location: CPT-07
Engineer: H. YOUNG
CPT Date: 03/28/01
CPT Time: 14:52
CPT File: 027C07.COR
Northing (m): 0.000
Easting (m): 0.000
Elevation (m): 0.000

Water Table (m): 3.35 (ft): 11.0
Su Nkt used: 12.50
Averaging Increment (m): 0.30
Phi Method : Robertson and Campanella, 1983
Dr Method : Jamiolkowski - All Sands
State Parameter M: 1.20
Used Unit Weights Assigned to Soil Zones
Values of 1.0E9 or UnDef are printed for parameters that are not valid for the material type (SBT)

Depth (ft)	k (cm/s)	Bq	Qtn	Rfn	SBTn	Qc1N	DeltaQc1N	Qc1Ncs	Fc (%)	Phi (Deg)	Dr (%)	OCR	State Param	Del(n1)60	(N1)60c
0.49	1.0E-15	0.00	2.4	0.10	1	0.2	UnDef	UnDef	100.0	UnDef	UnDef	1.0	UnDef	UnDef	UnDe
1.48	1.0E-15	0.00	0.1	0.10	1	0.2	UnDef	UnDef	100.0	UnDef	UnDef	1.0	UnDef	UnDef	UnDe
2.46	1.0E-15	0.00	0.1	0.10	1	0.2	UnDef	UnDef	100.0	UnDef	UnDef	1.0	UnDef	UnDef	UnDe
3.44	1.0E-15	0.00	0.0	0.10	1	0.2	UnDef	UnDef	100.0	UnDef	UnDef	1.0	UnDef	UnDef	UnDe
4.43	1.0E-15	0.00	0.0	0.10	1	0.2	UnDef	UnDef	100.0	UnDef	UnDef	1.0	UnDef	UnDef	UnDe
5.41	5.0E-08	0.04	24.6	3.47	6	14.4	57.8	72.2	41.8	UnDef	UnDef	6.0	UnDef	14.1	28.
6.40	5.0E-07	0.05	24.6	3.45	6	15.6	62.4	78.0	41.7	UnDef	UnDef	6.0	UnDef	10.2	20.
7.30	5.0E-08	0.01	23.7	4.76	1	16.0	UnDef	UnDef	100.0	UnDef	UnDef	6.0	UnDef	UnDef	UnDe
8.20	5.0E-08	0.05	9.2	3.93	1	7.0	UnDef	UnDef	100.0	UnDef	UnDef	3.0	UnDef	UnDef	UnDe
9.19	1.0E-07	0.37	6.3	1.53	4	5.2	20.9	26.1	59.7	UnDef	UnDef	3.0	UnDef	2.6	5.
10.17	1.0E-07	0.43	6.3	2.08	4	5.4	21.6	27.0	64.3	UnDef	UnDef	3.0	UnDef	2.6	5.
11.15	5.0E-08	0.26	7.5	3.30	1	6.5	UnDef	UnDef	100.0	UnDef	UnDef	3.0	UnDef	UnDef	UnDe
12.14	5.0E-08	0.33	6.4	2.96	4	5.9	23.4	29.3	69.5	UnDef	UnDef	3.0	UnDef	5.7	11.
13.21	5.0E-06	0.26	8.0	1.52	6	7.3	29.2	36.5	53.5	UnDef	UnDef	3.0	UnDef	3.6	7.
14.27	5.0E-06	0.16	10.9	1.63	6	9.8	39.3	49.1	47.4	UnDef	UnDef	3.0	UnDef	4.8	9.
15.26	5.0E-07	0.40	6.9	1.88	4	6.7	26.8	33.5	60.4	UnDef	UnDef	3.0	UnDef	4.4	8.
16.24	5.0E-08	0.26	7.5	3.28	1	7.4	UnDef	UnDef	100.0	UnDef	UnDef	3.0	UnDef	UnDef	UnDe
17.22	5.0E-07	0.19	8.2	3.16	4	8.1	32.5	40.7	64.1	UnDef	UnDef	3.0	UnDef	5.3	10.
18.21	5.0E-07	0.28	8.4	3.23	1	8.5	UnDef	UnDef	100.0	UnDef	UnDef	3.0	UnDef	UnDef	UnDe
19.19	5.0E-03	0.00	94.1	1.06	9	84.8	18.0	102.8	11.6	42	62.5	1.0	-0.19	2.6	23.
20.18	5.0E-05	-0.01	38.5	2.75	6	36.0	83.2	119.3	31.1	38	38.0	6.0	-0.20	10.9	25.
21.16	5.0E-06	0.00	12.9	2.57	6	13.0	52.2	65.2	50.1	UnDef	UnDef	6.0	UnDef	6.4	12.
22.15	5.0E-05	0.07	14.2	1.65	6	14.5	58.0	72.5	42.0	32	30.0	6.0	-0.03	5.7	11.
23.13	5.0E-06	0.25	8.6	1.68	6	9.4	37.6	47.0	53.3	UnDef	UnDef	3.0	UnDef	4.6	9.
24.11	5.0E-06	0.26	7.3	1.88	4	8.4	33.5	41.9	58.7	UnDef	UnDef	3.0	UnDef	4.1	8.
25.10	5.0E-07	0.35	6.5	3.02	1	7.7	UnDef	UnDef	100.0	UnDef	UnDef	3.0	UnDef	UnDef	UnDe
26.08	5.0E-07	0.26	6.8	3.23	1	8.1	UnDef	UnDef	100.0	UnDef	UnDef	3.0	UnDef	UnDef	UnDe
27.07	5.0E-07	0.23	8.2	3.18	4	9.7	38.7	48.4	64.1	UnDef	UnDef	3.0	UnDef	6.3	12.
28.05	5.0E-07	0.07	14.9	3.99	1	16.5	UnDef	UnDef	100.0	UnDef	UnDef	6.0	UnDef	UnDef	UnDe
29.04	5.0E-07	0.13	18.6	4.34	1	20.5	UnDef	UnDef	100.0	UnDef	UnDef	6.0	UnDef	UnDef	UnDe

Depth (ft)	k (cm/s)	Bq	Qtn	Rfn	SBTn	Qc1N	DeltaQc1N	Qc1Ncs	Fc (%)	Phi (Deg)	Dr (%)	OCR	State Param	Del(n1)60	(N1)60c
30.02	5.0E-06	0.00	73.4	4.00	6	77.2	117.1	194.3	27.6	UnDef	UnDef	10.0	UnDef	22.9	60.
31.00	5.0E-06	-0.01	75.8	4.09	6	80.6	120.9	201.5	27.5	UnDef	UnDef	10.0	UnDef	23.7	63.
31.99	5.0E-07	0.05	10.1	3.71	1	12.3	UnDef	UnDef	100.0	UnDef	UnDef	3.0	UnDef	UnDef	UnDe
32.97	5.0E-05	0.00	57.2	2.67	7	62.6	75.1	137.7	25.4	40	53.9	10.0	-0.24	12.7	37.
33.96	5.0E-05	-0.01	49.7	2.92	6	55.2	91.5	146.8	28.4	38	50.3	6.0	-0.24	13.8	35.
34.94	5.0E-06	0.25	13.5	3.26	4	16.4	65.7	82.2	52.7	UnDef	UnDef	6.0	UnDef	8.0	16.
35.92	5.0E-06	0.14	30.3	3.20	6	35.1	140.3	175.4	37.0	UnDef	UnDef	6.0	UnDef	17.2	34.
36.91	1.0E-15	-0.01	78.0	4.42	6	88.6	144.2	232.8	28.2	42	63.8	1.0	-0.43	54.8	141.
37.89	5.0E-06	0.11	24.9	3.13	6	29.8	119.2	149.0	40.0	UnDef	UnDef	6.0	UnDef	14.6	29.
38.88	5.0E-05	0.15	25.4	2.95	6	30.8	123.0	153.8	38.8	34	33.5	6.0	-0.14	12.0	24.
39.86	5.0E-06	0.13	13.3	3.14	4	17.2	68.8	86.0	52.4	UnDef	UnDef	6.0	UnDef	8.4	16.
40.85	5.0E-06	0.18	13.6	2.75	6	17.7	70.7	88.4	49.9	UnDef	UnDef	6.0	UnDef	8.7	17.
41.83	5.0E-05	0.02	65.6	2.70	7	78.6	80.2	158.8	23.9	40	60.4	10.0	-0.26	14.2	45.
42.81	5.0E-04	-0.01	159.4	2.29	7	189.8	57.1	246.9	13.7	44	85.6	1.0	-0.34	10.5	72.
43.80	5.0E-03	-0.01	147.7	1.90	9	177.8	44.6	222.4	12.5	44	83.8	1.0	-0.30	6.2	49.
44.78	5.0E-04	-0.01	110.2	2.38	7	134.5	64.2	198.6	17.1	42	75.8	1.0	-0.30	11.1	55.
45.77	5.0E-03	-0.01	110.1	1.71	7	135.6	42.7	178.3	14.0	42	76.0	1.0	-0.25	5.8	39.
46.75	5.0E-05	-0.02	51.1	2.73	7	64.6	93.3	157.9	27.1	38	54.8	10.0	-0.24	14.8	40.
47.74	5.0E-05	-0.07	13.1	2.33	6	18.3	73.3	91.6	48.2	32	30.0	6.0	-0.06	7.2	14.
48.72	5.0E-05	-0.05	17.6	2.41	6	24.1	96.3	120.3	42.6	32	30.0	6.0	-0.10	9.4	18.
49.70	5.0E-05	-0.07	11.7	2.76	4	16.9	67.6	84.5	53.2	30	30.0	3.0	-0.07	6.6	13.
50.69	5.0E-06	-0.06	14.4	3.11	4	20.4	81.6	101.9	50.6	UnDef	UnDef	6.0	UnDef	10.0	20.
51.67	5.0E-06	-0.05	15.3	3.08	6	21.6	86.6	108.2	49.2	UnDef	UnDef	6.0	UnDef	10.6	21.
52.66	5.0E-06	-0.05	14.6	3.04	6	21.0	84.0	105.0	49.9	UnDef	UnDef	6.0	UnDef	10.3	20.
53.64	5.0E-06	-0.03	27.2	3.85	6	37.4	149.5	186.9	41.6	UnDef	UnDef	6.0	UnDef	18.3	36.
54.63	5.0E-06	-0.03	21.0	4.20	1	29.7	UnDef	UnDef	100.0	UnDef	UnDef	6.0	UnDef	UnDef	UnDe
55.61	5.0E-07	-0.02	24.6	4.95	1	34.6	UnDef	UnDef	100.0	UnDef	UnDef	6.0	UnDef	UnDef	UnDe
56.59	1.0E-15	-0.02	27.2	5.31	1	38.2	UnDef	UnDef	100.0	36	39.7	1.0	-0.33	UnDef	UnDe
57.58	1.0E-15	-0.01	50.4	5.95	1	69.6	UnDef	UnDef	100.0	38	56.9	1.0	-0.57	UnDef	UnDe
58.56	1.0E-15	-0.01	45.1	5.99	1	63.1	UnDef	UnDef	100.0	38	54.1	1.0	-0.55	UnDef	UnDe
59.55	1.0E-15	-0.01	36.2	5.55	1	51.5	UnDef	UnDef	100.0	38	48.3	1.0	-0.42	UnDef	UnDe
60.53	1.0E-15	-0.02	29.3	5.62	1	42.6	UnDef	UnDef	100.0	36	42.8	1.0	-0.39	UnDef	UnDe
61.52	5.0E-05	-0.04	11.5	2.80	4	18.3	73.2	91.5	53.9	30	30.0	3.0	-0.06	7.2	14.
62.42	5.0E-08	-0.03	15.5	5.22	1	24.0	UnDef	UnDef	100.0	UnDef	UnDef	6.0	UnDef	UnDef	UnDe
63.32	5.0E-07	-0.04	12.6	4.70	1	20.1	UnDef	UnDef	100.0	UnDef	UnDef	6.0	UnDef	UnDef	UnDe
64.30	5.0E-06	-0.05	10.6	3.28	4	17.5	69.9	87.4	58.3	UnDef	UnDef	3.0	UnDef	8.6	17.
65.29	5.0E-06	-0.05	11.4	3.46	4	18.6	74.5	93.1	57.7	UnDef	UnDef	3.0	UnDef	9.1	18.
66.27	5.0E-05	-0.04	14.0	2.80	6	22.5	90.0	112.5	49.5	32	30.0	6.0	-0.09	8.8	17.
67.26	5.0E-06	-0.04	14.3	3.74	1	23.0	UnDef	UnDef	100.0	UnDef	UnDef	6.0	UnDef	UnDef	UnDe
68.24	1.0E-15	-0.02	25.2	5.68	1	38.9	UnDef	UnDef	100.0	34	40.2	1.0	-0.36	UnDef	UnDe
69.22	5.0E-07	-0.03	19.9	5.22	1	31.5	UnDef	UnDef	100.0	UnDef	UnDef	6.0	UnDef	UnDef	UnDe
70.21	1.0E-15	-0.02	26.9	5.76	1	42.0	UnDef	UnDef	100.0	36	42.4	1.0	-0.39	UnDef	UnDe
71.19	5.0E-06	-0.03	19.1	3.64	4	30.8	123.0	153.8	47.3	UnDef	UnDef	6.0	UnDef	15.1	30.
72.18	5.0E-06	-0.04	14.3	4.27	1	23.8	UnDef	UnDef	100.0	UnDef	UnDef	6.0	UnDef	UnDef	UnDe
73.16	5.0E-06	-0.03	17.0	4.69	1	28.1	UnDef	UnDef	100.0	UnDef	UnDef	6.0	UnDef	UnDef	UnDe
74.15	1.0E-15	-0.02	31.4	5.99	1	49.7	UnDef	UnDef	100.0	36	47.2	1.0	-0.46	UnDef	UnDe
75.13	1.0E-15	-0.01	43.9	6.50	1	68.9	UnDef	UnDef	100.0	38	56.6	1.0	-0.66	UnDef	UnDe
76.11	1.0E-15	-0.02	24.2	6.81	1	39.6	UnDef	UnDef	100.0	34	40.7	1.0	-0.56	UnDef	UnDe
77.10	5.0E-08	-0.03	19.4	5.57	1	32.4	UnDef	UnDef	100.0	UnDef	UnDef	6.0	UnDef	UnDef	UnDe
78.08	5.0E-05	-0.04	13.1	3.03	4	23.0	91.9	114.9	52.2	32	30.0	6.0	-0.09	9.0	18.
79.07	5.0E-06	-0.05	10.7	3.43	1	19.3	UnDef	UnDef	100.0	UnDef	UnDef	3.0	UnDef	UnDef	UnDe
80.05	5.0E-05	-0.06	9.4	2.94	4	17.5	70.1	87.6	59.3	30	30.0	3.0	-0.04	6.9	13.

Depth (ft)	k (cm/s)	Bq	Qtn	Rfn	SBTn	Qc1N	DeltaQc1N	Qc1Ncs	Fc (%)	Phi (Deg)	Dr (%)	OCR	State Param	Del(n1)60	(N1)60c
81.04	5.0E-06	-0.04	15.8	4.46	1	27.5	UnDef	UnDef	100.0	UnDef	UnDef	6.0	UnDef	UnDef	UnDe
82.02	1.0E-15	-0.03	21.8	5.60	1	37.1	UnDef	UnDef	100.0	34	38.8	1.0	-0.32	UnDef	UnDe
83.00	5.0E-06	-0.08	7.6	3.52	1	14.9	UnDef	UnDef	100.0	UnDef	UnDef	3.0	UnDef	UnDef	UnDe
83.99	5.0E-05	-0.02	27.3	3.42	6	46.1	184.5	230.6	39.7	36	45.1	6.0	-0.20	18.1	36.
84.97	5.0E-06	-0.04	14.1	3.89	1	25.5	UnDef	UnDef	100.0	UnDef	UnDef	6.0	UnDef	UnDef	UnDe
85.96	5.0E-06	-0.03	15.9	4.26	1	28.4	UnDef	UnDef	100.0	UnDef	UnDef	6.0	UnDef	UnDef	UnDe
86.94	5.0E-06	-0.04	12.4	4.26	1	23.0	UnDef	UnDef	100.0	UnDef	UnDef	3.0	UnDef	UnDef	UnDe
87.93	5.0E-06	-0.06	9.2	3.57	1	18.0	UnDef	UnDef	100.0	UnDef	UnDef	3.0	UnDef	UnDef	UnDe
88.91	5.0E-05	-0.06	9.9	3.14	4	19.2	76.7	95.9	59.2	30	30.0	3.0	-0.06	7.5	15.
89.89	5.0E-06	-0.05	12.5	3.93	1	23.5	UnDef	UnDef	100.0	UnDef	UnDef	6.0	UnDef	UnDef	UnDe
90.88	5.0E-06	-0.04	14.8	3.88	1	27.3	UnDef	UnDef	100.0	UnDef	UnDef	6.0	UnDef	UnDef	UnDe
91.86	1.0E-15	-0.02	31.9	5.57	1	55.5	UnDef	UnDef	100.0	36	50.4	1.0	-0.40	UnDef	UnDe
92.85	1.0E-15	-0.02	25.0	5.75	1	44.5	UnDef	UnDef	100.0	34	44.0	1.0	-0.37	UnDef	UnDe
93.83	5.0E-06	-0.04	13.0	3.51	4	24.7	98.8	123.5	54.9	UnDef	UnDef	6.0	UnDef	12.1	24.
94.82	5.0E-05	-0.07	8.1	2.69	4	16.6	66.6	83.2	61.8	30	30.0	3.0	-0.02	6.5	13.
95.80	5.0E-05	-0.06	9.0	2.78	4	18.3	73.2	91.5	59.6	30	30.0	3.0	-0.03	7.2	14.
96.78	5.0E-05	-0.09	6.5	2.35	4	14.2	56.7	70.9	65.2	30	30.0	3.0	0.01	5.6	11.
97.77	5.0E-05	-0.07	8.5	2.85	4	17.7	70.7	88.4	61.3	30	30.0	3.0	-0.03	6.9	13.
98.75	5.0E-06	-0.05	11.5	3.99	1	22.8	UnDef	UnDef	100.0	UnDef	UnDef	3.0	UnDef	UnDef	UnDe

Gregg In Situ, Inc.
Interpretation Output - Release 1.00.19e
Job No: 03-0203-1606-1720
Job No: 97-100
Client: CDM
Project: CPT SITE INVESTIGATION
Site: SHERWIN WILLIAMS
Location: CPT-06
Engineer: H. YOUNG
CPT Date: 03/28/01
CPT Time: 12:49
CPT File: 027C06.COR
Northing (m): 0.000
Easting (m): 0.000
Elevation (m): 0.000

Water Table (m): 3.35 (ft): 11.0
Su Nkt used: 12.50
Averaging Increment (m): 0.30
Phi Method : Robertson and Campanella, 1983
Dr Method : Jamiolkowski - All Sands
State Parameter M: 1.20
Used Unit Weights Assigned to Soil Zones
Values of 1.0E9 or UnDef are printed for parameters that are not valid for the material type (SBT)

Depth (ft)	AvgQt (tsf)	AvgFs (tsf)	AvgRf (%)	AvgUd (ft)	SBT	U.Wt. pcf	TStress (tsf)	EStress (tsf)	Ueq (tsf)	Cn	N60 (blows/ft)	(N1)60 (blows/ft)	Su (tsf)	CRR
0.49	0.0	0.00	0.00	0.0	UnDef	124.1	0.03	0.03	0.00	2.00	UnDef	UnDef	UnDef	0.00
1.48	0.0	0.00	0.00	0.0	UnDef	124.1	0.09	0.09	0.00	2.00	UnDef	UnDef	UnDef	0.00
2.46	0.0	0.00	0.00	0.0	UnDef	124.1	0.15	0.15	0.00	2.00	UnDef	UnDef	UnDef	0.00
3.44	0.0	0.00	0.00	0.0	UnDef	124.1	0.21	0.21	0.00	2.00	UnDef	UnDef	UnDef	0.00
4.43	0.0	0.00	0.00	0.0	UnDef	124.1	0.27	0.27	0.00	1.91	UnDef	UnDef	UnDef	0.00
5.41	6.3	0.16	2.58	7.6	4	114.6	0.33	0.33	0.00	1.73	4.0	6.9	0.48	0.09
6.40	10.8	0.20	1.86	21.6	5	114.6	0.39	0.39	0.00	1.60	5.2	8.3	0.83	0.10
7.30	19.1	0.30	1.58	9.1	6	114.6	0.44	0.44	0.00	1.50	7.3	11.0	1.49	0.10
8.20	40.9	0.26	0.63	16.0	7	117.8	0.49	0.49	0.00	1.42	13.0	18.6	UnDef	0.11
9.19	30.0	0.32	1.07	11.2	7	117.8	0.55	0.55	0.00	1.35	9.6	12.9	UnDef	0.10
10.17	5.3	0.06	1.10	44.2	1	79.6	0.60	0.60	0.00	1.29	2.5	3.3	0.38	0.08
11.15	7.1	0.14	1.90	62.1	5	114.6	0.65	0.64	0.00	1.25	3.4	4.3	0.52	0.09
12.14	6.0	0.07	1.13	64.1	1	79.6	0.70	0.66	0.04	1.23	2.9	3.6	0.43	0.08
13.21	6.0	0.09	1.53	63.8	5	114.6	0.75	0.68	0.07	1.21	2.9	3.5	0.42	0.08
14.27	13.9	0.20	1.43	29.1	6	114.6	0.81	0.71	0.10	1.19	5.3	6.3	1.04	0.13
15.26	6.8	0.09	1.35	60.5	5	114.6	0.87	0.73	0.13	1.17	3.3	3.8	0.48	0.09
16.24	6.8	0.14	2.07	81.1	4	114.6	0.92	0.76	0.16	1.15	4.3	5.0	0.47	0.09
17.22	11.4	0.14	1.22	73.6	5	114.6	0.98	0.78	0.19	1.13	5.5	6.2	0.83	0.10
18.21	10.3	0.13	1.25	83.4	5	114.6	1.04	0.81	0.23	1.11	4.9	5.5	0.74	0.10
19.19	9.0	0.14	1.52	89.7	5	114.6	1.09	0.84	0.26	1.09	4.3	4.7	0.63	0.09
20.18	8.4	0.16	1.95	90.8	5	114.6	1.15	0.86	0.29	1.08	4.0	4.3	0.58	0.09
21.16	9.7	0.14	1.42	101.5	5	114.6	1.20	0.89	0.32	1.06	4.6	4.9	0.68	0.09
22.15	8.6	0.18	2.03	91.1	5	114.6	1.26	0.91	0.35	1.05	4.1	4.3	0.59	0.09
23.13	7.7	0.20	2.60	88.2	4	114.6	1.32	0.94	0.38	1.03	4.9	5.1	0.51	0.00
24.11	8.2	0.27	3.31	75.4	3	111.4	1.37	0.96	0.41	1.02	7.8	8.0	0.54	0.00
25.10	10.0	0.35	3.49	80.9	3	111.4	1.43	0.99	0.44	1.01	9.5	9.6	0.68	0.00
26.08	11.2	0.42	3.74	63.6	3	111.4	1.48	1.01	0.47	0.99	10.7	10.6	0.78	0.00
27.07	11.2	0.33	2.98	76.1	4	114.6	1.54	1.04	0.50	0.98	7.2	7.0	0.77	0.00
28.05	11.3	0.26	2.31	113.2	5	114.6	1.59	1.06	0.53	0.97	5.4	5.2	0.77	0.09
29.04	32.3	1.29	3.98	52.2	4	114.6	1.65	1.09	0.56	0.96	20.6	19.8	2.45	0.40

Depth (ft)	AvgQt (tsf)	AvgFs (tsf)	AvgRf (%)	AvgUd (ft)	SBT	U.Wt. pcf	TStress (tsf)	EStress (tsf)	Ueq (tsf)	Cn	N60 (blows/ft)	(N1)60	Su (tsf)	CRR
30.02	19.3	0.84	4.34	29.8	3	111.4	1.71	1.11	0.59	0.95	18.5	17.5	1.41	0.00
31.00	19.2	0.64	3.32	90.1	5	114.6	1.76	1.14	0.62	0.94	9.2	8.6	1.40	0.14
31.99	20.7	0.78	3.77	94.8	4	114.6	1.82	1.16	0.66	0.93	13.2	12.3	1.51	0.00
32.97	19.4	0.84	4.35	55.9	3	111.4	1.87	1.19	0.69	0.92	18.6	17.0	1.40	0.00
33.96	17.3	0.69	3.99	72.9	3	111.4	1.93	1.21	0.72	0.91	16.6	15.0	1.23	0.00
34.94	25.9	0.76	2.93	161.1	5	114.6	1.98	1.24	0.75	0.90	12.4	11.2	1.92	0.22
35.92	76.4	2.55	3.34	141.6	6	114.6	2.04	1.26	0.78	0.89	29.3	26.0	5.95	0.00
36.91	86.3	2.31	2.68	0.4	6	114.6	2.10	1.29	0.81	0.88	33.1	29.1	6.74	0.41
37.89	30.8	0.85	2.77	194.6	5	114.6	2.15	1.31	0.84	0.87	14.7	12.8	2.29	0.29
38.88	22.2	0.67	3.02	146.5	5	114.6	2.21	1.34	0.87	0.86	10.6	9.2	1.60	0.16
39.86	18.9	0.34	1.81	189.8	6	114.6	2.27	1.37	0.90	0.86	7.3	6.2	1.33	0.13
40.85	20.9	0.49	2.36	198.1	6	114.6	2.32	1.39	0.93	0.85	8.0	6.8	1.49	0.14
41.83	25.5	0.83	3.25	191.1	5	114.6	2.38	1.42	0.96	0.84	12.2	10.3	1.85	0.19
42.81	31.3	1.09	3.48	211.8	5	114.6	2.44	1.44	0.99	0.83	15.0	12.5	2.31	0.27
43.80	71.0	3.41	4.81	89.6	11	130.5	2.50	1.47	1.02	0.82	68.0	56.1	UnDef	0.00
44.78	86.1	3.99	4.64	74.2	11	130.5	2.56	1.51	1.05	0.82	82.4	67.2	UnDef	0.00
45.77	57.5	2.37	4.13	184.7	5	114.6	2.62	1.53	1.09	0.81	27.5	22.2	4.39	0.00
46.75	40.9	1.65	4.03	109.5	5	114.6	2.68	1.56	1.12	0.80	19.6	15.7	3.06	0.00
47.74	22.5	0.42	1.86	138.8	6	114.6	2.73	1.59	1.15	0.79	8.6	6.8	1.58	0.14
48.72	26.6	0.69	2.59	215.0	6	114.6	2.79	1.61	1.18	0.79	10.2	8.0	1.90	0.18
49.70	26.8	0.91	3.38	99.9	5	114.6	2.85	1.64	1.21	0.78	12.9	10.0	1.92	0.00
50.69	34.7	1.17	3.36	112.5	5	114.6	2.90	1.66	1.24	0.78	16.6	12.9	2.54	0.29
51.67	40.2	1.25	3.11	140.3	5	114.6	2.96	1.69	1.27	0.77	19.2	14.8	2.98	0.40
52.66	32.4	0.88	2.73	201.8	6	114.6	3.02	1.71	1.30	0.76	12.4	9.5	2.35	0.24
53.64	44.9	1.46	3.25	273.7	5	114.6	3.07	1.74	1.33	0.76	21.5	16.3	3.35	0.00
54.63	47.0	1.71	3.64	171.8	5	114.6	3.13	1.77	1.36	0.75	22.5	16.9	3.51	0.00
55.61	35.4	0.88	2.48	236.7	6	114.6	3.18	1.79	1.39	0.75	13.6	10.1	2.58	0.28
56.59	36.3	1.17	3.23	192.1	5	114.6	3.24	1.82	1.42	0.74	17.4	12.9	2.64	0.29
57.58	35.6	1.31	3.67	205.3	5	114.6	3.30	1.84	1.45	0.74	17.1	12.6	2.59	0.00
58.56	33.6	1.06	3.16	208.9	5	114.6	3.35	1.87	1.49	0.73	16.1	11.8	2.42	0.24
59.55	32.0	1.03	3.21	224.0	5	114.6	3.41	1.89	1.52	0.73	15.3	11.1	2.29	0.22
60.53	32.5	0.87	2.69	307.9	6	114.6	3.47	1.92	1.55	0.72	12.4	9.0	2.32	0.22
61.52	52.6	2.01	3.82	219.8	5	114.6	3.52	1.95	1.58	0.72	25.2	18.1	3.93	0.00
62.42	36.9	1.68	4.56	86.4	4	114.6	3.57	1.97	1.61	0.71	23.5	16.8	2.66	0.00
63.32	30.0	1.08	3.60	119.2	5	114.6	3.63	1.99	1.63	0.71	14.4	10.2	2.11	0.00
64.30	32.5	1.10	3.38	172.5	5	114.6	3.68	2.02	1.66	0.70	15.6	11.0	2.31	0.00
65.29	35.1	1.29	3.66	186.5	5	114.6	3.74	2.04	1.70	0.70	16.8	11.8	2.51	0.00
66.27	69.5	4.19	6.03	101.5	11	130.5	3.80	2.07	1.73	0.69	66.6	46.2	UnDef	0.00
67.26	85.0	4.38	5.15	127.3	11	130.5	3.86	2.11	1.76	0.69	81.4	56.1	UnDef	0.00
68.24	104.5	6.01	5.75	16.2	11	130.5	3.93	2.14	1.79	0.68	100.1	68.4	UnDef	0.00
69.22	67.9	4.01	5.90	142.1	11	130.5	3.99	2.17	1.82	0.68	65.0	44.1	UnDef	0.00
70.21	59.3	3.14	5.30	152.7	11	130.5	4.06	2.21	1.85	0.67	56.8	38.2	UnDef	0.00
71.19	71.1	3.36	4.73	149.2	11	130.5	4.12	2.24	1.88	0.67	68.1	45.5	UnDef	0.00
72.18	43.5	1.88	4.32	168.8	4	114.6	4.18	2.27	1.91	0.66	27.8	18.4	3.15	0.00
73.16	26.8	0.71	2.63	221.1	5	114.6	4.24	2.30	1.94	0.66	12.8	8.5	1.81	0.14
74.15	31.9	1.07	3.36	193.6	5	114.6	4.29	2.32	1.97	0.66	15.3	10.0	2.21	0.00
75.13	39.1	1.32	3.39	312.1	5	114.6	4.35	2.35	2.00	0.65	18.7	12.2	2.78	0.00
76.11	42.2	1.28	3.03	353.0	5	114.6	4.41	2.37	2.03	0.65	20.2	13.1	3.02	0.30
77.10	35.6	1.21	3.41	296.4	5	114.6	4.46	2.40	2.06	0.65	17.0	11.0	2.49	0.00
78.08	27.6	0.82	2.95	285.3	5	114.6	4.52	2.42	2.09	0.64	13.2	8.5	1.85	0.00
79.07	27.0	0.71	2.64	320.7	5	114.6	4.58	2.45	2.13	0.64	12.9	8.3	1.80	0.14
80.05	32.4	0.82	2.51	407.7	6	114.6	4.63	2.48	2.16	0.64	12.4	7.9	2.23	0.18

Gregg In Situ, Inc.
Run No: 03-0203-1606-1720
CPT File: 027C06.COR

Depth (ft)	AvgQt (tsf)	AvgFs (tsf)	AvgRf (%)	AvgUd (ft)	SBT	U.Wt. pcf	TStress (tsf)	EStress (tsf)	Ueq (tsf)	Cn	N60 (blows/ft)	(N1)60 (blows/ft)	Su (tsf)	CRR
81.04	39.4	1.09	2.76	359.6	6	114.6	4.69	2.50	2.19	0.63	15.1	9.5	2.78	0.25
82.02	27.1	0.62	2.30	361.8	6	114.6	4.74	2.53	2.22	0.63	10.4	6.5	1.79	0.13
83.00	29.4	0.64	2.17	352.3	6	114.6	4.80	2.55	2.25	0.63	11.3	7.1	1.97	0.15
83.99	24.7	0.27	1.09	436.1	6	114.6	4.86	2.58	2.28	0.62	9.5	5.9	1.59	0.12
84.97	30.0	0.49	1.63	503.1	6	114.6	4.91	2.60	2.31	0.62	11.5	7.1	2.00	0.15
85.96	52.6	2.46	4.68	301.3	4	114.6	4.97	2.63	2.34	0.62	33.6	20.7	3.81	0.00
86.94	53.6	2.83	5.27	249.2	11	130.5	5.03	2.66	2.37	0.61	51.4	31.5	UnDef	0.00
87.93	37.2	1.23	3.31	385.6	5	114.6	5.09	2.69	2.40	0.61	17.8	10.9	2.56	0.00
88.91	51.5	2.42	4.69	242.9	4	114.6	5.15	2.71	2.43	0.61	32.9	20.0	3.71	0.00
89.89	65.5	2.67	4.08	305.1	5	114.6	5.20	2.74	2.46	0.60	31.3	18.9	4.82	0.00
90.88	63.7	3.84	6.04	189.7	11	130.5	5.26	2.77	2.49	0.60	61.0	36.6	UnDef	0.00
91.86	32.5	0.77	2.38	387.9	6	114.6	5.32	2.80	2.52	0.60	12.4	7.4	2.17	0.16
92.85	34.7	0.98	2.81	333.7	6	114.6	5.38	2.82	2.56	0.60	13.3	7.9	2.35	0.18
93.83	33.6	0.90	2.68	363.1	6	114.6	5.44	2.85	2.59	0.59	12.9	7.6	2.25	0.17
94.82	33.8	0.82	2.44	434.3	6	114.6	5.49	2.88	2.62	0.59	12.9	7.6	2.26	0.17
95.80	45.6	1.48	3.25	471.2	5	114.6	5.55	2.90	2.65	0.59	21.8	12.8	3.20	0.00
96.78	94.8	4.43	4.67	245.4	11	130.5	5.61	2.93	2.68	0.58	90.8	53.0	UnDef	0.00
97.77	46.1	2.29	4.97	250.9	3	111.4	5.67	2.96	2.71	0.58	44.2	25.7	3.24	0.00
98.75	31.8	0.81	2.54	361.3	6	114.6	5.72	2.98	2.74	0.58	12.2	7.0	2.08	0.15

Gregg In Situ, Inc.
Interpretation Output - Release 1.00.19e
Run No: 03-0203-1606-1720
Job No: 97-100
Client: CDM
Project: CPT SITE INVESTIGATION
Site: SHERWIN WILLIAMS
Location: CPT-06
Engineer: H. YOUNG
CPT Date: 03/28/01
CPT Time: 12:49
CPT File: 027C06.COR
Northing (m): 0.000
Easting (m): 0.000
Elevation (m): 0.000

Water Table (m): 3.35 (ft): 11.0
Su Nkt used: 12.50
Averaging Increment (m): 0.30
Phi Method : Robertson and Campanella, 1983
Dr Method : Jamiolkowski - All Sands
State Parameter M: 1.20
Used Unit Weights Assigned to Soil Zones
Values of 1.0E9 or UnDef are printed for parameters that are not valid for the material type (SBT)

Depth (ft)	k (cm/s)	Bq	Qtn	Rfn	SBTn	Qc1N	DeltaQc1N	Qc1Ncs	Fc (%)	Phi (Deg)	Dr (%)	OCR	State Param	Del(n1)60	(N1)60c
0.49	1.0E-15	0.00	2.4	0.10	1	0.2	UnDef	UnDef	100.0	UnDef	UnDef	1.0	UnDef	UnDef	UnDe
1.48	1.0E-15	0.00	0.1	0.10	1	0.2	UnDef	UnDef	100.0	UnDef	UnDef	1.0	UnDef	UnDef	UnDe
2.46	1.0E-15	0.00	0.1	0.10	1	0.2	UnDef	UnDef	100.0	UnDef	UnDef	1.0	UnDef	UnDef	UnDe
3.44	1.0E-15	0.00	0.0	0.10	1	0.2	UnDef	UnDef	100.0	UnDef	UnDef	1.0	UnDef	UnDef	UnDe
4.43	1.0E-15	0.00	0.0	0.10	1	0.2	UnDef	UnDef	100.0	UnDef	UnDef	1.0	UnDef	UnDef	UnDe
5.41	5.0E-07	0.04	17.8	2.72	6	10.6	42.6	53.2	44.2	UnDef	UnDef	6.0	UnDef	6.9	13.
6.40	5.0E-06	0.06	26.6	1.93	6	16.9	46.5	63.4	32.5	UnDef	UnDef	6.0	UnDef	7.0	15.
7.30	5.0E-05	0.02	42.3	1.62	7	28.1	28.3	56.4	23.8	38	30.9	6.0	-0.15	5.0	16.
8.20	5.0E-04	0.01	81.7	0.63	9	56.9	7.8	64.7	9.5	42	51.1	1.0	-0.13	1.5	20.
9.19	5.0E-04	0.01	53.4	1.09	7	39.5	19.5	59.0	17.4	40	40.7	1.0	-0.13	3.4	16.
10.17	1.0E-07	0.29	7.8	1.25	6	6.7	26.7	33.4	51.6	UnDef	UnDef	3.0	UnDef	3.3	6.
11.15	5.0E-06	0.30	10.1	2.09	6	8.7	34.8	43.5	52.5	UnDef	UnDef	3.0	UnDef	4.3	8.
12.14	1.0E-07	0.37	8.1	1.28	6	7.3	29.1	36.4	51.1	UnDef	UnDef	3.0	UnDef	3.6	7.
13.21	5.0E-06	0.37	7.7	1.75	4	7.1	28.5	35.6	56.3	UnDef	UnDef	3.0	UnDef	3.5	7.
14.27	5.0E-05	0.06	18.5	1.52	6	16.1	64.5	80.7	36.0	32	30.0	6.0	-0.05	6.3	12.
15.26	5.0E-06	0.29	8.1	1.54	6	7.8	31.2	39.0	53.4	UnDef	UnDef	3.0	UnDef	3.8	7.
16.24	5.0E-07	0.40	7.7	2.39	4	7.6	30.5	38.1	61.0	UnDef	UnDef	3.0	UnDef	5.0	10.
17.22	5.0E-06	0.20	13.3	1.33	6	12.6	50.4	63.0	40.7	UnDef	UnDef	6.0	UnDef	6.2	12.
18.21	5.0E-06	0.26	11.4	1.39	6	11.2	44.6	55.8	44.4	UnDef	UnDef	3.0	UnDef	5.5	10.
19.19	5.0E-06	0.32	9.5	1.73	6	9.7	38.6	48.3	51.2	UnDef	UnDef	3.0	UnDef	4.7	9.
20.18	5.0E-06	0.35	8.4	2.26	4	8.9	35.4	44.3	58.0	UnDef	UnDef	3.0	UnDef	4.3	8.
21.16	5.0E-06	0.34	9.5	1.62	6	10.1	40.2	50.3	50.2	UnDef	UnDef	3.0	UnDef	4.9	9.
22.15	5.0E-06	0.34	8.1	2.37	4	8.9	35.4	44.3	59.7	UnDef	UnDef	3.0	UnDef	4.3	8.
23.13	5.0E-07	0.37	6.8	3.13	1	7.8	UnDef	UnDef	100.0	UnDef	UnDef	3.0	UnDef	UnDef	UnDe
24.11	5.0E-08	0.29	7.1	3.98	1	8.1	UnDef	UnDef	100.0	UnDef	UnDef	3.0	UnDef	UnDef	UnDe
25.10	5.0E-08	0.24	8.6	4.07	1	9.8	UnDef	UnDef	100.0	UnDef	UnDef	3.0	UnDef	UnDef	UnDe
26.08	5.0E-08	0.16	9.6	4.31	1	10.9	UnDef	UnDef	100.0	UnDef	UnDef	3.0	UnDef	UnDef	UnDe
27.07	5.0E-07	0.19	9.3	3.45	1	10.8	UnDef	UnDef	100.0	UnDef	UnDef	3.0	UnDef	UnDef	UnDe
28.05	5.0E-06	0.31	9.1	2.69	4	10.7	42.8	53.5	58.8	UnDef	UnDef	3.0	UnDef	5.2	10.
29.04	5.0E-07	0.03	28.2	4.19	6	30.3	121.3	151.7	42.3	UnDef	UnDef	6.0	UnDef	19.8	39.

Depth (ft)	k (cm/s)	Bq	Qtn	Rfn	SBTn	Qc1N	DeltaQc1N	Qc1Ncs	Fc (%)	Phi (Deg)	Dr (%)	OCR	State Param	Del(n1)60	(N1)60c
30.02	5.0E-08	0.02	15.8	4.76	1	17.9	UnDef	UnDef	100.0	UnDef	UnDef	6.0	UnDef	UnDef	UnDe
31.00	5.0E-06	0.13	15.3	3.66	4	17.6	70.5	88.1	51.9	UnDef	UnDef	6.0	UnDef	8.6	17.
31.99	5.0E-07	0.12	16.3	4.13	1	18.8	UnDef	UnDef	100.0	UnDef	UnDef	6.0	UnDef	UnDef	UnDe
32.97	5.0E-08	0.06	14.7	4.82	1	17.4	UnDef	UnDef	100.0	UnDef	UnDef	6.0	UnDef	UnDef	UnDe
33.96	5.0E-08	0.10	12.7	4.49	1	15.4	UnDef	UnDef	100.0	UnDef	UnDef	6.0	UnDef	UnDef	UnDe
34.94	5.0E-06	0.18	19.4	3.17	6	22.8	91.2	114.0	44.8	UnDef	UnDef	6.0	UnDef	11.2	22.
35.92	5.0E-05	0.05	58.9	3.44	6	66.5	108.9	175.4	28.2	40	55.6	10.0	-0.29	16.5	42.
36.91	5.0E-05	-0.01	65.4	2.74	7	74.4	77.7	152.1	24.1	40	58.8	10.0	-0.27	13.7	42.
37.89	5.0E-06	0.18	21.8	2.97	6	26.3	105.0	131.3	41.7	UnDef	UnDef	6.0	UnDef	12.8	25.
38.88	5.0E-06	0.19	14.9	3.35	4	18.8	75.1	93.9	51.0	UnDef	UnDef	6.0	UnDef	9.2	18.
39.86	5.0E-05	0.30	12.2	2.05	6	15.9	63.5	79.3	47.9	30	30.0	3.0	0.00	6.2	12.
40.85	5.0E-05	0.28	13.4	2.66	6	17.4	69.5	86.9	49.7	32	30.0	6.0	-0.03	6.8	13.
41.83	5.0E-06	0.22	16.3	3.58	4	21.0	83.9	104.9	50.2	UnDef	UnDef	6.0	UnDef	10.3	20.
42.81	5.0E-06	0.19	20.0	3.77	4	25.5	101.9	127.4	47.0	UnDef	UnDef	6.0	UnDef	12.5	24.
43.80	1.0E-15	0.03	46.5	4.98	6	57.3	229.1	286.4	36.9	38	51.3	1.0	-0.40	56.1	112.
44.78	1.0E-15	0.02	55.5	4.78	6	68.6	226.6	295.2	33.7	40	56.5	1.0	-0.41	62.0	129.
45.77	5.0E-06	0.09	35.8	4.32	6	45.4	181.7	227.1	38.8	UnDef	UnDef	6.0	UnDef	22.2	44.
46.75	5.0E-06	0.06	24.5	4.31	4	32.0	128.1	160.1	45.3	UnDef	UnDef	6.0	UnDef	15.7	31.
47.74	5.0E-05	0.16	12.4	2.12	6	17.4	69.8	87.2	48.0	30	30.0	3.0	-0.02	6.8	13.
48.72	5.0E-05	0.23	14.8	2.89	6	20.5	82.0	102.5	48.9	32	30.0	6.0	-0.06	8.0	16.
49.70	5.0E-06	0.08	14.7	3.78	1	20.5	UnDef	UnDef	100.0	UnDef	UnDef	6.0	UnDef	UnDef	UnDe
50.69	5.0E-06	0.07	19.1	3.67	4	26.3	105.3	131.7	47.4	UnDef	UnDef	6.0	UnDef	12.9	25.
51.67	5.0E-06	0.08	22.0	3.36	6	30.2	121.0	151.2	43.3	UnDef	UnDef	6.0	UnDef	14.8	29.
52.66	5.0E-05	0.17	17.1	3.01	6	24.2	96.8	121.1	46.5	32	30.0	6.0	-0.09	9.5	19.
53.64	5.0E-06	0.17	24.0	3.49	6	33.3	133.3	166.6	42.3	UnDef	UnDef	6.0	UnDef	16.3	32.
54.63	5.0E-06	0.09	24.9	3.90	6	34.6	138.5	173.2	43.4	UnDef	UnDef	6.0	UnDef	16.9	33.
.61	5.0E-05	0.19	18.0	2.72	6	25.9	103.7	129.6	44.0	32	30.0	6.0	-0.08	10.1	20.
56.59	5.0E-06	0.14	18.2	3.55	4	26.4	105.4	131.8	47.8	UnDef	UnDef	6.0	UnDef	12.9	25.
57.58	5.0E-06	0.15	17.5	4.05	1	25.7	UnDef	UnDef	100.0	UnDef	UnDef	6.0	UnDef	UnDef	UnDe
58.56	5.0E-06	0.17	16.2	3.51	4	24.0	96.1	120.1	50.1	UnDef	UnDef	6.0	UnDef	11.8	23.
59.55	5.0E-06	0.19	15.1	3.59	4	22.8	91.1	113.8	51.9	UnDef	UnDef	6.0	UnDef	11.1	22.
60.53	5.0E-05	0.28	15.1	3.01	6	22.9	91.7	114.7	49.0	32	30.0	6.0	-0.06	9.0	18.
61.52	5.0E-06	0.11	25.2	4.10	6	36.9	147.7	184.6	43.9	UnDef	UnDef	6.0	UnDef	18.1	36.
62.42	5.0E-07	0.03	16.9	5.05	1	25.7	UnDef	UnDef	100.0	UnDef	UnDef	6.0	UnDef	UnDef	UnDe
63.32	5.0E-06	0.08	13.2	4.10	1	20.8	UnDef	UnDef	100.0	UnDef	UnDef	6.0	UnDef	UnDef	UnDe
64.30	5.0E-06	0.13	14.3	3.81	1	22.4	UnDef	UnDef	100.0	UnDef	UnDef	6.0	UnDef	UnDef	UnDe
65.29	5.0E-06	0.13	15.4	4.10	1	24.1	UnDef	UnDef	100.0	UnDef	UnDef	6.0	UnDef	UnDef	UnDe
66.27	1.0E-15	0.02	31.7	6.38	1	47.2	UnDef	UnDef	100.0	36	45.8	1.0	-0.52	UnDef	UnDe
67.26	1.0E-15	0.03	38.5	5.40	1	57.3	UnDef	UnDef	100.0	38	51.3	1.0	-0.41	UnDef	UnDe
68.24	1.0E-15	-0.01	47.0	5.97	1	69.9	UnDef	UnDef	100.0	38	57.0	1.0	-0.55	UnDef	UnDe
69.22	1.0E-15	0.04	29.4	6.27	1	45.1	UnDef	UnDef	100.0	36	44.4	1.0	-0.47	UnDef	UnDe
70.21	1.0E-15	0.05	25.0	5.69	1	39.1	UnDef	UnDef	100.0	34	40.3	1.0	-0.34	UnDef	UnDe
71.19	1.0E-15	0.04	29.9	5.02	1	46.5	UnDef	UnDef	100.0	36	45.3	1.0	-0.31	UnDef	UnDe
72.18	5.0E-07	0.09	17.3	4.78	1	28.3	UnDef	UnDef	100.0	UnDef	UnDef	6.0	UnDef	UnDef	UnDe
73.16	5.0E-06	0.22	9.8	3.13	4	17.3	69.3	86.6	59.4	UnDef	UnDef	3.0	UnDef	8.5	17.
74.15	5.0E-06	0.15	11.9	3.88	1	20.5	UnDef	UnDef	100.0	UnDef	UnDef	3.0	UnDef	UnDef	UnDe
75.13	5.0E-06	0.22	14.8	3.81	1	25.0	UnDef	UnDef	100.0	UnDef	UnDef	6.0	UnDef	UnDef	UnDe
76.11	5.0E-06	0.24	15.9	3.38	4	26.8	107.1	133.9	49.8	UnDef	UnDef	6.0	UnDef	13.1	26.
77.10	5.0E-06	0.23	13.0	3.90	1	22.5	UnDef	UnDef	100.0	UnDef	UnDef	6.0	UnDef	UnDef	UnDe
78.08	5.0E-06	0.29	9.5	3.53	1	17.4	UnDef	UnDef	100.0	UnDef	UnDef	3.0	UnDef	UnDef	UnDe
79.07	5.0E-06	0.35	9.2	3.18	4	16.9	67.6	84.5	61.3	UnDef	UnDef	3.0	UnDef	8.3	16.
80.05	5.0E-05	0.38	11.2	2.93	4	20.2	80.7	100.9	55.1	30	30.0	3.0	0.00	7.9	15.

Gregg In Situ, Inc.
Run No: 03-0203-1606-1720
CPT File: 027C06.COR

Depth (ft)	k (cm/s)	Bq	Qtn	Rfn	SBTn	Qc1N	DeltaQc1N	Qc1Ncs	Fc (%)	Phi (Deg)	Dr (%)	OCR	State Param	Del(n1)60	(N1)60c
81.04	5.0E-05	0.26	13.9	3.13	4	24.4	97.5	121.8	51.5	32	30.0	6.0	-0.05	9.5	19.
82.02	5.0E-05	0.41	8.9	2.79	4	16.7	66.8	83.5	60.0	30	30.0	3.0	0.04	6.5	13.
83.00	5.0E-05	0.36	9.6	2.60	4	18.0	72.1	90.1	56.8	30	30.0	3.0	0.02	7.1	14.
83.99	5.0E-05	0.57	7.7	1.36	6	15.1	60.2	75.3	53.0	30	30.0	3.0	0.12	5.9	11.
84.97	5.0E-05	0.53	9.6	1.95	6	18.2	72.7	90.9	52.6	30	30.0	3.0	0.07	7.1	14.
85.96	5.0E-07	0.15	18.1	5.16	1	31.7	UnDef	UnDef	100.0	UnDef	UnDef	6.0	UnDef	UnDef	UnDe
86.94	1.0E-15	0.11	18.3	5.81	1	32.2	UnDef	UnDef	100.0	32	34.8	1.0	-0.27	UnDef	UnDe
87.93	5.0E-06	0.30	11.9	3.83	1	22.2	UnDef	UnDef	100.0	UnDef	UnDef	3.0	UnDef	UnDef	UnDe
88.91	5.0E-07	0.11	17.1	5.21	1	30.6	UnDef	UnDef	100.0	UnDef	UnDef	6.0	UnDef	UnDef	UnDe
89.89	5.0E-06	0.12	22.0	4.44	1	38.7	UnDef	UnDef	100.0	UnDef	UnDef	6.0	UnDef	UnDef	UnDe
90.88	1.0E-15	0.06	21.1	6.58	1	37.4	UnDef	UnDef	100.0	34	39.1	1.0	-0.43	UnDef	UnDe
91.86	5.0E-05	0.35	9.7	2.84	4	19.0	76.0	95.0	58.1	30	30.0	3.0	0.02	7.4	14.
92.85	5.0E-05	0.27	10.4	3.33	4	20.2	80.9	101.1	59.1	30	30.0	3.0	-0.02	7.9	15.
93.83	5.0E-05	0.31	9.9	3.20	4	19.5	77.9	97.4	59.6	30	30.0	3.0	0.00	7.6	15.
94.82	5.0E-05	0.39	9.8	2.91	4	19.5	77.9	97.4	58.2	30	30.0	3.0	0.02	7.6	15.
95.80	5.0E-06	0.30	13.8	3.70	1	26.2	UnDef	UnDef	100.0	UnDef	UnDef	6.0	UnDef	UnDef	UnDe
96.78	1.0E-15	0.06	30.4	4.96	1	54.2	UnDef	UnDef	100.0	36	49.7	1.0	-0.31	UnDef	UnDe
97.77	5.0E-08	0.13	13.7	5.67	1	26.2	UnDef	UnDef	100.0	UnDef	UnDef	6.0	UnDef	UnDef	UnDe
98.75	5.0E-05	0.33	8.7	3.10	4	18.0	72.0	90.0	62.2	30	30.0	3.0	0.02	7.0	14.

Gregg In Situ, Inc.
Interpretation Output - Release 1.00.19e
Run No: 03-0203-1606-1660
Job No: 97-100
Client: CDM
Project: CPT SITE INVESTIGATION
Site: SHERWIN WILLIAMS
Location: CPT-05
Engineer: H. YOUNG
CPT Date: 03/28/01
CPT Time: 10:52
CPT File: 027C05.COR
Northing (m): 0.000
Easting (m): 0.000
Elevation (m): 0.000

Water Table (m): 1.83 (ft): 6.0
Su Nkt used: 12.50
Averaging Increment (m): 0.30
Phi Method : Robertson and Campanella, 1983
Dr Method : Jamiolkowski - All Sands
State Parameter M: 1.20
Used Unit Weights Assigned to Soil Zones
Values of 1.0E9 or UnDef are printed for parameters that are not valid for the material type (SBT)

Depth (ft)	AvgQt (tsf)	AvgFs (tsf)	AvgRf (%)	AvgUd (ft)	SBT	U.Wt. pcf	TStress (tsf)	EStress (tsf)	Ueq (tsf)	Cn	N60 (blows/ft)	(N1)60 (blows/ft)	Su (tsf)	CRR
0.49	0.0	0.00	0.00	0.0	UnDef	124.1	0.03	0.03	0.00	2.00	UnDef	UnDef	UnDef	0.00
1.48	0.0	0.00	0.00	0.0	UnDef	124.1	0.09	0.09	0.00	2.00	UnDef	UnDef	UnDef	0.00
2.46	0.0	0.00	0.00	0.0	UnDef	124.1	0.15	0.15	0.00	2.00	UnDef	UnDef	UnDef	0.00
3.44	0.0	0.00	0.00	0.0	UnDef	124.1	0.21	0.21	0.00	2.00	UnDef	UnDef	UnDef	0.00
4.43	0.0	0.00	0.00	0.0	UnDef	124.1	0.27	0.27	0.00	1.91	UnDef	UnDef	UnDef	0.00
5.41	7.7	0.29	3.72	33.1	3	111.4	0.33	0.33	0.00	1.73	7.4	12.8	0.59	0.11
6.40	6.2	0.28	4.56	20.5	3	111.4	0.39	0.38	0.01	1.63	5.9	9.7	0.46	0.00
7.30	4.2	0.14	3.40	16.7	3	111.4	0.44	0.40	0.04	1.59	4.1	6.4	0.30	0.00
8.20	7.4	0.22	2.92	16.5	4	114.6	0.49	0.42	0.07	1.54	4.8	7.3	0.56	0.10
9.19	6.9	0.10	1.46	14.3	5	114.6	0.55	0.45	0.10	1.50	3.3	4.9	0.51	0.09
10.17	5.6	0.16	2.79	24.9	3	111.4	0.60	0.47	0.13	1.46	5.3	7.8	0.40	0.09
11.15	7.0	0.13	1.86	24.1	5	114.6	0.66	0.50	0.16	1.42	3.4	4.8	0.51	0.09
12.14	10.1	0.22	2.22	31.5	5	114.6	0.71	0.52	0.19	1.39	4.8	6.7	0.75	0.11
13.21	8.9	0.15	1.75	25.2	5	114.6	0.77	0.55	0.22	1.35	4.2	5.7	0.65	0.10
14.27	5.9	0.11	1.77	26.5	4	114.6	0.84	0.58	0.26	1.32	3.8	5.0	0.41	0.09
15.26	5.3	0.12	2.22	40.1	4	114.6	0.89	0.60	0.29	1.29	3.4	4.3	0.35	0.08
16.24	12.5	0.22	1.74	70.0	5	114.6	0.95	0.63	0.32	1.26	6.0	7.6	0.92	0.12
17.22	12.5	0.23	1.85	94.9	5	114.6	1.00	0.65	0.35	1.24	6.0	7.4	0.92	0.12
18.21	13.6	0.19	1.39	136.1	6	114.6	1.06	0.68	0.38	1.21	5.2	6.3	1.00	0.13
19.19	20.8	0.28	1.34	265.0	6	114.6	1.12	0.71	0.41	1.19	8.0	9.5	1.57	0.10
20.18	19.3	0.23	1.19	249.2	6	114.6	1.17	0.73	0.44	1.17	7.4	8.6	1.45	0.10
21.16	23.6	0.46	1.94	227.4	6	114.6	1.23	0.76	0.47	1.15	9.1	10.4	1.79	0.15
22.15	27.4	0.70	2.57	197.4	6	114.6	1.29	0.78	0.50	1.13	10.5	11.9	2.09	0.24
23.13	23.7	0.79	3.33	118.1	5	114.6	1.34	0.81	0.53	1.11	11.3	12.6	1.79	0.28
24.11	56.7	2.25	3.97	112.7	5	114.6	1.40	0.83	0.57	1.10	27.2	29.7	4.42	0.00
25.10	81.5	3.17	3.89	97.4	5	114.6	1.46	0.86	0.60	1.08	39.0	42.1	6.41	0.00
26.08	115.7	4.13	3.56	55.2	6	114.6	1.51	0.88	0.63	1.06	44.3	47.1	9.14	0.00
27.07	39.4	1.92	4.89	45.1	3	111.4	1.57	0.91	0.66	1.05	37.7	39.6	3.03	0.00
28.05	31.2	1.30	4.18	81.1	4	114.6	1.62	0.93	0.69	1.03	20.0	20.6	2.37	0.45
29.04	29.7	1.24	4.17	138.8	4	114.6	1.68	0.96	0.72	1.02	18.9	19.3	2.24	0.38

Gregg In Situ, Inc.
Run No: 03-0203-1606-1660
CPT File: 027C05.COR

Depth (ft)	AvgQt (tsf)	AvgFs (tsf)	AvgRf (%)	AvgUd (ft)	SBT	U.Wt. pcf	TStress (tsf)	EStress (tsf)	Ueq (tsf)	Cn	N60 (blows/ft)	(N1)60	Su (tsf)	CRR
30.02	26.6	1.12	4.20	104.6	4	114.6	1.74	0.99	0.75	1.01	17.0	17.1	1.99	0.00
31.00	44.4	1.43	3.23	117.2	5	114.6	1.79	1.01	0.78	0.99	21.3	21.2	3.41	0.00
31.99	179.8	4.43	2.46	56.1	7	117.8	1.85	1.04	0.81	0.98	57.4	56.4	UnDef	0.00
32.97	176.4	4.05	2.29	15.2	7	117.8	1.91	1.07	0.84	0.97	56.3	54.6	UnDef	0.00
33.96	167.9	3.63	2.16	-7.7	7	117.8	1.97	1.09	0.87	0.96	53.6	51.3	UnDef	0.00
34.94	190.3	3.94	2.07	-14.2	7	117.8	2.02	1.12	0.90	0.95	60.7	57.4	UnDef	0.00
35.92	125.8	4.18	3.32	-14.0	6	114.6	2.08	1.15	0.93	0.93	48.2	45.0	9.90	0.00
36.91	41.8	1.71	4.09	-11.5	5	114.6	2.14	1.17	0.97	0.92	20.0	18.5	3.17	0.00
37.89	21.7	0.60	2.76	-8.2	5	114.6	2.19	1.20	1.00	0.91	10.4	9.5	1.56	0.17
38.88	21.5	0.48	2.24	3.7	6	114.6	2.25	1.22	1.03	0.90	8.2	7.5	1.54	0.16
39.86	44.3	1.61	3.64	4.6	5	114.6	2.31	1.25	1.06	0.90	21.2	19.0	3.36	0.00
40.85	46.5	2.80	6.01	4.6	3	111.4	2.36	1.27	1.09	0.89	44.5	39.5	3.53	0.00
41.83	31.0	0.96	3.08	15.1	5	114.6	2.42	1.30	1.12	0.88	14.9	13.0	2.29	0.30
42.81	30.0	0.98	3.28	16.2	5	114.6	2.47	1.32	1.15	0.87	14.4	12.5	2.20	0.27
43.80	123.1	4.27	3.47	16.7	6	114.6	2.53	1.35	1.18	0.86	47.1	40.6	9.64	0.00
44.78	67.3	2.24	3.33	13.4	6	114.6	2.59	1.38	1.21	0.85	25.8	22.0	5.18	0.00
45.77	25.2	0.55	2.19	15.3	6	114.6	2.64	1.40	1.24	0.84	9.7	8.2	1.81	0.19
46.75	21.6	0.42	1.94	16.5	6	114.6	2.70	1.43	1.27	0.84	8.3	6.9	1.51	0.14
47.74	43.6	1.67	3.82	19.3	5	114.6	2.76	1.45	1.30	0.83	20.9	17.3	3.27	0.00
48.72	159.6	8.07	5.06	28.3	11	130.5	2.82	1.48	1.33	0.82	152.8	125.6	UnDef	0.00
49.70	38.6	1.80	4.67	26.8	4	114.6	2.88	1.51	1.36	0.81	24.7	20.1	2.86	0.00
50.69	30.9	0.72	2.34	27.7	6	114.6	2.93	1.54	1.40	0.81	11.8	9.5	2.23	0.25
51.67	24.5	0.51	2.06	27.4	6	114.6	2.99	1.56	1.43	0.80	9.4	7.5	1.72	0.16
52.66	31.9	0.60	1.87	28.8	6	114.6	3.05	1.59	1.46	0.79	12.2	9.7	2.31	0.26
53.64	35.2	0.95	2.71	29.2	6	114.6	3.10	1.61	1.49	0.79	13.5	10.6	2.56	0.31
54.63	32.5	0.94	2.89	29.5	5	114.6	3.16	1.64	1.52	0.78	15.5	12.1	2.35	0.26
.61	28.6	0.70	2.46	30.9	6	114.6	3.21	1.67	1.55	0.77	10.9	8.5	2.03	0.20
6.59	32.7	0.87	2.66	31.5	6	114.6	3.27	1.69	1.58	0.77	12.5	9.6	2.35	0.25
57.58	25.2	0.59	2.36	31.2	6	114.6	3.33	1.72	1.61	0.76	9.6	7.4	1.75	0.16
58.56	25.0	0.64	2.55	32.3	5	114.6	3.38	1.74	1.64	0.76	12.0	9.1	1.73	0.15
59.55	23.0	0.55	2.41	32.4	6	114.6	3.44	1.77	1.67	0.75	8.8	6.6	1.57	0.14
60.53	27.4	0.86	3.13	33.2	5	114.6	3.50	1.79	1.70	0.75	13.1	9.8	1.92	0.17
61.52	28.2	0.87	3.10	34.5	5	114.6	3.55	1.82	1.73	0.74	13.5	10.0	1.97	0.18
62.42	29.5	0.75	2.54	35.7	6	114.6	3.60	1.84	1.76	0.74	11.3	8.3	2.07	0.19
63.32	36.4	0.89	2.45	38.4	6	114.6	3.66	1.87	1.79	0.73	13.9	10.2	2.62	0.29
64.30	31.6	0.83	2.63	40.9	6	114.6	3.71	1.89	1.82	0.73	12.1	8.8	2.23	0.21
65.29	29.3	0.96	3.26	43.6	5	114.6	3.77	1.92	1.85	0.72	14.1	10.1	2.05	0.00
66.27	30.8	0.89	2.88	44.9	5	114.6	3.83	1.94	1.88	0.72	14.8	10.6	2.16	0.20
67.26	33.8	0.94	2.78	47.8	6	114.6	3.88	1.97	1.91	0.71	12.9	9.2	2.39	0.23
68.24	35.3	0.85	2.40	56.0	6	114.6	3.94	1.99	1.94	0.71	13.5	9.6	2.51	0.25
69.22	47.6	1.29	2.70	59.7	6	114.6	3.99	2.02	1.97	0.70	18.2	12.8	3.49	0.00
70.21	92.7	4.73	5.11	66.5	11	130.5	4.05	2.05	2.00	0.70	88.7	62.0	UnDef	0.00
71.19	124.2	6.16	4.96	65.8	11	130.5	4.12	2.08	2.04	0.69	119.0	82.4	UnDef	0.00
72.18	40.8	1.20	2.94	66.5	6	114.6	4.18	2.11	2.07	0.69	15.6	10.8	2.93	0.32
73.16	39.7	1.03	2.60	70.8	6	114.6	4.24	2.14	2.10	0.68	15.2	10.4	2.83	0.30
74.15	46.5	1.18	2.53	73.8	6	114.6	4.29	2.16	2.13	0.68	17.8	12.1	3.38	0.42
75.13	54.5	2.21	4.05	76.0	5	114.6	4.35	2.19	2.16	0.68	26.1	17.6	4.01	0.00
76.11	50.2	2.21	4.41	77.2	5	114.6	4.40	2.22	2.19	0.67	24.0	16.2	3.66	0.00
77.10	37.4	1.54	4.13	73.3	4	114.6	4.46	2.24	2.22	0.67	23.9	16.0	2.64	0.00
78.08	36.2	0.79	2.17	78.4	6	114.6	4.52	2.27	2.25	0.66	13.9	9.2	2.54	0.23
79.07	34.7	0.86	2.48	80.0	6	114.6	4.57	2.29	2.28	0.66	13.3	8.8	2.41	0.21
80.05	35.8	0.95	2.65	81.4	6	114.6	4.63	2.32	2.31	0.66	13.7	9.0	2.49	0.22

Gregg In Situ, Inc.
Run No: 03-0203-1606-1660
CPT File: 027C05.COR

Depth (ft)	AvgQt (tsf)	AvgFs (tsf)	AvgRf (%)	AvgUd (ft)	SBT	U.Wt. pcf	TStress (tsf)	EStress (tsf)	Ueq (tsf)	Cn	N60 (blows/ft)	(N1)60 (blows/ft)	Su (tsf)	CRR
81.04	41.4	1.30	3.15	85.6	5	114.6	4.69	2.34	2.34	0.65	19.8	13.0	2.94	0.30
82.02	45.9	1.50	3.27	89.9	5	114.6	4.74	2.37	2.37	0.65	22.0	14.3	3.29	0.37
83.00	48.6	1.39	2.86	94.8	6	114.6	4.80	2.40	2.40	0.65	18.6	12.0	3.50	0.42
83.99	65.3	3.47	5.31	100.7	11	130.5	4.86	2.42	2.44	0.64	62.5	40.1	UnDef	0.00
84.97	38.5	1.23	3.21	94.5	5	114.6	4.92	2.45	2.47	0.64	18.4	11.8	2.68	0.00
85.96	53.0	2.18	4.11	105.4	5	114.6	4.98	2.48	2.50	0.64	25.4	16.1	3.84	0.00
86.94	118.7	6.37	5.36	128.4	11	130.5	5.04	2.51	2.53	0.63	113.7	71.8	UnDef	0.00
87.93	134.6	7.20	5.35	152.5	11	130.5	5.10	2.54	2.56	0.63	128.9	80.9	UnDef	0.00
88.91	32.2	1.06	3.31	128.7	5	114.6	5.16	2.57	2.59	0.62	15.4	9.6	2.16	0.00
89.89	30.9	0.75	2.43	138.5	6	114.6	5.22	2.60	2.62	0.62	11.9	7.4	2.06	0.16
90.88	78.0	3.58	4.59	146.0	11	130.5	5.28	2.63	2.65	0.62	74.7	46.1	UnDef	0.00
91.86	25.2	0.82	3.26	120.6	5	114.6	5.34	2.66	2.68	0.61	12.1	7.4	1.59	0.00
92.85	25.6	0.55	2.13	132.9	6	114.6	5.39	2.68	2.71	0.61	9.8	6.0	1.62	0.12
93.83	25.4	0.63	2.50	131.3	6	114.6	5.45	2.71	2.74	0.61	9.7	5.9	1.60	0.00
94.82	25.7	0.69	2.68	130.3	5	114.6	5.51	2.73	2.77	0.60	12.3	7.4	1.62	0.00
95.80	34.0	1.16	3.41	139.7	5	114.6	5.56	2.76	2.80	0.60	16.3	9.8	2.27	0.00
96.78	31.3	0.93	2.98	138.4	5	114.6	5.62	2.79	2.83	0.60	15.0	9.0	2.05	0.00
97.77	37.1	0.92	2.49	155.0	6	114.6	5.68	2.81	2.87	0.60	14.2	8.5	2.51	0.20
98.75	42.9	1.35	3.16	165.7	5	114.6	5.73	2.84	2.90	0.59	20.5	12.2	2.97	0.00

Gregg In Situ, Inc.
Interpretation Output - Release 1.00.19e
Run No: 03-0203-1606-1660
Job No: 97-100
Client: CDM
Project: CPT SITE INVESTIGATION
Site: SHERWIN WILLIAMS
Location: CPT-05
Engineer: H. YOUNG
CPT Date: 03/28/01
CPT Time: 10:52
CPT File: 027C05.COR
Northing (m): 0.000
Easting (m): 0.000
Elevation (m): 0.000

Water Table (m): 1.83 (ft): 6.0
Su Nkt used: 12.50
Averaging Increment (m): 0.30
Phi Method : Robertson and Campanella, 1983
Dr Method : Jamiolkowski - All Sands
State Parameter M: 1.20
Used Unit Weights Assigned to Soil Zones
Values of 1.0E9 or UnDef are printed for parameters that are not valid for the material type (SBT)

Depth (ft)	k (cm/s)	Bq	Qtn	Rfn	SBTn	Qc1N	DeltaQc1N	Qc1Ncs	Fc (%)	Phi (Deg)	Dr (%)	OCR	State Param	Del(n1)60	(N1)60c
0.49	1.0E-15	0.00	2.4	0.10	1	0.2	UnDef	UnDef	100.0	UnDef	UnDef	1.0	UnDef	UnDef	UnDe
1.48	1.0E-15	0.00	0.1	0.10	1	0.2	UnDef	UnDef	100.0	UnDef	UnDef	1.0	UnDef	UnDef	UnDe
2.46	1.0E-15	0.00	0.1	0.10	1	0.2	UnDef	UnDef	100.0	UnDef	UnDef	1.0	UnDef	UnDef	UnDe
3.44	1.0E-15	0.00	0.0	0.10	1	0.2	UnDef	UnDef	100.0	UnDef	UnDef	1.0	UnDef	UnDef	UnDe
4.43	1.0E-15	0.00	0.0	0.10	1	0.2	UnDef	UnDef	100.0	UnDef	UnDef	1.0	UnDef	UnDef	UnDe
5.41	5.0E-08	0.14	22.1	3.89	6	13.0	52.1	65.2	45.5	UnDef	UnDef	6.0	UnDef	12.8	25.
6.40	5.0E-08	0.11	15.5	4.87	1	9.9	UnDef	UnDef	100.0	UnDef	UnDef	6.0	UnDef	UnDef	UnDe
7.30	5.0E-08	0.13	9.6	3.79	1	6.6	UnDef	UnDef	100.0	UnDef	UnDef	3.0	UnDef	UnDef	UnDe
8.20	5.0E-07	0.06	16.6	3.12	6	11.2	45.0	56.2	47.7	UnDef	UnDef	6.0	UnDef	7.3	14.
9.19	5.0E-06	0.06	14.2	1.59	6	10.1	40.2	50.3	41.5	UnDef	UnDef	6.0	UnDef	4.9	9.
10.17	5.0E-08	0.13	10.5	3.13	4	7.9	31.8	39.7	57.7	UnDef	UnDef	3.0	UnDef	7.8	15.
11.15	5.0E-06	0.09	12.8	2.05	6	9.8	39.1	48.8	46.8	UnDef	UnDef	6.0	UnDef	4.8	9.
12.14	5.0E-06	0.08	18.0	2.38	6	13.7	54.8	68.5	42.1	UnDef	UnDef	6.0	UnDef	6.7	13.
13.21	5.0E-06	0.07	14.7	1.91	6	11.7	46.8	58.5	43.1	UnDef	UnDef	6.0	UnDef	5.7	11.
14.27	5.0E-07	0.11	8.8	2.06	4	7.7	30.6	38.3	55.4	UnDef	UnDef	3.0	UnDef	5.0	10.
15.26	5.0E-07	0.22	7.3	2.67	4	6.7	26.6	33.3	64.3	UnDef	UnDef	3.0	UnDef	4.3	8.
16.24	5.0E-06	0.16	18.4	1.88	6	15.4	61.8	77.2	38.5	UnDef	UnDef	6.0	UnDef	7.6	15.
17.22	5.0E-06	0.23	17.5	2.01	6	15.1	60.4	75.5	40.3	UnDef	UnDef	6.0	UnDef	7.4	14.
18.21	5.0E-05	0.31	18.4	1.51	6	16.1	64.3	80.4	36.0	32	30.0	6.0	-0.02	6.3	12.
19.19	5.0E-05	0.40	27.9	1.42	7	24.2	39.9	64.1	28.3	36	30.0	6.0	-0.04	6.0	15.
20.18	5.0E-05	0.41	24.8	1.26	7	22.1	39.3	61.4	29.0	34	30.0	6.0	-0.02	5.8	14.
21.16	5.0E-05	0.30	29.6	2.05	7	26.6	64.4	90.9	31.5	36	30.0	6.0	-0.10	8.3	18.
22.15	5.0E-05	0.22	33.4	2.69	6	30.3	90.6	120.9	33.1	36	33.1	6.0	-0.15	10.5	22.
23.13	5.0E-06	0.14	27.6	3.53	6	25.8	103.0	128.8	40.0	UnDef	UnDef	6.0	UnDef	12.6	25.
24.11	5.0E-06	0.05	66.4	4.07	6	60.8	108.8	169.6	29.0	UnDef	UnDef	10.0	UnDef	19.9	49.
25.10	5.0E-06	0.03	93.2	3.96	12	86.1	UnDef	UnDef	0.0	UnDef	UnDef	10.0	UnDef	UnDef	UnDe
26.08	5.0E-05	0.01	129.1	3.61	12	120.4	UnDef	UnDef	0.0	44	72.6	10.0	-0.42	UnDef	UnDe
27.07	5.0E-08	0.02	41.6	5.09	6	40.4	161.7	202.1	39.0	UnDef	UnDef	6.0	UnDef	39.6	79.
28.05	5.0E-07	0.06	31.7	4.40	6	31.6	126.5	158.2	41.1	UnDef	UnDef	6.0	UnDef	20.6	41.
29.04	5.0E-07	0.13	29.1	4.42	6	29.6	118.5	148.1	42.6	UnDef	UnDef	6.0	UnDef	19.3	38.

Gregg In Situ, Inc.
Run No: 03-0203-1606-1660
CPT File: 027C05.COR

Depth (ft)	k (cm/s)	Bq	Qtn	Rfn	SBTn	Qc1N	DeltaQc1N	Qc1Ncs	Fc (%)	Phi (Deg)	Dr (%)	OCR	State Param	Del(n1)60	(N1)60c
30.02	5.0E-07	0.10	25.2	4.49	1	26.2	UnDef	UnDef	100.0	UnDef	UnDef	6.0	UnDef	UnDef	UnDe
31.00	5.0E-06	0.07	42.2	3.36	6	43.2	120.1	163.3	32.5	UnDef	UnDef	6.0	UnDef	18.0	39.
31.99	5.0E-04	0.01	171.5	2.49	7	172.8	53.8	226.6	13.9	44	82.9	1.0	-0.36	9.8	66.
32.97	5.0E-04	0.00	163.8	2.32	7	167.2	49.6	216.8	13.6	44	82.0	1.0	-0.34	9.1	63.
33.96	5.0E-04	-0.01	151.9	2.19	7	157.2	46.7	203.9	13.6	44	80.2	1.0	-0.32	8.6	59.
34.94	5.0E-04	-0.01	168.2	2.09	9	176.0	43.6	219.6	12.4	44	83.5	1.0	-0.33	8.1	65.
35.92	5.0E-05	-0.01	108.0	3.37	7	115.0	87.4	202.4	21.2	42	71.3	10.0	-0.38	16.7	61.
36.91	5.0E-06	-0.03	33.8	4.31	6	37.8	151.0	188.8	39.6	UnDef	UnDef	6.0	UnDef	18.5	37.
37.89	5.0E-06	-0.06	16.3	3.07	6	19.4	77.6	97.0	47.8	UnDef	UnDef	6.0	UnDef	9.5	19.
38.88	5.0E-05	-0.05	15.8	2.51	6	19.0	76.2	95.2	45.4	32	30.0	6.0	-0.09	7.5	14.
39.86	5.0E-06	-0.02	33.7	3.84	6	38.8	155.3	194.1	37.9	UnDef	UnDef	6.0	UnDef	19.0	38.
40.85	5.0E-08	-0.02	34.7	6.33	1	40.3	UnDef	UnDef	100.0	UnDef	UnDef	6.0	UnDef	UnDef	UnDe
41.83	5.0E-06	-0.02	22.0	3.34	6	26.7	106.6	133.3	43.2	UnDef	UnDef	6.0	UnDef	13.0	26.
42.81	5.0E-06	-0.02	20.8	3.57	6	25.5	102.0	127.6	45.3	UnDef	UnDef	6.0	UnDef	12.5	25.
43.80	5.0E-05	-0.01	89.3	3.54	7	103.7	103.7	207.3	23.7	42	68.3	10.0	-0.37	18.5	59.
44.78	5.0E-05	-0.01	47.1	3.46	6	56.2	133.3	189.5	31.4	38	50.7	6.0	-0.27	17.3	39.
45.77	5.0E-05	-0.03	16.1	2.45	6	20.8	83.4	104.2	44.7	32	30.0	6.0	-0.09	8.2	16.
46.75	5.0E-05	-0.04	13.3	2.22	6	17.7	70.8	88.6	47.3	32	30.0	6.0	-0.06	6.9	13.
47.74	5.0E-06	-0.02	28.1	4.08	6	35.4	141.7	177.1	41.9	UnDef	UnDef	6.0	UnDef	17.3	34.
48.72	1.0E-15	0.00	105.8	5.15	11	128.3	UnDef	UnDef	0.0	42	74.4	1.0	-0.58	UnDef	UnDe
49.70	5.0E-07	-0.01	23.7	5.05	1	30.8	UnDef	UnDef	100.0	UnDef	UnDef	6.0	UnDef	UnDef	UnDe
50.69	5.0E-05	-0.02	18.2	2.58	6	24.4	97.5	121.8	43.1	32	30.0	6.0	-0.11	9.5	19.
51.67	5.0E-05	-0.03	13.8	2.35	6	19.2	76.8	96.1	47.3	32	30.0	6.0	-0.07	7.5	15.
52.66	5.0E-05	-0.02	18.2	2.07	6	24.8	99.1	123.8	40.0	32	30.0	6.0	-0.08	9.7	19.
53.64	5.0E-05	-0.02	19.9	2.97	6	27.1	108.3	135.4	43.4	34	30.0	6.0	-0.13	10.6	21.
54.63	5.0E-06	-0.02	17.9	3.20	6	24.8	99.3	124.1	46.6	UnDef	UnDef	6.0	UnDef	12.1	24.
.61	5.0E-05	-0.02	15.2	2.77	6	21.7	86.7	108.4	47.6	32	30.0	6.0	-0.09	8.5	17.
6.59	5.0E-05	-0.02	17.4	2.96	6	24.6	98.3	122.9	45.9	32	30.0	6.0	-0.12	9.6	19.
57.58	5.0E-05	-0.03	12.7	2.72	6	18.8	75.2	94.1	51.2	32	30.0	6.0	-0.07	7.4	14.
58.56	5.0E-06	-0.03	12.4	2.95	4	18.5	74.1	92.6	53.0	UnDef	UnDef	3.0	UnDef	9.1	18.
59.55	5.0E-05	-0.03	11.1	2.83	4	17.0	67.8	84.8	54.9	30	30.0	3.0	-0.06	6.6	13.
60.53	5.0E-06	-0.03	13.4	3.59	4	20.1	80.2	100.3	54.6	UnDef	UnDef	6.0	UnDef	9.8	19.
61.52	5.0E-06	-0.03	13.5	3.54	4	20.4	81.8	102.2	54.0	UnDef	UnDef	6.0	UnDef	10.0	20.
62.42	5.0E-05	-0.02	14.0	2.90	6	21.3	85.0	106.3	50.0	32	30.0	6.0	-0.09	8.3	16.
63.32	5.0E-05	-0.02	17.5	2.72	6	26.1	104.2	130.3	44.5	32	30.0	6.0	-0.11	10.2	20.
64.30	5.0E-05	-0.02	14.8	2.98	6	22.5	90.0	112.5	49.4	32	30.0	6.0	-0.10	8.8	17.
65.29	5.0E-06	-0.02	13.3	3.74	1	20.7	UnDef	UnDef	100.0	UnDef	UnDef	6.0	UnDef	UnDef	UnDe
66.27	5.0E-06	-0.02	13.9	3.29	4	21.6	86.6	108.2	52.2	UnDef	UnDef	6.0	UnDef	10.6	21.
67.26	5.0E-05	-0.01	15.2	3.15	4	23.6	94.2	117.8	49.6	32	30.0	6.0	-0.11	9.2	18.
68.24	5.0E-05	-0.01	15.7	2.70	6	24.4	97.8	122.2	46.6	32	30.0	6.0	-0.09	9.6	19.
69.22	5.0E-05	0.00	21.6	2.95	6	32.8	131.2	164.0	41.7	34	35.3	6.0	-0.14	12.8	25.
70.21	1.0E-15	0.00	43.2	5.34	1	63.3	UnDef	UnDef	100.0	38	54.2	1.0	-0.43	UnDef	UnDe
71.19	1.0E-15	0.00	57.7	5.13	6	84.2	302.8	387.0	34.3	40	62.4	1.0	-0.46	79.0	161.
72.18	5.0E-05	0.00	17.3	3.27	6	27.5	110.0	137.5	47.5	32	30.3	6.0	-0.13	10.8	21.
73.16	5.0E-05	0.00	16.6	2.92	6	26.5	106.1	132.7	46.7	32	30.0	6.0	-0.11	10.4	20.
74.15	5.0E-05	0.00	19.5	2.79	6	30.9	123.7	154.7	42.8	34	33.6	6.0	-0.12	12.1	24.
75.13	5.0E-06	0.00	22.9	4.40	1	36.0	UnDef	UnDef	100.0	UnDef	UnDef	6.0	UnDef	UnDef	UnDe
76.11	5.0E-06	0.00	20.7	4.83	1	33.0	UnDef	UnDef	100.0	UnDef	UnDef	6.0	UnDef	UnDef	UnDe
77.10	5.0E-07	0.00	14.7	4.69	1	24.5	UnDef	UnDef	100.0	UnDef	UnDef	6.0	UnDef	UnDef	UnDe
78.08	5.0E-05	0.01	14.0	2.48	6	23.5	94.2	117.7	47.7	32	30.0	6.0	-0.07	9.2	18.
79.07	5.0E-05	0.01	13.1	2.86	4	22.4	89.7	112.1	51.2	32	30.0	6.0	-0.07	8.8	17.
80.05	5.0E-05	0.01	13.4	3.05	4	23.0	92.0	115.0	51.8	32	30.0	6.0	-0.08	9.0	18.

Gregg In Situ, Inc.
Run No: 03-0203-1606-1660
CPT File: 027C05.COR

Depth (ft)	k (cm/s)	Bq	Qtn	Rfn	SBTn	Qc1N	DeltaQc1N	Qc1Ncs	Fc (%)	Phi (Deg)	Dr (%)	OCR	State Param	Del(n1)60	(N1)60c
81.04	5.0E-06	0.01	15.7	3.55	4	26.5	105.9	132.3	50.9	UnDef	UnDef	6.0	UnDef	13.0	25.
82.02	5.0E-06	0.01	17.4	3.65	4	29.2	116.7	145.9	49.2	UnDef	UnDef	6.0	UnDef	14.3	28.
83.00	5.0E-05	0.01	18.3	3.17	6	30.7	123.0	153.7	46.0	32	33.5	6.0	-0.13	12.0	24.
83.99	1.0E-15	0.01	24.9	5.74	1	41.0	UnDef	UnDef	100.0	34	41.7	1.0	-0.36	UnDef	UnDe
84.97	5.0E-06	0.01	13.7	3.68	1	24.0	UnDef	UnDef	100.0	UnDef	UnDef	6.0	UnDef	UnDef	UnDe
85.96	5.0E-06	0.02	19.3	4.54	1	32.9	UnDef	UnDef	100.0	UnDef	UnDef	6.0	UnDef	UnDef	UnDe
86.94	1.0E-15	0.01	45.3	5.60	1	73.3	UnDef	UnDef	100.0	38	58.4	1.0	-0.47	UnDef	UnDe
87.93	1.0E-15	0.02	50.9	5.56	6	82.6	330.4	413.1	37.3	38	61.8	1.0	-0.49	80.9	161.
88.91	5.0E-06	0.05	10.5	3.94	1	19.6	UnDef	UnDef	100.0	UnDef	UnDef	3.0	UnDef	UnDef	UnDe
89.89	5.0E-05	0.07	9.9	2.92	4	18.8	75.1	93.9	58.1	30	30.0	3.0	-0.03	7.4	14.
90.88	1.0E-15	0.03	27.7	4.92	1	47.1	UnDef	UnDef	100.0	36	45.7	1.0	-0.29	UnDef	UnDe
91.86	5.0E-06	0.05	7.5	4.13	1	15.2	UnDef	UnDef	100.0	UnDef	UnDef	3.0	UnDef	UnDef	UnDe
92.85	5.0E-05	0.07	7.5	2.70	4	15.3	61.2	76.5	63.7	30	30.0	3.0	0.01	6.0	12.
93.83	5.0E-05	0.07	7.4	3.18	1	15.1	UnDef	UnDef	100.0	30	30.0	3.0	0.00	UnDef	UnDe
94.82	5.0E-06	0.06	7.4	3.42	1	15.2	UnDef	UnDef	100.0	UnDef	UnDef	3.0	UnDef	UnDef	UnDe
95.80	5.0E-06	0.05	10.3	4.08	1	20.0	UnDef	UnDef	100.0	UnDef	UnDef	3.0	UnDef	UnDef	UnDe
96.78	5.0E-06	0.06	9.2	3.63	1	18.3	UnDef	UnDef	100.0	UnDef	UnDef	3.0	UnDef	UnDef	UnDe
97.77	5.0E-05	0.06	11.2	2.94	4	21.6	86.6	108.2	55.3	30	30.0	3.0	-0.05	8.5	16.
98.75	5.0E-06	0.06	13.1	3.64	1	24.9	UnDef	UnDef	100.0	UnDef	UnDef	6.0	UnDef	UnDef	UnDe

Gregg In Situ, Inc.
Interpretation Output - Release 1.00.19e
n No: 03-0203-1606-1605
ob No: 97-100
Client: CDM
Project: CPT SITE INVESTIGATION
Site: SHERWIN WILLIAMS
Location: CPT-04
Engineer: H. YOUNG
CPT Date: 03/28/01
CPT Time: 08:29
CPT File: 027C04.COR
Northing (m): 0.000
Easting (m): 0.000
Elevation (m): 0.000

Water Table (m): 2.44 (ft): 8.0
Su Nkt used: 12.50
Averaging Increment (m): 0.30
Phi Method : Robertson and Campanella, 1983
Dr Method : Jamiolkowski - All Sands
State Parameter M: 1.20
Used Unit Weights Assigned to Soil Zones
Values of 1.0E9 or UnDef are printed for parameters that are not valid for the material type (SBT)

Depth (ft)	AvgQt (tsf)	AvgFs (tsf)	AvgRf (%)	AvgUd (ft)	SBT	U.Wt. pcf	TStress (tsf)	EStress (tsf)	Ueq (tsf)	Cn	N60 (blows/ft)	(N1)60 (blows/ft)	Su (tsf)	CRR
0.49	0.0	0.00	0.00	0.0	UnDef	124.1	0.03	0.03	0.00	2.00	UnDef	UnDef	UnDef	0.00
1.48	0.0	0.00	0.00	0.0	UnDef	124.1	0.09	0.09	0.00	2.00	UnDef	UnDef	UnDef	0.00
2.46	0.0	0.00	0.00	0.0	UnDef	124.1	0.15	0.15	0.00	2.00	UnDef	UnDef	UnDef	0.00
3.44	0.0	0.00	0.00	0.0	UnDef	124.1	0.21	0.21	0.00	2.00	UnDef	UnDef	UnDef	0.00
.43	0.0	0.00	0.00	0.0	UnDef	124.1	0.27	0.27	0.00	1.91	UnDef	UnDef	UnDef	0.00
5.41	12.4	0.53	4.30	34.6	3	111.4	0.33	0.33	0.00	1.73	11.9	20.6	0.96	0.19
6.40	13.9	0.60	4.34	16.0	3	111.4	0.39	0.39	0.00	1.61	13.3	21.4	1.08	0.20
7.30	8.2	0.14	1.74	1.6	5	114.6	0.44	0.44	0.00	1.51	3.9	5.9	0.62	0.10
8.20	5.2	0.10	1.82	15.8	4	114.6	0.49	0.48	0.01	1.44	3.3	4.8	0.38	0.08
9.19	5.3	0.16	2.95	13.9	3	111.4	0.55	0.51	0.04	1.40	5.0	7.1	0.38	0.08
10.17	25.6	0.15	0.59	6.5	7	117.8	0.60	0.53	0.07	1.37	8.2	11.2	UnDef	0.09
11.15	67.8	0.33	0.49	-10.2	8	120.9	0.66	0.56	0.10	1.33	16.2	21.6	UnDef	0.14
12.14	86.8	0.43	0.49	-16.9	8	120.9	0.72	0.59	0.13	1.30	20.8	27.0	UnDef	0.21
13.21	61.5	0.33	0.54	-5.9	8	120.9	0.78	0.62	0.16	1.27	14.7	18.7	UnDef	0.13
14.27	7.7	0.07	0.84	80.5	5	114.6	0.85	0.65	0.20	1.24	3.7	4.6	0.55	0.09
15.26	12.1	0.17	1.41	79.1	5	114.6	0.90	0.68	0.23	1.21	5.8	7.1	0.90	0.11
16.24	71.3	0.76	1.06	8.0	8	120.9	0.96	0.70	0.26	1.19	17.1	20.3	UnDef	0.17
17.22	53.5	0.62	1.17	22.9	7	117.8	1.02	0.73	0.29	1.17	17.1	20.0	UnDef	0.13
18.21	77.0	0.53	0.69	11.5	8	120.9	1.08	0.76	0.32	1.15	18.4	21.1	UnDef	0.16
19.19	33.4	0.24	0.73	22.6	7	117.8	1.14	0.79	0.35	1.13	10.7	12.0	UnDef	0.10
20.18	6.4	0.12	1.90	80.5	4	114.6	1.20	0.82	0.38	1.11	4.1	4.5	0.42	0.08
21.16	6.8	0.18	2.67	67.7	4	114.6	1.25	0.84	0.41	1.09	4.4	4.8	0.45	0.00
22.15	9.8	0.41	4.19	46.2	3	111.4	1.31	0.87	0.44	1.07	9.4	10.1	0.68	0.00
23.13	12.5	0.63	5.02	20.3	3	111.4	1.36	0.89	0.47	1.06	12.0	12.7	0.89	0.00
24.11	14.3	0.70	4.89	15.2	3	111.4	1.42	0.91	0.50	1.05	13.7	14.3	1.03	0.00
25.10	16.4	0.76	4.64	34.0	3	111.4	1.47	0.94	0.53	1.03	15.7	16.2	1.20	0.00
26.08	21.6	0.82	3.79	88.2	4	114.6	1.53	0.96	0.56	1.02	13.8	14.1	1.61	0.20
27.07	19.4	0.64	3.30	78.7	5	114.6	1.58	0.99	0.60	1.01	9.3	9.3	1.42	0.16
28.05	17.0	0.44	2.58	106.3	5	114.6	1.64	1.01	0.63	0.99	8.2	8.1	1.23	0.13
29.04	13.6	0.26	1.93	115.3	5	114.6	1.70	1.04	0.66	0.98	6.5	6.4	0.95	0.11

Depth (ft)	AvgQt (tsf)	AvgFs (tsf)	AvgRf (%)	AvgUd (ft)	SBT	U.Wt. pcf	TStress (tsf)	EStress (tsf)	Ueq (tsf)	Cn	N60 (blows/ft)	(N1)60 (blows/ft)	Su (tsf)	CRR
30.02	11.6	0.18	1.58	136.3	5	114.6	1.75	1.07	0.69	0.97	5.6	5.4	0.79	0.10
31.00	14.5	0.21	1.47	173.0	6	114.6	1.81	1.09	0.72	0.96	5.6	5.3	1.02	0.11
31.99	21.5	0.45	2.08	218.6	6	114.6	1.87	1.12	0.75	0.95	8.2	7.8	1.57	0.17
32.97	27.7	0.75	2.69	216.4	5	114.6	1.92	1.14	0.78	0.94	13.3	12.4	2.06	0.27
33.96	39.4	1.36	3.44	60.2	5	114.6	1.98	1.17	0.81	0.93	18.9	17.5	3.00	0.00
34.94	102.0	1.79	1.76	-4.9	7	117.8	2.04	1.19	0.84	0.91	32.6	29.8	UnDef	0.30
35.92	133.2	1.26	0.95	-12.7	9	124.1	2.10	1.22	0.87	0.90	25.5	23.1	UnDef	0.31
36.91	44.5	1.00	2.25	91.5	6	114.6	2.15	1.25	0.90	0.89	17.1	15.2	3.39	0.28
37.89	19.9	0.40	2.01	148.0	6	114.6	2.21	1.28	0.93	0.88	7.6	6.8	1.42	0.14
38.88	29.0	0.82	2.81	179.9	5	114.6	2.27	1.30	0.96	0.88	13.9	12.2	2.14	0.26
39.86	38.1	0.92	2.41	332.5	6	114.6	2.32	1.33	0.99	0.87	14.6	12.7	2.87	0.00
40.85	83.6	4.47	5.35	51.2	11	130.5	2.38	1.36	1.03	0.86	80.1	68.7	UnDef	0.00
41.83	55.3	3.07	5.56	110.0	11	130.5	2.45	1.39	1.06	0.85	53.0	44.9	UnDef	0.00
42.81	34.4	1.55	4.51	107.3	4	114.6	2.51	1.42	1.09	0.84	21.9	18.4	2.55	0.00
43.80	23.3	0.69	2.97	77.2	5	114.6	2.56	1.45	1.12	0.83	11.2	9.3	1.66	0.16
44.78	53.6	1.62	3.03	115.7	6	114.6	2.62	1.47	1.15	0.82	20.5	16.9	4.08	0.00
45.77	53.6	2.08	3.88	45.2	5	114.6	2.68	1.50	1.18	0.82	25.7	21.0	4.08	0.00
46.75	42.7	1.64	3.84	34.7	5	114.6	2.73	1.52	1.21	0.81	20.5	16.6	3.20	0.00
47.74	24.2	0.63	2.60	164.7	5	114.6	2.79	1.55	1.24	0.80	11.6	9.3	1.71	0.16
48.72	59.3	2.08	3.50	102.2	5	114.6	2.85	1.58	1.27	0.80	28.4	22.6	4.52	0.00
49.70	23.0	0.62	2.71	131.0	5	114.6	2.90	1.60	1.30	0.79	11.0	8.7	1.61	0.15
50.69	23.4	0.56	2.39	159.3	6	114.6	2.96	1.63	1.33	0.78	9.0	7.0	1.63	0.15
51.67	54.6	1.63	2.98	258.6	6	114.6	3.02	1.65	1.36	0.78	20.9	16.3	4.13	0.00
52.66	225.0	5.10	2.27	2.1	7	117.8	3.07	1.68	1.39	0.77	71.8	55.4	UnDef	0.00
53.64	38.0	1.43	3.76	156.9	5	114.6	3.13	1.70	1.43	0.77	18.2	13.9	2.79	0.35
54.63	125.0	1.96	1.57	42.5	8	120.9	3.19	1.73	1.46	0.76	29.9	22.7	UnDef	0.34
55.61	59.0	1.58	2.67	107.2	6	114.6	3.25	1.76	1.49	0.75	22.6	17.0	4.46	0.00
56.59	78.4	3.59	4.58	80.3	11	130.5	3.31	1.79	1.52	0.75	75.1	56.1	UnDef	0.00
57.58	38.2	1.16	3.04	197.5	5	114.6	3.37	1.82	1.55	0.74	18.3	13.6	2.79	0.33
58.56	40.6	1.12	2.76	223.4	6	114.6	3.42	1.84	1.58	0.74	15.6	11.5	2.98	0.37
59.55	34.7	0.92	2.65	304.3	6	114.6	3.48	1.87	1.61	0.73	13.3	9.7	2.50	0.26
60.53	34.1	0.69	2.02	394.5	6	114.6	3.54	1.90	1.64	0.73	13.0	9.5	2.44	0.24
61.52	39.3	0.77	1.97	410.1	6	114.6	3.59	1.92	1.67	0.72	15.0	10.9	2.85	0.33
62.42	39.4	0.85	2.15	308.2	6	114.6	3.64	1.94	1.70	0.72	15.1	10.8	2.86	0.33
63.32	40.4	1.00	2.47	257.9	6	114.6	3.70	1.97	1.73	0.71	15.5	11.0	2.94	0.34
64.30	34.6	0.89	2.59	237.3	6	114.6	3.75	1.99	1.76	0.71	13.2	9.4	2.46	0.24
65.29	32.8	0.76	2.31	286.1	6	114.6	3.81	2.02	1.79	0.70	12.5	8.8	2.32	0.21
66.27	29.8	0.63	2.12	347.5	6	114.6	3.86	2.05	1.82	0.70	11.4	8.0	2.08	0.18
67.26	32.6	0.63	1.92	307.8	6	114.6	3.92	2.07	1.85	0.69	12.5	8.7	2.29	0.21
68.24	37.0	1.02	2.77	230.0	6	114.6	3.98	2.10	1.88	0.69	14.2	9.8	2.64	0.26
69.22	55.1	2.09	3.79	187.5	5	114.6	4.03	2.12	1.91	0.69	26.4	18.1	4.09	0.00
70.21	77.5	4.20	5.42	112.4	11	130.5	4.09	2.15	1.94	0.68	74.2	50.6	UnDef	0.00
71.19	118.3	6.52	5.51	78.7	11	130.5	4.16	2.19	1.97	0.68	113.3	76.7	UnDef	0.00
72.18	104.5	5.80	5.55	257.9	11	130.5	4.22	2.22	2.00	0.67	100.0	67.2	UnDef	0.00
73.16	48.0	1.32	2.75	402.8	6	114.6	4.28	2.25	2.03	0.67	18.4	12.3	3.49	0.44
74.15	52.6	1.33	2.54	518.6	6	114.6	4.34	2.27	2.07	0.66	20.1	13.4	3.86	0.00
75.13	152.3	7.48	4.91	232.0	11	130.5	4.40	2.30	2.10	0.66	145.9	96.1	UnDef	0.00
76.11	80.7	4.11	5.09	271.3	11	130.5	4.46	2.34	2.13	0.65	77.3	50.6	UnDef	0.00
77.10	65.2	3.09	4.74	256.4	11	130.5	4.53	2.37	2.16	0.65	62.5	40.6	UnDef	0.00
78.08	63.8	2.70	4.23	255.7	5	114.6	4.59	2.40	2.19	0.65	30.5	19.7	4.74	0.00
79.07	96.2	5.55	5.77	173.6	11	130.5	4.65	2.43	2.22	0.64	92.1	59.1	UnDef	0.00
80.05	98.9	5.15	5.21	219.4	11	130.5	4.71	2.46	2.25	0.64	94.7	60.3	UnDef	0.00

Gregg In Situ, Inc.
Run No: 03-0203-1606-1605
CPT File: 027C04.COR

Depth (ft)	AvgQt (tsf)	AvgFs (tsf)	AvgRf (%)	AvgUd (ft)	SBT	U.Wt. pcf	TStress (tsf)	EStress (tsf)	Ueq (tsf)	Cn	N60 (blows/ft)	(N1)60 (blows/ft)	Su (tsf)	CRR
81.04	113.9	6.12	5.37	117.5	11	130.5	4.78	2.50	2.28	0.63	109.1	69.1	UnDef	0.00
82.02	108.4	3.70	3.41	391.0	6	114.6	4.84	2.53	2.31	0.63	41.5	26.1	8.29	0.00
83.00	132.3	6.58	4.97	105.6	11	130.5	4.90	2.56	2.34	0.63	126.7	79.2	UnDef	0.00
83.99	96.2	4.65	4.83	123.1	11	130.5	4.96	2.59	2.37	0.62	92.1	57.3	UnDef	0.00
84.97	33.6	0.80	2.39	195.3	6	114.6	5.02	2.62	2.40	0.62	12.9	8.0	2.29	0.18
85.96	36.2	0.60	1.66	353.0	6	114.6	5.08	2.64	2.43	0.62	13.9	8.5	2.49	0.20
86.94	29.9	0.48	1.60	321.2	6	114.6	5.13	2.67	2.46	0.61	11.4	7.0	1.98	0.15
87.93	29.1	0.60	2.08	369.9	6	114.6	5.19	2.70	2.50	0.61	11.1	6.8	1.91	0.14
88.91	75.5	4.18	5.54	160.3	11	130.5	5.25	2.73	2.53	0.61	72.3	43.8	UnDef	0.00
89.89	44.7	1.78	3.99	274.0	5	114.6	5.31	2.75	2.56	0.60	21.4	12.9	3.15	0.00
90.88	38.0	1.13	2.97	375.5	5	114.6	5.37	2.78	2.59	0.60	18.2	10.9	2.61	0.21
91.86	40.8	1.17	2.88	440.3	6	114.6	5.42	2.81	2.62	0.60	15.6	9.3	2.83	0.24
92.85	35.1	0.83	2.37	453.7	6	114.6	5.48	2.83	2.65	0.59	13.5	8.0	2.37	0.18
93.83	35.9	1.14	3.17	488.8	5	114.6	5.54	2.86	2.68	0.59	17.2	10.2	2.43	0.00
94.82	50.0	2.14	4.27	255.6	5	114.6	5.59	2.88	2.71	0.59	23.9	14.1	3.55	0.00
95.80	39.9	1.04	2.60	365.0	6	114.6	5.65	2.91	2.74	0.59	15.3	9.0	2.74	0.22
96.78	55.2	1.75	3.16	526.5	6	114.6	5.71	2.93	2.77	0.58	21.1	12.3	3.96	0.44
97.77	61.0	2.05	3.36	628.9	5	114.6	5.76	2.96	2.80	0.58	29.2	17.0	4.42	0.00
98.75	62.3	2.41	3.86	513.4	5	114.6	5.82	2.99	2.83	0.58	29.8	17.3	4.52	0.00

Gregg In Situ, Inc.
Interpretation Output - Release 1.00.19e
Run No: 03-0203-1606-1605
Job No: 97-100
Client: CDM
Project: CPT SITE INVESTIGATION
Site: SHERWIN WILLIAMS
Location: CPT-04
Engineer: H. YOUNG
CPT Date: 03/28/01
CPT Time: 08:29
CPT File: 027C04.COR
Northing (m): 0.000
Easting (m): 0.000
Elevation (m): 0.000

Water Table (m): 2.44 (ft): 8.0
Su Nkt used: 12.50
Averaging Increment (m): 0.30
Phi Method : Robertson and Campanella, 1983
Dr Method : Jamiolkowski - All Sands
State Parameter M: 1.20
Used Unit Weights Assigned to Soil Zones
Values of 1.0E9 or UnDef are printed for parameters that are not valid for the material type (SBT)

Depth (ft)	k (cm/s)	Bq	Qtn	Rfn	SBTn	Qc1N	DeltaQc1N	Qc1Ncs	Fc (%)	Phi (Deg)	Dr (%)	OCR	State Param	Del(n1)60	(N1)60c
0.49	1.0E-15	0.00	2.4	0.10	1	0.2	UnDef	UnDef	100.0	UnDef	UnDef	1.0	UnDef	UnDef	UnDe
1.48	1.0E-15	0.00	0.1	0.10	1	0.2	UnDef	UnDef	100.0	UnDef	UnDef	1.0	UnDef	UnDef	UnDe
2.46	1.0E-15	0.00	0.1	0.10	1	0.2	UnDef	UnDef	100.0	UnDef	UnDef	1.0	UnDef	UnDef	UnDe
3.44	1.0E-15	0.00	0.0	0.10	1	0.2	UnDef	UnDef	100.0	UnDef	UnDef	1.0	UnDef	UnDef	UnDe
4.43	1.0E-15	0.00	0.0	0.10	1	0.2	UnDef	UnDef	100.0	UnDef	UnDef	1.0	UnDef	UnDef	UnDe
5.41	5.0E-08	0.09	36.2	4.42	6	21.0	84.1	105.1	38.9	UnDef	UnDef	6.0	UnDef	20.6	41.
6.40	5.0E-08	0.04	35.0	4.46	6	21.9	87.6	109.5	39.6	UnDef	UnDef	6.0	UnDef	21.4	42.
7.30	5.0E-06	0.01	17.7	1.84	6	12.1	48.4	60.5	39.0	UnDef	UnDef	6.0	UnDef	5.9	11.
8.20	5.0E-07	0.10	9.8	2.01	6	7.4	29.5	36.8	52.5	UnDef	UnDef	3.0	UnDef	4.8	9.
9.19	5.0E-08	0.08	9.3	3.29	4	7.2	28.9	36.2	61.6	UnDef	UnDef	3.0	UnDef	7.1	14.
10.17	5.0E-04	0.01	46.7	0.61	9	34.2	11.9	46.2	14.7	38	36.5	1.0	-0.07	2.2	13.
11.15	5.0E-03	-0.01	119.4	0.49	9	88.5	0.0	88.5	5.0	42	63.8	1.0	-0.14	0.0	21.
12.14	5.0E-03	-0.01	145.6	0.49	9	110.5	0.0	110.5	4.3	44	70.1	1.0	-0.16	0.0	27.
13.21	5.0E-03	-0.01	97.5	0.55	9	76.2	5.1	81.4	7.4	42	59.5	1.0	-0.13	0.8	19.
14.27	5.0E-06	0.34	10.6	0.95	6	9.4	37.5	46.9	41.7	UnDef	UnDef	3.0	UnDef	4.6	9.
15.26	5.0E-06	0.20	16.6	1.52	6	14.4	57.7	72.1	37.9	UnDef	UnDef	6.0	UnDef	7.1	14.
16.24	5.0E-03	0.00	99.7	1.08	9	83.1	16.4	99.5	11.2	42	62.0	1.0	-0.19	2.3	22.
17.22	5.0E-04	0.01	71.6	1.19	7	61.2	22.1	83.3	14.9	40	53.2	1.0	-0.17	4.0	23.
18.21	5.0E-03	0.00	99.8	0.70	9	86.4	8.7	95.1	8.4	42	63.1	1.0	-0.15	1.3	22.
19.19	5.0E-04	0.01	40.9	0.75	7	36.8	18.7	55.4	17.6	38	38.6	1.0	-0.08	3.2	15.
20.18	5.0E-07	0.41	6.4	2.34	4	6.9	27.8	34.7	65.7	UnDef	UnDef	3.0	UnDef	4.5	9.
21.16	5.0E-07	0.30	6.6	3.26	1	7.3	UnDef	UnDef	100.0	UnDef	UnDef	3.0	UnDef	UnDef	UnDe
22.15	5.0E-08	0.12	9.8	4.83	1	10.3	UnDef	UnDef	100.0	UnDef	UnDef	3.0	UnDef	UnDef	UnDe
23.13	5.0E-08	0.01	12.5	5.64	1	13.0	UnDef	UnDef	100.0	UnDef	UnDef	6.0	UnDef	UnDef	UnDe
24.11	5.0E-08	0.00	14.1	5.43	1	14.6	UnDef	UnDef	100.0	UnDef	UnDef	6.0	UnDef	UnDef	UnDe
25.10	5.0E-08	0.04	15.9	5.10	1	16.6	UnDef	UnDef	100.0	UnDef	UnDef	6.0	UnDef	UnDef	UnDe
26.08	5.0E-07	0.11	20.9	4.08	4	21.6	86.3	107.9	47.4	UnDef	UnDef	6.0	UnDef	14.1	28.
27.07	5.0E-06	0.10	18.0	3.60	4	19.1	76.3	95.4	48.3	UnDef	UnDef	6.0	UnDef	9.3	18.
28.05	5.0E-06	0.17	15.2	2.85	6	16.6	66.2	82.8	48.1	UnDef	UnDef	6.0	UnDef	8.1	16.
29.04	5.0E-06	0.25	11.5	2.20	6	13.1	52.3	65.4	50.3	UnDef	UnDef	3.0	UnDef	6.4	12.

Depth (ft)	k (cm/s)	Bq	Qtn	Rfn	SBTn	Qc1N	DeltaQc1N	Qc1Ncs	Fc (%)	Phi (Deg)	Dr (%)	OCR	State Param	Del(n1)60	(N1)60c
30.02	5.0E-06	0.36	9.3	1.86	6	11.0	44.2	55.2	52.7	UnDef	UnDef	3.0	UnDef	5.4	10.
31.00	5.0E-05	0.37	11.6	1.68	6	13.6	54.3	67.9	46.3	30	30.0	3.0	0.03	5.3	10.
31.99	5.0E-05	0.31	17.6	2.27	6	19.9	79.5	99.4	41.9	32	30.0	6.0	-0.05	7.8	15.
32.97	5.0E-06	0.23	22.6	2.89	6	25.4	101.5	126.9	40.6	UnDef	UnDef	6.0	UnDef	12.4	24.
33.96	5.0E-06	0.03	32.1	3.62	6	35.7	142.8	178.5	37.9	UnDef	UnDef	6.0	UnDef	17.5	34.
34.94	5.0E-04	-0.01	83.7	1.80	7	91.3	42.8	134.1	17.0	42	64.7	1.0	-0.23	7.4	37.
35.92	5.0E-02	-0.01	107.1	0.96	9	117.8	17.5	135.4	9.9	42	72.0	1.0	-0.19	2.0	25.
36.91	5.0E-05	0.05	33.9	2.36	6	38.9	90.2	129.2	31.2	36	40.2	6.0	-0.16	11.8	27.
37.89	5.0E-05	0.21	13.9	2.26	6	17.3	69.0	86.3	46.6	32	30.0	6.0	-0.03	6.8	13.
38.88	5.0E-06	0.17	20.5	3.05	6	24.9	99.4	124.3	43.2	UnDef	UnDef	6.0	UnDef	12.2	24.
39.86	5.0E-05	0.26	27.0	2.57	6	32.4	129.5	161.9	35.9	36	35.0	6.0	-0.11	12.7	25.
40.85	1.0E-15	0.01	59.8	5.51	6	70.2	278.8	349.0	34.9	40	57.1	1.0	-0.52	68.6	137.
41.83	1.0E-15	0.04	38.0	5.82	1	45.9	UnDef	UnDef	100.0	38	44.9	1.0	-0.46	UnDef	UnDe
42.81	5.0E-07	0.07	22.4	4.86	1	28.2	UnDef	UnDef	100.0	UnDef	UnDef	6.0	UnDef	UnDef	UnDe
43.80	5.0E-06	0.06	14.4	3.34	4	19.0	75.9	94.9	51.8	UnDef	UnDef	6.0	UnDef	9.3	18.
44.78	5.0E-05	0.05	34.6	3.18	6	43.2	167.3	210.5	34.8	38	43.2	6.0	-0.21	16.7	33.
45.77	5.0E-06	0.00	34.0	4.08	6	42.9	171.5	214.4	38.7	UnDef	UnDef	6.0	UnDef	21.0	42.
46.75	5.0E-06	0.00	26.3	4.10	6	33.9	135.6	169.5	43.2	UnDef	UnDef	6.0	UnDef	16.6	33.
47.74	5.0E-06	0.18	13.8	2.94	4	19.0	76.1	95.1	50.6	UnDef	UnDef	6.0	UnDef	9.3	18.
48.72	5.0E-06	0.03	35.8	3.68	6	46.2	185.0	231.2	36.3	UnDef	UnDef	6.0	UnDef	22.6	45.
49.70	5.0E-06	0.14	12.6	3.10	4	17.8	71.3	89.1	53.5	UnDef	UnDef	6.0	UnDef	8.7	17.
50.69	5.0E-05	0.18	12.6	2.74	4	18.0	71.8	89.8	51.6	32	30.0	6.0	-0.04	7.0	14.
51.67	5.0E-05	0.13	31.2	3.16	6	41.6	166.3	207.8	36.3	36	42.1	6.0	-0.18	16.3	32.
52.66	5.0E-04	-0.01	132.2	2.30	7	169.9	63.3	233.3	15.2	44	82.5	1.0	-0.32	11.3	66.
53.64	5.0E-06	0.10	20.4	4.10	4	28.5	113.8	142.3	47.9	UnDef	UnDef	6.0	UnDef	13.9	27.
54.63	5.0E-03	0.00	70.3	1.61	7	92.9	47.8	140.7	17.7	40	65.2	1.0	-0.20	6.1	28.
55.61	5.0E-05	0.03	31.7	2.83	6	43.5	162.5	206.0	34.5	36	43.4	6.0	-0.18	16.6	33.
56.59	1.0E-15	0.01	42.0	4.78	6	57.3	229.4	286.7	37.8	38	51.3	1.0	-0.36	56.1	112.
57.58	5.0E-06	0.13	19.1	3.33	6	27.7	110.9	138.6	45.8	UnDef	UnDef	6.0	UnDef	13.6	27.
58.56	5.0E-05	0.14	20.2	3.01	6	29.3	117.1	146.4	43.3	34	32.1	6.0	-0.11	11.5	22.
59.55	5.0E-05	0.25	16.7	2.95	6	24.9	99.4	124.3	46.6	32	30.0	6.0	-0.07	9.7	19.
60.53	5.0E-05	0.35	16.1	2.26	6	24.2	96.8	121.0	43.5	32	30.0	6.0	-0.03	9.5	19.
61.52	5.0E-05	0.31	18.6	2.16	6	27.7	110.9	138.6	40.2	32	30.5	6.0	-0.05	10.9	21.
62.42	5.0E-05	0.22	18.4	2.37	6	27.6	110.5	138.1	41.6	32	30.4	6.0	-0.07	10.8	21.
63.32	5.0E-05	0.17	18.6	2.72	6	28.2	112.7	140.9	43.3	32	31.0	6.0	-0.09	11.0	22.
64.30	5.0E-05	0.18	15.4	2.90	6	23.9	95.8	119.7	48.0	32	30.0	6.0	-0.07	9.4	18.
65.29	5.0E-05	0.25	14.3	2.61	6	22.6	90.2	112.8	48.0	32	30.0	6.0	-0.04	8.8	17.
66.27	5.0E-05	0.35	12.7	2.43	6	20.4	81.6	102.0	49.5	32	30.0	6.0	-0.01	8.0	16.
67.26	5.0E-05	0.27	13.8	2.19	6	22.2	88.7	110.8	46.1	32	30.0	6.0	-0.02	8.7	17.
68.24	5.0E-05	0.16	15.7	3.11	6	25.0	99.9	124.9	48.7	32	30.0	6.0	-0.08	9.8	19.
69.22	5.0E-06	0.08	24.1	4.09	6	37.0	148.1	185.2	44.7	UnDef	UnDef	6.0	UnDef	18.1	36.
70.21	1.0E-15	0.02	34.1	5.72	1	51.7	UnDef	UnDef	100.0	38	48.4	1.0	-0.43	UnDef	UnDe
71.19	1.0E-15	0.00	52.2	5.71	1	78.3	UnDef	UnDef	100.0	40	60.3	1.0	-0.53	UnDef	UnDe
72.18	1.0E-15	0.06	45.2	5.79	1	68.6	UnDef	UnDef	100.0	38	56.5	1.0	-0.49	UnDef	UnDe
73.16	5.0E-05	0.24	19.4	3.02	6	31.3	125.2	156.5	44.0	34	34.0	6.0	-0.09	12.3	24.
74.15	5.0E-05	0.29	21.2	2.77	6	34.1	136.5	170.7	41.1	34	36.5	6.0	-0.09	13.4	26.
75.13	1.0E-15	0.03	64.2	5.05	6	98.2	275.7	373.9	32.6	40	66.8	1.0	-0.46	82.3	178.
76.11	1.0E-15	0.08	32.6	5.39	1	51.7	UnDef	UnDef	100.0	36	48.4	1.0	-0.36	UnDef	UnDe
77.10	1.0E-15	0.10	25.6	5.10	1	41.5	UnDef	UnDef	100.0	36	42.0	1.0	-0.28	UnDef	UnDe
78.08	5.0E-06	0.10	24.7	4.55	1	40.3	UnDef	UnDef	100.0	UnDef	UnDef	6.0	UnDef	UnDef	UnDe
79.07	1.0E-15	0.03	37.7	6.06	1	60.4	UnDef	UnDef	100.0	38	52.8	1.0	-0.50	UnDef	UnDe
80.05	1.0E-15	0.05	38.2	5.47	1	61.6	UnDef	UnDef	100.0	38	53.4	1.0	-0.41	UnDef	UnDe

Depth (ft)	k (cm/s)	Bq	Qtn	Rfn	SBTn	Qc1N	DeltaQc1N	Qc1Ncs	Fc (%)	Phi (Deg)	Dr (%)	OCR	State Param	Del(n1)60	(N1)60c
81.04	1.0E-15	0.01	43.7	5.61	1	70.6	UnDef	UnDef	100.0	38	57.3	1.0	-0.47	UnDef	UnDe
82.02	5.0E-05	0.10	41.0	3.57	6	66.8	221.9	288.7	33.8	38	55.7	6.0	-0.24	24.2	50.
83.00	1.0E-15	0.01	49.8	5.17	6	81.0	323.9	404.8	36.5	38	61.2	1.0	-0.43	79.2	158.
83.99	1.0E-15	0.02	35.2	5.09	1	58.5	UnDef	UnDef	100.0	38	51.9	1.0	-0.36	UnDef	UnDe
84.97	5.0E-05	0.13	10.9	2.81	4	20.3	81.3	101.6	55.1	30	30.0	3.0	-0.03	8.0	15.
85.96	5.0E-05	0.28	11.8	1.93	6	21.8	87.1	108.9	47.9	30	30.0	3.0	0.00	8.5	17.
86.94	5.0E-05	0.31	9.3	1.94	6	17.9	71.6	89.5	53.4	30	30.0	3.0	0.03	7.0	14.
87.93	5.0E-05	0.38	8.9	2.53	4	17.3	69.4	86.7	58.4	30	30.0	3.0	0.04	6.8	13.
88.91	1.0E-15	0.04	25.8	5.95	1	44.7	UnDef	UnDef	100.0	36	44.2	1.0	-0.39	UnDef	UnDe
89.89	5.0E-06	0.15	14.3	4.53	1	26.4	UnDef	UnDef	100.0	UnDef	UnDef	6.0	UnDef	UnDef	UnDe
90.88	5.0E-06	0.28	11.7	3.46	4	22.3	89.2	111.5	56.9	UnDef	UnDef	3.0	UnDef	10.9	21.
91.86	5.0E-05	0.31	12.6	3.32	4	23.8	95.2	119.0	54.6	32	30.0	6.0	-0.03	9.3	18.
92.85	5.0E-05	0.39	10.5	2.81	4	20.4	81.7	102.2	56.1	30	30.0	3.0	0.01	8.0	16.
93.83	5.0E-06	0.41	10.6	3.75	1	20.8	UnDef	UnDef	100.0	UnDef	UnDef	3.0	UnDef	UnDef	UnDe
94.82	5.0E-06	0.12	15.4	4.81	1	28.8	UnDef	UnDef	100.0	UnDef	UnDef	6.0	UnDef	UnDef	UnDe
95.80	5.0E-05	0.25	11.8	3.03	4	22.9	91.5	114.4	54.6	30	30.0	3.0	-0.03	9.0	17.
96.78	5.0E-05	0.28	16.9	3.53	4	31.5	126.2	157.7	49.3	32	34.2	6.0	-0.09	12.3	24.
97.77	5.0E-06	0.30	18.7	3.71	4	34.7	138.8	173.6	48.0	UnDef	UnDef	6.0	UnDef	17.0	34.
98.75	5.0E-06	0.23	18.9	4.26	1	35.3	UnDef	UnDef	100.0	UnDef	UnDef	6.0	UnDef	UnDef	UnDe

Interpretation Output - Release 1.00.19e

Sn No: 03-0203-1606-1545
Job No: 97-100
Client: CDM
Project: CPT SITE INVESTIGATION
Site: SHERWIN WILLIAMS
Location: CPT-02
Engineer: H. YOUNG
CPT Date: 03/29/01
CPT Time: 09:33
CPT File: 027C02.COR
Northing (m): 0.000
Easting (m): 0.000
Elevation (m): 0.000

Water Table (m): 4.57 (ft): 15.0
Su Nkt used: 12.50
Averaging Increment (m): 0.30
Phi Method : Robertson and Campanella, 1983
Dr Method : Jamiolkowski - All Sands
State Parameter M: 1.20
Used Unit Weights Assigned to Soil Zones
Values of 1.0E9 or UnDef are printed for parameters that are not valid for the material type (SBT)

Depth (ft)	AvgQt (tsf)	AvgFs (tsf)	AvgRf (%)	AvgUd (ft)	SBT	U.Wt. pcf	TStress (tsf)	EStress (tsf)	Ueq (tsf)	Cn	N60 (blows/ft)	(N1)60 (blows/ft)	Su (tsf)	CRR
0.49	0.0	0.00	0.00	0.0	UnDef	124.1	0.03	0.03	0.00	2.00	UnDef	UnDef	UnDef	0.00
1.48	0.0	0.00	0.00	0.0	UnDef	124.1	0.09	0.09	0.00	2.00	UnDef	UnDef	UnDef	0.00
2.46	0.0	0.00	0.00	0.0	UnDef	124.1	0.15	0.15	0.00	2.00	UnDef	UnDef	UnDef	0.00
3.44	0.0	0.00	0.00	0.0	UnDef	124.1	0.21	0.21	0.00	2.00	UnDef	UnDef	UnDef	0.00
4.43	0.0	0.00	0.00	0.0	UnDef	124.1	0.27	0.27	0.00	1.91	UnDef	UnDef	UnDef	0.00
5.41	29.8	1.31	4.40	7.8	4	114.6	0.33	0.33	0.00	1.73	19.1	33.0	2.36	0.00
6.40	18.1	0.86	4.75	-5.6	3	111.4	0.39	0.39	0.00	1.60	17.4	27.8	1.42	0.35
7.30	16.5	0.76	4.58	0.6	3	111.4	0.44	0.44	0.00	1.51	15.8	23.9	1.29	0.25
8.20	17.7	0.87	4.91	-0.1	3	111.4	0.49	0.49	0.00	1.43	16.9	24.2	1.37	0.00
9.19	18.2	0.82	4.49	-3.8	3	111.4	0.54	0.54	0.00	1.36	17.5	23.7	1.42	0.24
10.17	8.9	0.25	2.76	-1.2	4	114.6	0.60	0.60	0.00	1.29	5.7	7.3	0.66	0.10
11.15	8.5	0.17	1.98	5.2	5	114.6	0.66	0.66	0.00	1.23	4.1	5.0	0.63	0.09
12.14	8.8	0.15	1.69	7.2	5	114.6	0.71	0.71	0.00	1.18	4.2	5.0	0.65	0.09
13.21	8.4	0.15	1.74	9.1	5	114.6	0.77	0.77	0.00	1.14	4.0	4.6	0.61	0.09
14.27	8.5	0.29	3.41	6.0	3	111.4	0.83	0.83	0.00	1.09	8.2	8.9	0.62	0.00
15.26	43.0	0.25	0.59	4.4	7	117.8	0.89	0.88	0.01	1.06	13.7	14.6	UnDef	0.10
16.24	65.3	0.44	0.67	5.9	8	120.9	0.95	0.91	0.04	1.05	15.6	16.4	UnDef	0.13
17.22	9.0	0.21	2.33	36.8	5	114.6	1.01	0.94	0.07	1.03	4.3	4.5	0.64	0.09
18.21	27.7	0.31	1.11	42.7	6	114.6	1.06	0.96	0.10	1.02	10.6	10.8	2.13	0.10
19.19	26.4	0.45	1.72	27.4	6	114.6	1.12	0.99	0.13	1.01	10.1	10.2	2.02	0.16
20.18	33.4	0.22	0.65	56.4	7	117.8	1.18	1.02	0.16	0.99	10.7	10.6	UnDef	0.09
21.16	48.4	0.64	1.32	3.9	7	117.8	1.24	1.04	0.19	0.98	15.4	15.1	UnDef	0.13
22.15	14.1	0.39	2.78	28.4	5	114.6	1.29	1.07	0.22	0.97	6.8	6.5	1.03	0.11
23.13	9.6	0.15	1.54	60.6	5	114.6	1.35	1.10	0.25	0.96	4.6	4.4	0.66	0.09
24.11	7.1	0.16	2.27	52.1	4	114.6	1.41	1.12	0.28	0.94	4.5	4.3	0.46	0.08
25.10	7.7	0.26	3.39	53.8	3	111.4	1.46	1.15	0.32	0.93	7.4	6.9	0.50	0.00
26.08	9.1	0.36	3.89	60.0	3	111.4	1.52	1.17	0.35	0.92	8.8	8.1	0.61	0.00
27.07	11.3	0.51	4.46	58.0	3	111.4	1.57	1.19	0.38	0.92	10.9	9.9	0.78	0.00
28.05	14.0	0.61	4.34	62.0	3	111.4	1.63	1.22	0.41	0.91	13.4	12.2	0.99	0.00
29.04	22.2	0.82	3.71	82.1	4	114.6	1.68	1.24	0.44	0.90	14.2	12.7	1.64	0.00

Depth (ft)	AvgQt (tsf)	AvgFs (tsf)	AvgRf (%)	AvgUd (ft)	SBT	U.Wt. pcf	TStress (tsf)	EStress (tsf)	Ueq (tsf)	Cn	N60 (blows/ft)	(N1)60 (blows/ft)	Su (tsf)	CRR
30.02	12.7	0.58	4.56	32.6	3	111.4	1.74	1.27	0.47	0.89	12.1	10.8	0.87	0.00
31.00	7.9	0.13	1.65	77.2	5	114.6	1.79	1.29	0.50	0.88	3.8	3.3	0.49	0.08
31.99	19.3	0.40	2.07	66.4	6	114.6	1.85	1.32	0.53	0.87	7.4	6.4	1.39	0.13
32.97	85.2	0.66	0.78	2.6	8	120.9	1.91	1.35	0.56	0.86	20.4	17.6	UnDef	0.15
33.96	63.9	1.39	2.17	-11.0	7	117.8	1.97	1.37	0.59	0.85	20.4	17.4	UnDef	0.26
34.94	102.1	2.15	2.10	-13.6	7	117.8	2.02	1.40	0.62	0.85	32.6	27.5	UnDef	0.35
35.92	167.5	1.75	1.04	-13.7	9	124.1	2.08	1.43	0.65	0.84	32.1	26.8	UnDef	0.44
36.91	182.3	1.28	0.70	-13.1	9	124.1	2.14	1.46	0.68	0.83	34.9	28.9	UnDef	0.43
37.89	73.5	1.23	1.67	8.9	7	117.8	2.20	1.49	0.71	0.82	23.5	19.2	UnDef	0.21
38.88	18.3	0.56	3.09	128.4	5	114.6	2.26	1.51	0.75	0.81	8.8	7.1	1.28	0.00
39.86	15.6	0.52	3.36	119.9	4	114.6	2.32	1.54	0.78	0.81	9.9	8.0	1.06	0.00
40.85	16.9	0.53	3.14	143.1	5	114.6	2.37	1.57	0.81	0.80	8.1	6.5	1.16	0.00
41.83	22.4	0.54	2.43	204.0	6	114.6	2.43	1.59	0.84	0.79	8.6	6.8	1.60	0.14
42.81	17.0	0.26	1.55	202.4	6	114.6	2.49	1.62	0.87	0.79	6.5	5.1	1.16	0.11
43.80	30.9	0.94	3.02	216.5	5	114.6	2.54	1.64	0.90	0.78	14.8	11.6	2.27	0.23
44.78	30.5	1.57	5.17	88.8	3	111.4	2.60	1.67	0.93	0.77	29.2	22.6	2.23	0.00
45.77	24.2	1.01	4.15	128.3	4	114.6	2.65	1.69	0.96	0.77	15.5	11.9	1.73	0.00
46.75	24.0	0.63	2.62	162.9	5	114.6	2.71	1.72	0.99	0.76	11.5	8.8	1.70	0.15
47.74	23.2	0.57	2.47	201.4	6	114.6	2.77	1.74	1.02	0.76	8.9	6.7	1.64	0.14
48.72	68.5	2.81	4.11	130.8	5	114.6	2.82	1.77	1.05	0.75	32.8	24.7	5.26	0.00
49.70	59.5	3.02	5.08	74.9	11	130.5	2.88	1.80	1.08	0.75	57.0	42.5	UnDef	0.00
50.69	25.8	0.63	2.45	205.8	6	114.6	2.94	1.83	1.11	0.74	9.9	7.3	1.83	0.16
51.67	77.4	1.96	2.53	120.3	6	114.6	3.00	1.85	1.15	0.73	29.6	21.8	5.95	0.00
52.66	108.2	3.84	3.55	32.8	6	114.6	3.06	1.88	1.18	0.73	41.4	30.2	8.41	0.00
53.64	37.2	0.98	2.62	239.5	6	114.6	3.11	1.91	1.21	0.72	14.3	10.3	2.73	0.29
54.63	128.1	4.83	3.77	135.9	6	114.6	3.17	1.93	1.24	0.72	49.1	35.3	10.00	0.00
55.61	223.8	5.32	2.38	20.0	7	117.8	3.23	1.96	1.27	0.71	71.4	51.1	UnDef	0.00
56.59	184.8	3.29	1.78	-0.2	8	120.9	3.28	1.99	1.30	0.71	44.2	31.4	UnDef	0.00
57.58	32.8	0.74	2.24	101.6	6	114.6	3.34	2.01	1.33	0.70	12.6	8.9	2.36	0.21
58.56	34.5	0.67	1.95	180.3	6	114.6	3.40	2.04	1.36	0.70	13.2	9.3	2.49	0.23
59.55	28.8	0.68	2.37	178.9	6	114.6	3.46	2.06	1.39	0.70	11.0	7.7	2.03	0.17
60.53	26.3	0.57	2.19	183.2	6	114.6	3.51	2.09	1.42	0.69	10.1	7.0	1.82	0.15
61.52	26.4	0.57	2.14	334.1	6	114.6	3.57	2.12	1.45	0.69	10.1	7.0	1.83	0.15
62.42	34.5	0.68	1.98	386.7	6	114.6	3.62	2.14	1.48	0.68	13.2	9.0	2.47	0.22
63.32	35.6	1.09	3.07	251.8	5	114.6	3.67	2.16	1.51	0.68	17.1	11.6	2.56	0.23
64.30	29.1	0.98	3.37	202.2	5	114.6	3.73	2.19	1.54	0.68	14.0	9.4	2.03	0.00
65.29	30.3	0.87	2.86	230.7	5	114.6	3.78	2.21	1.57	0.67	14.5	9.8	2.12	0.17
66.27	31.1	0.83	2.68	326.9	6	114.6	3.84	2.24	1.60	0.67	11.9	8.0	2.18	0.18
67.26	87.1	4.28	4.91	179.7	11	130.5	3.90	2.27	1.63	0.66	83.4	55.4	UnDef	0.00
68.24	52.4	2.21	4.21	147.0	5	114.6	3.96	2.30	1.66	0.66	25.1	16.5	3.87	0.00
69.22	31.6	0.78	2.47	253.3	6	114.6	4.02	2.32	1.69	0.66	12.1	7.9	2.20	0.18
70.21	39.3	1.32	3.37	279.9	5	114.6	4.07	2.35	1.72	0.65	18.8	12.3	2.82	0.26
71.19	71.3	4.12	5.78	68.0	11	130.5	4.13	2.38	1.75	0.65	68.3	44.2	UnDef	0.00
72.18	60.4	3.01	4.98	210.1	11	130.5	4.20	2.41	1.79	0.64	57.8	37.2	UnDef	0.00
73.16	38.1	1.23	3.24	257.1	5	114.6	4.26	2.44	1.82	0.64	18.2	11.7	2.71	0.24
74.15	44.6	1.32	2.96	233.3	6	114.6	4.32	2.47	1.85	0.64	17.1	10.9	3.22	0.33
75.13	48.8	1.33	2.73	401.4	6	114.6	4.37	2.49	1.88	0.63	18.7	11.8	3.55	0.40
76.11	54.9	2.25	4.09	296.4	5	114.6	4.43	2.52	1.91	0.63	26.3	16.6	4.04	0.00
77.10	59.8	2.82	4.71	238.3	4	114.6	4.48	2.55	1.94	0.63	38.2	23.9	4.43	0.00
78.08	69.0	3.83	5.56	173.2	11	130.5	4.54	2.58	1.97	0.62	66.1	41.2	UnDef	0.00
79.07	82.1	4.52	5.50	161.3	11	130.5	4.61	2.61	2.00	0.62	78.6	48.7	UnDef	0.00
80.05	128.3	7.97	6.21	86.6	11	130.5	4.67	2.64	2.03	0.62	122.9	75.6	UnDef	0.00

pth (ft)	AvgQt (tsf)	AvgFs (tsf)	AvgRf (%)	AvgUd (ft)	SBT	U.Wt. pcf	TStress (tsf)	EStress (tsf)	Ueq (tsf)	Cn	N60 (blows/ft)	(N1)60	Su (tsf)	CRR
81.04	160.3	8.67	5.41	96.4	11	130.5	4.74	2.68	2.06	0.61	153.5	93.8	UnDef	0.00
82.02	106.7	6.70	6.28	70.2	11	130.5	4.80	2.71	2.09	0.61	102.2	62.1	UnDef	0.00
83.00	32.9	1.19	3.63	236.3	5	114.6	4.86	2.74	2.12	0.60	15.7	9.5	2.24	0.00
83.99	55.3	2.15	3.89	245.0	5	114.6	4.92	2.76	2.15	0.60	26.5	15.9	4.03	0.00
84.97	126.5	7.91	6.25	115.2	11	130.5	4.98	2.79	2.18	0.60	121.2	72.5	UnDef	0.00
85.96	153.9	8.46	5.50	124.4	11	130.5	5.04	2.83	2.22	0.59	147.4	87.6	UnDef	0.00
86.94	224.3	9.11	4.06	52.4	12	120.9	5.10	2.86	2.25	0.59	107.4	63.5	UnDef	0.00
87.93	101.6	5.09	5.01	38.5	11	130.5	5.17	2.89	2.28	0.59	97.3	57.2	UnDef	0.00
88.91	35.3	0.79	2.24	154.0	6	114.6	5.23	2.92	2.31	0.59	13.5	7.9	2.40	0.18
89.89	73.4	3.45	4.70	197.0	11	130.5	5.29	2.95	2.34	0.58	70.3	40.9	UnDef	0.00
90.88	85.3	5.44	6.38	114.3	11	130.5	5.35	2.98	2.37	0.58	81.7	47.3	UnDef	0.00
91.86	91.6	5.93	6.47	136.8	11	130.5	5.42	3.02	2.40	0.58	87.7	50.5	UnDef	0.00
92.85	114.3	7.01	6.14	89.5	11	130.5	5.48	3.05	2.43	0.57	109.4	62.7	UnDef	0.00
93.83	82.1	3.78	4.60	155.8	11	130.5	5.54	3.08	2.46	0.57	78.7	44.8	UnDef	0.00
94.82	74.3	3.69	4.97	174.0	11	130.5	5.61	3.12	2.49	0.57	71.2	40.3	UnDef	0.00
95.80	91.4	4.56	4.99	160.1	11	130.5	5.67	3.15	2.52	0.56	87.5	49.3	UnDef	0.00
96.78	108.7	6.24	5.74	138.4	11	130.5	5.74	3.18	2.55	0.56	104.1	58.3	UnDef	0.00
97.77	102.1	5.26	5.15	184.6	11	130.5	5.80	3.22	2.58	0.56	97.8	54.5	UnDef	0.00
98.75	152.2	6.60	4.34	89.0	11	130.5	5.87	3.25	2.61	0.55	145.8	80.9	UnDef	0.00

Gregg In Situ, Inc.
Interpretation Output - Release 1.00.19e
Run No: 03-0203-1606-1545
Job No: 97-100
Client: CDM
Project: CPT SITE INVESTIGATION
Site: SHERWIN WILLIAMS
Location: CPT-02
Engineer: H. YOUNG
CPT Date: 03/29/01
CPT Time: 09:33
CPT File: 027C02.COR
Northing (m): 0.000
Easting (m): 0.000
Elevation (m): 0.000

Water Table (m): 4.57 (ft): 15.0
Su Nkt used: 12.50
Averaging Increment (m): 0.30
Phi Method : Robertson and Campanella, 1983
Dr Method : Jamiolkowski - All Sands
State Parameter M: 1.20
Used Unit Weights Assigned to Soil Zones
Values of 1.0E9 or UnDef are printed for parameters that are not valid for the material type (SBT)

Depth (ft)	k (cm/s)	Bq	Qtn	Rfn	SBTn	Qc1N	DeltaQc1N	Qc1Ncs	Fc (%)	Phi (Deg)	Dr (%)	OCR	State Param	Del(n1)60	(N1)60c
0.49	1.0E-15	0.00	2.4	0.10	1	0.2	UnDef	UnDef	100.0	UnDef	UnDef	1.0	UnDef	UnDef	UnDe
1.48	1.0E-15	0.00	0.1	0.10	1	0.2	UnDef	UnDef	100.0	UnDef	UnDef	1.0	UnDef	UnDef	UnDe
2.46	1.0E-15	0.00	0.1	0.10	1	0.2	UnDef	UnDef	100.0	UnDef	UnDef	1.0	UnDef	UnDef	UnDe
3.44	1.0E-15	0.00	0.0	0.10	1	0.2	UnDef	UnDef	100.0	UnDef	UnDef	1.0	UnDef	UnDef	UnDe
4.43	1.0E-15	0.00	0.0	0.10	1	0.2	UnDef	UnDef	100.0	UnDef	UnDef	1.0	UnDef	UnDef	UnDe
5.41	5.0E-07	0.01	88.5	4.45	11	50.6	UnDef	UnDef	0.0	UnDef	UnDef	10.0	UnDef	UnDef	UnDe
6.40	5.0E-08	-0.01	45.6	4.85	6	28.4	113.7	142.2	36.8	UnDef	UnDef	6.0	UnDef	27.8	55.
7.30	5.0E-08	0.00	36.6	4.70	6	24.4	97.5	121.9	39.7	UnDef	UnDef	6.0	UnDef	23.9	47.
8.20	5.0E-08	0.00	35.1	5.05	1	24.7	UnDef	UnDef	100.0	UnDef	UnDef	6.0	UnDef	UnDef	UnDe
9.19	5.0E-08	-0.01	32.5	4.63	6	24.2	96.8	121.0	41.4	UnDef	UnDef	6.0	UnDef	23.7	47.
10.17	5.0E-07	0.00	13.8	2.96	4	11.3	45.0	56.3	50.6	UnDef	UnDef	6.0	UnDef	7.3	14.
11.15	5.0E-06	0.02	12.0	2.14	6	10.3	41.2	51.5	48.9	UnDef	UnDef	3.0	UnDef	5.0	10.
12.14	5.0E-06	0.03	11.4	1.83	6	10.2	40.9	51.1	48.0	UnDef	UnDef	3.0	UnDef	5.0	10.
13.21	5.0E-06	0.04	9.8	1.92	6	9.3	37.3	46.7	51.8	UnDef	UnDef	3.0	UnDef	4.6	9.
14.27	5.0E-08	0.02	9.2	3.78	1	9.1	UnDef	UnDef	100.0	UnDef	UnDef	3.0	UnDef	UnDef	UnDe
15.26	5.0E-04	0.00	47.8	0.60	9	44.8	14.9	59.7	14.3	38	44.3	1.0	-0.08	2.7	17.
16.24	5.0E-03	0.00	70.7	0.68	9	67.0	13.2	80.2	11.2	40	55.8	1.0	-0.12	1.9	18.
17.22	5.0E-06	0.13	8.6	2.62	4	9.1	36.5	45.6	59.9	UnDef	UnDef	3.0	UnDef	4.5	8.
18.21	5.0E-05	0.05	27.6	1.15	7	27.6	36.8	64.4	26.4	36	30.4	6.0	-0.07	6.0	16.
19.19	5.0E-05	0.03	25.5	1.79	7	26.0	69.5	95.5	32.3	34	30.0	6.0	-0.10	8.5	18.
20.18	5.0E-04	0.05	31.7	0.68	7	32.5	21.9	54.3	20.1	36	35.0	1.0	-0.04	3.6	14.
21.16	5.0E-04	0.00	45.2	1.35	7	46.3	35.2	81.6	21.2	38	45.2	1.0	-0.14	5.6	20.
22.15	5.0E-06	0.05	12.0	3.06	4	13.4	53.5	66.9	54.3	UnDef	UnDef	3.0	UnDef	6.5	13.
23.13	5.0E-06	0.20	7.6	1.79	4	9.0	36.1	45.1	57.2	UnDef	UnDef	3.0	UnDef	4.4	8.
24.11	5.0E-07	0.23	5.1	2.83	4	6.6	26.3	32.9	75.3	UnDef	UnDef	1.5	UnDef	4.3	8.
25.10	5.0E-08	0.22	5.5	4.18	1	7.1	UnDef	UnDef	100.0	UnDef	UnDef	1.5	UnDef	UnDef	UnDe
26.08	5.0E-08	0.20	6.5	4.67	1	8.3	UnDef	UnDef	100.0	UnDef	UnDef	3.0	UnDef	UnDef	UnDe
27.07	5.0E-08	0.15	8.2	5.18	1	10.2	UnDef	UnDef	100.0	UnDef	UnDef	3.0	UnDef	UnDef	UnDe
28.05	5.0E-08	0.12	10.2	4.90	1	12.4	UnDef	UnDef	100.0	UnDef	UnDef	3.0	UnDef	UnDef	UnDe
29.04	5.0E-07	0.10	16.5	4.01	1	19.5	UnDef	UnDef	100.0	UnDef	UnDef	6.0	UnDef	UnDef	UnDe

Depth (ft)	k (cm/s)	Bq	Qtn	Rfn	SBTn	Qc1N	DeltaQc1N	Qc1Ncs	Fc (%)	Phi (Deg)	Dr (%)	OCR	State Param	Del(n1)60	(N1)60c
30.02	5.0E-08	0.05	8.6	5.28	1	11.0	UnDef	UnDef	100.0	UnDef	UnDef	3.0	UnDef	UnDef	UnDe
31.00	5.0E-06	0.31	4.7	2.13	4	6.8	27.2	34.0	72.7	UnDef	UnDef	1.5	UnDef	3.3	6.
31.99	5.0E-05	0.09	13.2	2.29	6	16.4	65.6	82.0	47.8	32	30.0	6.0	-0.05	6.4	12.
32.97	5.0E-03	-0.01	61.9	0.80	9	71.9	21.0	92.9	13.5	40	57.8	1.0	-0.12	2.9	20.
33.96	5.0E-04	-0.02	45.1	2.24	7	53.4	71.4	124.8	26.4	38	49.3	1.0	-0.19	9.7	27.
34.94	5.0E-04	-0.01	71.4	2.14	7	84.4	58.7	143.1	20.4	40	62.4	1.0	-0.24	9.5	37.
35.92	5.0E-02	-0.01	115.8	1.06	9	137.1	20.5	157.6	9.9	42	76.3	1.0	-0.21	2.4	29.
36.91	5.0E-02	-0.01	123.4	0.71	9	147.7	8.4	156.0	7.0	42	78.4	1.0	-0.18	1.0	29.
37.89	5.0E-04	-0.01	47.9	1.72	7	59.0	53.2	112.2	22.8	38	52.1	1.0	-0.17	8.1	27.
38.88	5.0E-06	0.20	10.6	3.52	1	14.5	UnDef	UnDef	100.0	UnDef	UnDef	3.0	UnDef	UnDef	UnDe
39.86	5.0E-07	0.22	8.6	3.94	1	12.3	UnDef	UnDef	100.0	UnDef	UnDef	3.0	UnDef	UnDef	UnDe
40.85	5.0E-06	0.25	9.3	3.65	1	13.2	UnDef	UnDef	100.0	UnDef	UnDef	3.0	UnDef	UnDef	UnDe
41.83	5.0E-05	0.28	12.6	2.72	4	17.4	69.6	87.0	51.5	30	30.0	6.0	-0.03	6.8	13.
42.81	5.0E-05	0.38	8.9	1.81	6	13.1	52.2	65.3	53.3	30	30.0	3.0	0.05	5.1	10.
43.80	5.0E-06	0.21	17.3	3.30	6	23.6	94.5	118.1	47.7	UnDef	UnDef	6.0	UnDef	11.6	23.
44.78	5.0E-08	0.07	16.7	5.65	1	23.1	UnDef	UnDef	100.0	UnDef	UnDef	6.0	UnDef	UnDef	UnDe
45.77	5.0E-07	0.14	12.7	4.66	1	18.2	UnDef	UnDef	100.0	UnDef	UnDef	6.0	UnDef	UnDef	UnDe
46.75	5.0E-06	0.19	12.4	2.95	4	17.9	71.7	89.6	53.0	UnDef	UnDef	3.0	UnDef	8.8	17.
47.74	5.0E-05	0.26	11.7	2.81	4	17.2	68.9	86.1	53.5	30	30.0	3.0	-0.02	6.7	13.
48.72	5.0E-06	0.05	37.1	4.28	6	50.4	201.6	252.0	38.0	UnDef	UnDef	6.0	UnDef	24.7	49.
49.70	1.0E-15	0.02	31.5	5.34	1	43.4	UnDef	UnDef	100.0	36	43.3	1.0	-0.36	UnDef	UnDe
50.69	5.0E-05	0.23	12.5	2.76	4	18.7	74.7	93.4	51.8	30	30.0	6.0	-0.03	7.3	14.
51.67	5.0E-05	0.04	40.1	2.63	6	55.6	112.0	167.6	30.0	38	50.4	6.0	-0.20	15.6	37.
52.66	5.0E-05	0.00	55.9	3.65	6	77.2	150.5	227.7	29.8	40	59.9	10.0	-0.31	21.3	51.
53.64	5.0E-05	0.18	17.9	2.86	6	26.4	105.6	132.0	44.8	32	30.0	6.0	-0.09	10.3	20.
54.63	5.0E-05	0.02	64.7	3.87	6	90.2	154.5	244.7	28.6	40	64.3	10.0	-0.34	23.0	58.
55.61	5.0E-04	0.00	112.6	2.41	7	156.5	74.1	230.6	17.0	42	80.1	1.0	-0.31	12.8	63.
56.59	5.0E-03	-0.01	91.4	1.81	7	128.3	54.7	182.9	16.2	42	74.4	1.0	-0.24	7.2	38.
57.58	5.0E-05	0.06	14.6	2.50	6	22.6	90.5	113.1	46.9	32	30.0	6.0	-0.07	8.9	17.
58.56	5.0E-05	0.14	15.3	2.16	6	23.7	94.6	118.3	44.0	32	30.0	6.0	-0.05	9.3	18.
59.55	5.0E-05	0.17	12.3	2.69	4	19.6	78.5	98.1	51.8	30	30.0	3.0	-0.04	7.7	15.
60.53	5.0E-05	0.19	10.9	2.53	4	17.8	71.1	88.8	53.6	30	30.0	3.0	-0.02	7.0	13.
61.52	5.0E-05	0.39	10.8	2.48	4	17.8	71.1	88.9	53.4	30	30.0	3.0	0.02	7.0	13.
62.42	5.0E-05	0.34	14.4	2.21	6	23.1	92.4	115.5	45.4	32	30.0	6.0	-0.02	9.0	18.
63.32	5.0E-06	0.20	14.8	3.42	4	23.7	94.8	118.5	51.6	UnDef	UnDef	6.0	UnDef	11.6	23.
64.30	5.0E-06	0.19	11.6	3.87	1	19.3	UnDef	UnDef	100.0	UnDef	UnDef	3.0	UnDef	UnDef	UnDe
65.29	5.0E-06	0.21	12.0	3.26	4	19.9	79.7	99.7	55.4	UnDef	UnDef	3.0	UnDef	9.8	19.
66.27	5.0E-05	0.32	12.2	3.06	4	20.3	81.4	101.7	54.0	30	30.0	3.0	-0.02	8.0	15.
67.26	1.0E-15	0.05	36.7	5.14	1	56.6	UnDef	UnDef	100.0	38	51.0	1.0	-0.36	UnDef	UnDe
68.24	5.0E-06	0.06	21.1	4.55	1	33.8	UnDef	UnDef	100.0	UnDef	UnDef	6.0	UnDef	UnDef	UnDe
69.22	5.0E-05	0.23	11.8	2.83	4	20.2	81.0	101.2	53.4	30	30.0	3.0	-0.03	7.9	15.
70.21	5.0E-06	0.20	15.0	3.75	4	25.1	100.4	125.5	52.8	UnDef	UnDef	6.0	UnDef	12.3	24.
71.19	1.0E-15	0.01	28.2	6.13	1	45.2	UnDef	UnDef	100.0	36	44.5	1.0	-0.45	UnDef	UnDe
72.18	1.0E-15	0.09	23.3	5.36	1	38.0	UnDef	UnDef	100.0	34	39.6	1.0	-0.28	UnDef	UnDe
73.16	5.0E-06	0.18	13.8	3.65	4	23.8	95.4	119.2	54.0	UnDef	UnDef	6.0	UnDef	11.7	23.
74.15	5.0E-05	0.13	16.3	3.28	6	27.8	111.1	138.9	48.8	32	30.6	6.0	-0.10	10.9	21.
75.13	5.0E-05	0.24	17.8	3.00	6	30.2	121.0	151.2	45.6	32	33.0	6.0	-0.08	11.8	23.
76.11	5.0E-06	0.15	20.0	4.45	1	33.9	UnDef	UnDef	100.0	UnDef	UnDef	6.0	UnDef	UnDef	UnDe
77.10	5.0E-07	0.10	21.7	5.09	1	36.7	UnDef	UnDef	100.0	UnDef	UnDef	6.0	UnDef	UnDef	UnDe
78.08	1.0E-15	0.05	25.0	5.95	1	42.1	UnDef	UnDef	100.0	34	42.5	1.0	-0.37	UnDef	UnDe
79.07	1.0E-15	0.04	29.7	5.83	1	49.7	UnDef	UnDef	100.0	36	47.3	1.0	-0.40	UnDef	UnDe
80.05	1.0E-15	0.01	46.8	6.45	1	77.2	UnDef	UnDef	100.0	38	59.9	1.0	-0.66	UnDef	UnDe

Depth (ft)	k (cm/s)	Bq	Qtn	Rfn	SBTn	Qc1N	DeltaQc1N	Qc1Ncs	Fc (%)	Phi (Deg)	Dr (%)	OCR	State Param	Del(n1)60	(N1)60c
81.04	1.0E-15	0.01	58.1	5.58	6	95.9	383.5	479.4	35.5	40	66.1	1.0	-0.53	93.8	187.
82.02	1.0E-15	0.00	37.6	6.58	1	63.5	UnDef	UnDef	100.0	38	54.2	1.0	-0.63	UnDef	UnDe
83.00	5.0E-06	0.19	10.2	4.26	1	19.4	UnDef	UnDef	100.0	UnDef	UnDef	3.0	UnDef	UnDef	UnDe
83.99	5.0E-06	0.11	18.2	4.27	1	32.5	UnDef	UnDef	100.0	UnDef	UnDef	6.0	UnDef	UnDef	UnDe
84.97	1.0E-15	0.01	43.5	6.51	1	74.1	UnDef	UnDef	100.0	38	58.7	1.0	-0.65	UnDef	UnDe
85.96	1.0E-15	0.01	52.6	5.69	1	89.6	UnDef	UnDef	100.0	40	64.1	1.0	-0.52	UnDef	UnDe
86.94	1.0E-15	0.00	76.7	4.16	6	129.8	196.6	326.4	27.6	40	74.8	1.0	-0.40	38.4	101.
87.93	1.0E-15	-0.01	33.4	5.28	1	58.5	UnDef	UnDef	100.0	36	51.9	1.0	-0.37	UnDef	UnDe
88.91	5.0E-05	0.08	10.3	2.62	4	20.2	80.8	101.0	55.4	30	30.0	3.0	-0.03	7.9	15.
89.89	1.0E-15	0.06	23.1	5.06	1	41.8	UnDef	UnDef	100.0	34	42.3	1.0	-0.26	UnDef	UnDe
90.88	1.0E-15	0.02	26.8	6.80	1	48.4	UnDef	UnDef	100.0	36	46.4	1.0	-0.58	UnDef	UnDe
91.86	1.0E-15	0.02	28.6	6.88	1	51.6	UnDef	UnDef	100.0	36	48.3	1.0	-0.62	UnDef	UnDe
92.85	1.0E-15	0.00	35.7	6.45	1	64.0	UnDef	UnDef	100.0	38	54.5	1.0	-0.58	UnDef	UnDe
93.83	1.0E-15	0.03	24.8	4.93	1	45.8	UnDef	UnDef	100.0	34	44.9	1.0	-0.27	UnDef	UnDe
94.82	1.0E-15	0.04	22.1	5.37	1	41.2	UnDef	UnDef	100.0	34	41.9	1.0	-0.28	UnDef	UnDe
95.80	1.0E-15	0.03	27.2	5.32	1	50.4	UnDef	UnDef	100.0	36	47.6	1.0	-0.32	UnDef	UnDe
96.78	1.0E-15	0.02	32.3	6.06	1	59.6	UnDef	UnDef	100.0	36	52.4	1.0	-0.47	UnDef	UnDe
97.77	1.0E-15	0.03	30.0	5.46	1	55.7	UnDef	UnDef	100.0	36	50.5	1.0	-0.36	UnDef	UnDe
98.75	1.0E-15	0.00	45.0	4.51	6	82.6	330.5	413.1	35.9	38	61.8	1.0	-0.35	80.9	161.

Gregg In Situ, Inc.
Interpretation Output - Release 1.00.19e
Job No: 03-0203-1606-1479
Job No: 97-100
Client: CDM
Project: CPT SITE INVESTIGATION
Site: SHERWIN WILLIAMS
Location: CPT-01
Engineer: H. YOUNG
CPT Date: 03/29/01
CPT Time: 11:54
CPT File: 027C01.COR
Northing (m): 0.000
Easting (m): 0.000
Elevation (m): 0.000

Water Table (m): 4.57 (ft): 15.0
Su Nkt used: 12.50
Averaging Increment (m): 0.30
Phi Method : Robertson and Campanella, 1983
Dr Method : Jamiolkowski - All Sands
State Parameter M: 1.20
Used Unit Weights Assigned to Soil Zones
Values of 1.0E9 or UnDef are printed for parameters that are not valid for the material type (SBT)

Depth (ft)	AvgQt (tsf)	AvgFs (tsf)	AvgRf (%)	AvgUd (ft)	SBT	U.Wt. pcf	TStress (tsf)	EStress (tsf)	Ueq (tsf)	Cn	N60 (blows/ft)	(N1)60 (blows/ft)	Su (tsf)	CRR
0.49	0.0	0.00	0.00	0.0	UnDef	124.1	0.03	0.03	0.00	2.00	UnDef	UnDef	UnDef	0.00
1.48	0.0	0.00	0.00	0.0	UnDef	124.1	0.09	0.09	0.00	2.00	UnDef	UnDef	UnDef	0.00
2.46	0.0	0.00	0.00	0.0	UnDef	124.1	0.15	0.15	0.00	2.00	UnDef	UnDef	UnDef	0.00
3.44	0.0	0.00	0.00	0.0	UnDef	124.1	0.21	0.21	0.00	2.00	UnDef	UnDef	UnDef	0.00
4.43	0.0	0.00	0.00	0.0	UnDef	124.1	0.27	0.27	0.00	1.91	UnDef	UnDef	UnDef	0.00
5.41	14.8	0.35	2.34	1.3	5	114.6	0.33	0.33	0.00	1.73	7.1	12.2	1.15	0.10
6.40	19.8	0.49	2.46	1.7	5	114.6	0.39	0.39	0.00	1.60	9.5	15.2	1.55	0.12
7.30	31.3	0.75	2.41	-5.4	6	114.6	0.44	0.44	0.00	1.50	12.0	18.0	2.47	0.14
8.20	24.4	1.03	4.21	-1.5	4	114.6	0.49	0.49	0.00	1.42	15.6	22.2	1.91	0.40
9.19	16.9	0.60	3.58	2.2	4	114.6	0.55	0.55	0.00	1.35	10.8	14.6	1.31	0.21
10.17	14.8	0.49	3.29	21.1	4	114.6	0.61	0.61	0.00	1.28	9.5	12.1	1.14	0.16
11.15	13.7	0.55	3.99	22.4	3	111.4	0.66	0.66	0.00	1.23	13.1	16.2	1.04	0.00
12.14	46.7	0.54	1.15	29.4	7	117.8	0.72	0.72	0.00	1.18	14.9	17.6	UnDef	0.12
13.21	132.5	0.85	0.65	-0.6	9	124.1	0.78	0.78	0.00	1.13	25.4	28.7	UnDef	0.37
14.27	32.6	0.40	1.23	1.1	7	117.8	0.85	0.85	0.00	1.09	10.4	11.3	UnDef	0.11
15.26	7.1	0.11	1.54	21.5	5	114.6	0.90	0.90	0.01	1.06	3.4	3.6	0.49	0.08
16.24	7.7	0.13	1.62	46.1	5	114.6	0.96	0.92	0.04	1.04	3.7	3.9	0.54	0.09
17.22	8.9	0.21	2.36	50.8	5	114.6	1.02	0.95	0.07	1.03	4.2	4.4	0.63	0.09
18.21	8.1	0.14	1.68	44.2	5	114.6	1.07	0.97	0.10	1.01	3.9	4.0	0.57	0.09
19.19	8.2	0.07	0.79	71.1	5	114.6	1.13	1.00	0.13	1.00	3.9	3.9	0.57	0.09
20.18	14.1	0.21	1.47	48.8	6	114.6	1.19	1.02	0.16	0.99	5.4	5.3	1.03	0.11
21.16	59.5	0.39	0.66	11.7	8	120.9	1.24	1.05	0.19	0.98	14.2	13.9	UnDef	0.12
22.15	21.8	0.38	1.74	20.1	6	114.6	1.30	1.08	0.22	0.96	8.4	8.1	1.64	0.18
23.13	7.4	0.12	1.57	64.8	5	114.6	1.36	1.10	0.25	0.95	3.5	3.3	0.48	0.08
24.11	7.3	0.16	2.16	72.7	4	114.6	1.42	1.13	0.28	0.94	4.7	4.4	0.47	0.08
25.10	7.9	0.23	2.89	64.2	4	114.6	1.47	1.16	0.32	0.93	5.0	4.7	0.51	0.00
26.08	11.9	0.35	2.97	83.8	4	114.6	1.53	1.18	0.35	0.92	7.6	7.0	0.83	0.00
27.07	82.6	2.00	2.43	59.6	7	117.8	1.59	1.21	0.38	0.91	26.4	24.0	UnDef	0.33
28.05	108.2	3.16	2.92	-21.7	6	114.6	1.64	1.23	0.41	0.90	41.5	37.3	8.53	0.00
29.04	82.7	1.87	2.26	-15.5	7	117.8	1.70	1.26	0.44	0.89	26.4	23.5	UnDef	0.31

Depth (ft)	AvgQt (tsf)	AvgFs (tsf)	AvgRf (%)	AvgUd (ft)	SBT	U.Wt. pcf	TStress (tsf)	EStress (tsf)	Ueq (tsf)	Cn	N60 (blows/ft)	(N1)60 (blows/ft)	Su (tsf)	CRR
30.02	97.7	1.52	1.56	-12.2	7	117.8	1.76	1.29	0.47	0.88	31.2	27.5	UnDef	0.26
31.00	40.8	1.66	4.07	47.7	5	114.6	1.81	1.31	0.50	0.87	19.6	17.1	3.12	0.00
31.99	27.3	1.13	4.13	63.6	4	114.6	1.87	1.34	0.53	0.86	17.4	15.1	2.03	0.00
32.97	18.6	0.81	4.36	76.9	3	111.4	1.93	1.37	0.56	0.86	17.8	15.2	1.33	0.00
33.96	19.3	0.69	3.57	133.0	4	114.6	1.98	1.39	0.59	0.85	12.3	10.4	1.38	0.00
34.94	20.4	0.56	2.76	168.3	5	114.6	2.04	1.42	0.62	0.84	9.8	8.2	1.47	0.14
35.92	21.1	0.61	2.88	190.5	5	114.6	2.09	1.44	0.65	0.83	10.1	8.4	1.52	0.14
36.91	22.3	0.60	2.68	201.1	5	114.6	2.15	1.47	0.68	0.83	10.7	8.8	1.61	0.15
37.89	19.0	0.57	3.00	164.7	5	114.6	2.21	1.49	0.71	0.82	9.1	7.4	1.34	0.12
38.88	18.9	0.57	3.03	162.2	5	114.6	2.26	1.52	0.75	0.81	9.0	7.3	1.33	0.12
39.86	20.1	0.61	3.03	163.8	5	114.6	2.32	1.54	0.78	0.80	9.6	7.8	1.43	0.13
40.85	47.5	1.67	3.51	146.6	5	114.6	2.38	1.57	0.81	0.80	22.7	18.2	3.61	0.00
41.83	36.6	1.65	4.51	129.7	4	114.6	2.43	1.60	0.84	0.79	23.4	18.5	2.73	0.00
42.81	53.0	1.57	2.97	120.8	6	114.6	2.49	1.62	0.87	0.79	20.3	15.9	4.04	0.00
43.80	21.5	0.29	1.35	286.5	6	114.6	2.55	1.65	0.90	0.78	8.2	6.4	1.51	0.13
44.78	24.2	0.59	2.45	229.0	6	114.6	2.60	1.67	0.93	0.77	9.3	7.2	1.73	0.15
45.77	23.0	0.90	3.90	127.8	4	114.6	2.66	1.70	0.96	0.77	14.7	11.3	1.63	0.00
46.75	22.6	0.76	3.35	164.0	5	114.6	2.72	1.72	0.99	0.76	10.8	8.3	1.59	0.00
47.74	32.0	0.95	2.96	208.7	5	114.6	2.77	1.75	1.02	0.76	15.3	11.6	2.34	0.23
48.72	69.5	2.57	3.70	83.2	5	114.6	2.83	1.78	1.05	0.75	33.3	25.0	5.33	0.00
49.70	28.9	0.74	2.55	216.6	6	114.6	2.88	1.80	1.08	0.75	11.1	8.2	2.08	0.19
50.69	28.4	0.69	2.44	190.5	6	114.6	2.94	1.83	1.11	0.74	10.9	8.1	2.04	0.18
51.67	27.6	0.90	3.27	94.5	5	114.6	3.00	1.85	1.15	0.73	13.2	9.7	1.97	0.00
52.66	35.4	1.06	3.00	197.5	5	114.6	3.05	1.88	1.18	0.73	16.9	12.4	2.58	0.27
53.64	83.0	3.73	4.49	120.8	11	130.5	3.11	1.91	1.21	0.72	79.5	57.6	UnDef	0.00
54.63	115.8	4.53	3.91	118.4	5	114.6	3.17	1.94	1.24	0.72	55.4	39.8	9.01	0.00
55.61	262.4	5.44	2.07	-7.8	8	120.9	3.23	1.96	1.27	0.71	62.8	44.8	UnDef	0.00
56.59	379.4	2.76	0.73	-0.6	9	124.1	3.29	1.99	1.30	0.71	72.7	51.5	UnDef	0.00
57.58	334.3	2.43	0.73	14.6	9	124.1	3.35	2.02	1.33	0.70	64.0	45.0	UnDef	0.00
58.56	29.9	0.82	2.73	219.7	5	114.6	3.41	2.05	1.36	0.70	14.3	10.0	2.12	0.18
59.55	26.1	0.44	1.70	262.6	6	114.6	3.47	2.08	1.39	0.69	10.0	6.9	1.81	0.14
60.53	31.9	0.44	1.38	339.5	6	114.6	3.52	2.10	1.42	0.69	12.2	8.4	2.27	0.20
61.52	34.1	0.83	2.44	225.8	6	114.6	3.58	2.13	1.45	0.69	13.1	9.0	2.44	0.22
62.42	32.1	0.83	2.60	200.6	6	114.6	3.63	2.15	1.48	0.68	12.3	8.4	2.27	0.19
63.32	30.0	0.74	2.45	235.0	6	114.6	3.68	2.18	1.51	0.68	11.5	7.8	2.10	0.17
64.30	32.6	0.82	2.52	254.3	6	114.6	3.74	2.20	1.54	0.67	12.5	8.4	2.31	0.20
65.29	34.5	0.80	2.32	263.9	6	114.6	3.80	2.23	1.57	0.67	13.2	8.9	2.46	0.21
66.27	32.6	0.64	1.97	355.3	6	114.6	3.85	2.25	1.60	0.67	12.5	8.3	2.30	0.19
67.26	83.7	3.19	3.81	224.5	5	114.6	3.91	2.28	1.63	0.66	40.1	26.6	6.39	0.00
68.24	135.9	6.32	4.65	-12.0	11	130.5	3.97	2.31	1.66	0.66	130.1	85.7	UnDef	0.00
69.22	62.2	3.26	5.24	62.5	11	130.5	4.03	2.34	1.69	0.65	59.6	38.9	UnDef	0.00
70.21	41.1	1.29	3.14	206.5	5	114.6	4.10	2.37	1.72	0.65	19.7	12.8	2.96	0.29
71.19	39.6	1.03	2.61	232.3	6	114.6	4.15	2.40	1.75	0.65	15.2	9.8	2.83	0.26
72.18	34.4	0.70	2.02	263.7	6	114.6	4.21	2.42	1.79	0.64	13.2	8.5	2.41	0.20
73.16	37.5	0.94	2.51	235.8	6	114.6	4.26	2.45	1.82	0.64	14.4	9.2	2.66	0.23
74.15	36.2	1.20	3.31	229.8	5	114.6	4.32	2.47	1.85	0.64	17.3	11.0	2.55	0.00
75.13	38.2	1.14	2.97	264.3	5	114.6	4.38	2.50	1.88	0.63	18.3	11.6	2.71	0.23
76.11	44.5	1.40	3.13	213.4	5	114.6	4.43	2.53	1.91	0.63	21.3	13.4	3.21	0.32
77.10	54.9	2.23	4.07	283.7	5	114.6	4.49	2.55	1.94	0.63	26.3	16.4	4.03	0.00
78.08	77.6	4.39	5.66	128.1	11	130.5	4.55	2.58	1.97	0.62	74.3	46.3	UnDef	0.00
79.07	57.6	2.59	4.50	137.9	5	114.6	4.61	2.61	2.00	0.62	27.6	17.1	4.24	0.00
80.05	29.5	0.72	2.44	218.0	6	114.6	4.67	2.64	2.03	0.62	11.3	7.0	1.99	0.15

Gregg In Situ, Inc.
Run No: 03-0203-1606-1479
CPT File: 027C01.COR

Depth (ft)	AvgQt (tsf)	AvgFs (tsf)	AvgRf (%)	AvgUd (ft)	SBT	U.Wt. pcf	TStress (tsf)	EStress (tsf)	Ueq (tsf)	Cn	N60 (blows/ft)	(N1)60	Su (tsf)	CRR
81.04	30.2	0.64	2.11	298.4	6	114.6	4.72	2.66	2.06	0.61	11.6	7.1	2.04	0.15
82.02	53.2	1.58	2.96	329.5	6	114.6	4.78	2.69	2.09	0.61	20.4	12.4	3.88	0.45
83.00	51.2	1.28	2.51	308.6	6	114.6	4.84	2.71	2.12	0.61	19.6	11.9	3.71	0.41
83.99	91.4	3.75	4.11	215.2	5	114.6	4.89	2.74	2.15	0.60	43.8	26.5	6.92	0.00
84.97	152.6	8.36	5.48	14.7	11	130.5	4.95	2.77	2.18	0.60	146.1	87.8	UnDef	0.00
85.96	118.3	7.05	5.96	19.7	11	130.5	5.02	2.80	2.22	0.60	113.3	67.7	UnDef	0.00
86.94	45.4	1.83	4.03	115.2	5	114.6	5.08	2.83	2.25	0.59	21.7	12.9	3.22	0.00
87.93	43.4	0.89	2.06	298.1	6	114.6	5.13	2.86	2.28	0.59	16.6	9.8	3.06	0.26
88.91	124.3	5.60	4.50	195.1	11	130.5	5.19	2.89	2.31	0.59	119.0	70.1	UnDef	0.00
89.89	60.7	3.62	5.96	15.9	11	130.5	5.26	2.92	2.34	0.59	58.1	34.0	UnDef	0.00
90.88	29.4	0.59	1.99	217.7	6	114.6	5.32	2.95	2.37	0.58	11.3	6.6	1.93	0.13
91.86	35.8	0.74	2.07	342.4	6	114.6	5.37	2.97	2.40	0.58	13.7	7.9	2.43	0.18
92.85	42.6	1.18	2.77	355.1	6	114.6	5.43	3.00	2.43	0.58	16.3	9.4	2.97	0.24
93.83	46.8	1.82	3.89	230.8	5	114.6	5.49	3.03	2.46	0.57	22.4	12.9	3.31	0.00
94.82	36.5	1.50	4.13	199.3	4	114.6	5.54	3.05	2.49	0.57	23.3	13.3	2.47	0.00
95.80	28.0	0.81	2.89	271.5	5	114.6	5.60	3.08	2.52	0.57	13.4	7.6	1.79	0.00
96.78	30.4	0.89	2.92	290.3	5	114.6	5.66	3.10	2.55	0.57	14.6	8.3	1.98	0.00
97.77	32.8	0.97	2.95	300.0	5	114.6	5.71	3.13	2.58	0.57	15.7	8.9	2.16	0.00
98.75	33.3	1.01	3.02	264.5	5	114.6	5.77	3.15	2.61	0.56	16.0	9.0	2.20	0.00

Interpretation Output - Release 1.00.19e

Run No: 03-0203-1606-1479
Job No: 97-100
Client: CDM
Project: CPT SITE INVESTIGATION
Site: SHERWIN WILLIAMS
Location: CPT-01
Engineer: H. YOUNG
CPT Date: 03/29/01
CPT Time: 11:54
CPT File: 027C01.COR
Northing (m): 0.000
Easting (m): 0.000
Elevation (m): 0.000

Water Table (m): 4.57 (ft): 15.0
Su Nkt used: 12.50
Averaging Increment (m): 0.30
Phi Method : Robertson and Campanella, 1983
Dr Method : Jamiolkowski - All Sands
State Parameter M: 1.20
Used Unit Weights Assigned to Soil Zones
Values of 1.0E9 or UnDef are printed for parameters that are not valid for the material type (SBT)

Depth (ft)	k (cm/s)	Bq	Qtn	Rfn	SBTn	Qc1N	DeltaQc1N	Qc1Ncs	Fc (%)	Phi (Deg)	Dr (%)	OCR	State Param	Del(n1)60	(N1)60c
0.49	1.0E-15	0.00	2.4	0.10	1	0.2	UnDef	UnDef	100.0	UnDef	UnDef	1.0	UnDef	UnDef	UnDe
1.48	1.0E-15	0.00	0.1	0.10	1	0.2	UnDef	UnDef	100.0	UnDef	UnDef	1.0	UnDef	UnDef	UnDe
2.46	1.0E-15	0.00	0.1	0.10	1	0.2	UnDef	UnDef	100.0	UnDef	UnDef	1.0	UnDef	UnDef	UnDe
3.44	1.0E-15	0.00	0.0	0.10	1	0.2	UnDef	UnDef	100.0	UnDef	UnDef	1.0	UnDef	UnDef	UnDe
4.43	1.0E-15	0.00	0.0	0.10	1	0.2	UnDef	UnDef	100.0	UnDef	UnDef	1.0	UnDef	UnDef	UnDe
5.41	5.0E-06	0.00	43.3	2.40	7	25.0	38.9	63.9	27.8	UnDef	UnDef	6.0	UnDef	7.5	19.
6.40	5.0E-06	0.00	49.7	2.51	7	31.0	41.6	72.6	26.5	UnDef	UnDef	6.0	UnDef	8.5	23.
7.30	5.0E-05	-0.01	69.9	2.44	7	46.1	38.4	84.5	22.0	40	45.1	10.0	-0.25	7.2	25.
8.20	5.0E-07	0.00	48.5	4.29	6	34.0	117.0	151.0	34.0	UnDef	UnDef	6.0	UnDef	20.9	43.
9.19	5.0E-07	0.00	29.8	3.70	6	22.3	89.3	111.6	39.4	UnDef	UnDef	6.0	UnDef	14.6	29.
10.17	5.0E-07	0.05	23.4	3.43	6	18.6	74.5	93.1	42.5	UnDef	UnDef	6.0	UnDef	12.1	24.
11.15	5.0E-08	0.05	19.7	4.20	1	16.5	UnDef	UnDef	100.0	UnDef	UnDef	6.0	UnDef	UnDef	UnDe
12.14	5.0E-04	0.02	64.1	1.17	7	54.0	22.1	76.1	15.9	40	49.6	1.0	-0.16	3.9	21.
13.21	5.0E-02	0.00	168.3	0.65	9	146.5	0.0	146.5	4.6	44	78.2	1.0	-0.20	0.0	28.
14.27	5.0E-04	0.00	37.5	1.26	7	34.7	31.8	66.5	22.9	38	36.9	1.0	-0.11	4.8	16.
15.26	5.0E-06	0.11	6.9	1.76	4	7.3	29.2	36.6	59.4	UnDef	UnDef	3.0	UnDef	3.6	7.
16.24	5.0E-06	0.21	7.4	1.85	4	7.9	31.6	39.5	58.4	UnDef	UnDef	3.0	UnDef	3.9	7.
17.22	5.0E-06	0.19	8.3	2.67	4	8.9	35.6	44.5	61.0	UnDef	UnDef	3.0	UnDef	4.4	8.
18.21	5.0E-06	0.18	7.3	1.94	4	8.1	32.3	40.4	59.4	UnDef	UnDef	3.0	UnDef	4.0	7.
19.19	5.0E-06	0.29	7.1	0.92	6	8.0	32.2	40.2	50.4	UnDef	UnDef	3.0	UnDef	3.9	7.
20.18	5.0E-05	0.11	12.6	1.61	6	13.6	54.4	68.0	44.1	30	30.0	6.0	-0.01	5.3	10.
21.16	5.0E-03	0.00	55.3	0.68	9	56.7	16.8	73.5	13.5	40	51.0	1.0	-0.10	2.3	16.
22.15	5.0E-05	0.02	19.0	1.85	6	20.6	82.3	102.8	37.7	32	30.0	6.0	-0.08	8.1	16.
23.13	5.0E-06	0.30	5.4	1.92	4	6.8	27.4	34.2	67.1	UnDef	UnDef	1.5	UnDef	3.3	6.
24.11	5.0E-07	0.33	5.2	2.68	4	6.8	27.0	33.8	73.5	UnDef	UnDef	1.5	UnDef	4.4	8.
25.10	5.0E-07	0.26	5.5	3.56	1	7.2	UnDef	UnDef	100.0	UnDef	UnDef	1.5	UnDef	UnDef	UnDe
26.08	5.0E-07	0.22	8.8	3.40	1	10.7	UnDef	UnDef	100.0	UnDef	UnDef	3.0	UnDef	UnDef	UnDe
27.07	5.0E-04	0.02	67.0	2.47	7	73.5	65.5	139.0	22.6	40	58.5	1.0	-0.25	10.0	34.
28.05	5.0E-05	-0.01	86.3	2.96	7	95.3	78.5	173.8	21.9	42	65.9	10.0	-0.32	14.7	52.
29.04	5.0E-04	-0.01	64.2	2.31	7	72.1	62.2	134.3	22.3	40	57.9	1.0	-0.24	9.6	33.

Depth (ft)	k (cm/s)	Bq	Qtn	Rfn	SBTn	Qc1N	DeltaQc1N	Qc1Ncs	Fc (%)	Phi (Deg)	Dr (%)	OCR	State Param	Del(n1)60	(N1)60c
30.02	5.0E-04	-0.01	74.5	1.59	7	84.2	39.6	123.9	17.0	40	62.4	1.0	-0.21	6.9	34.
31.00	5.0E-06	0.03	29.7	4.26	6	34.8	139.4	174.2	41.7	UnDef	UnDef	6.0	UnDef	17.1	34.
31.99	5.0E-07	0.06	19.0	4.43	1	23.1	UnDef	UnDef	100.0	UnDef	UnDef	6.0	UnDef	UnDef	UnDe
32.97	5.0E-08	0.11	12.2	4.87	1	15.6	UnDef	UnDef	100.0	UnDef	UnDef	3.0	UnDef	UnDef	UnDe
33.96	5.0E-07	0.21	12.4	3.98	1	16.0	UnDef	UnDef	100.0	UnDef	UnDef	3.0	UnDef	UnDef	UnDe
34.94	5.0E-06	0.25	13.0	3.07	4	16.8	67.2	84.1	52.6	UnDef	UnDef	6.0	UnDef	8.2	16.
35.92	5.0E-06	0.28	13.2	3.20	4	17.2	68.9	86.2	52.9	UnDef	UnDef	6.0	UnDef	8.4	16.
36.91	5.0E-06	0.28	13.8	2.96	4	18.0	72.2	90.2	50.8	UnDef	UnDef	6.0	UnDef	8.8	17.
37.89	5.0E-06	0.26	11.2	3.39	4	15.2	60.9	76.1	57.5	UnDef	UnDef	3.0	UnDef	7.4	14.
38.88	5.0E-06	0.26	10.9	3.44	4	15.0	59.9	74.9	58.4	UnDef	UnDef	3.0	UnDef	7.3	14.
39.86	5.0E-06	0.24	11.5	3.42	4	15.9	63.4	79.3	57.1	UnDef	UnDef	3.0	UnDef	7.8	15.
40.85	5.0E-06	0.08	28.7	3.69	6	37.1	148.4	185.5	40.0	UnDef	UnDef	6.0	UnDef	18.2	36.
41.83	5.0E-07	0.09	21.4	4.83	1	28.3	UnDef	UnDef	100.0	UnDef	UnDef	6.0	UnDef	UnDef	UnDe
42.81	5.0E-05	0.06	31.2	3.11	6	40.7	162.9	203.6	36.1	36	41.5	6.0	-0.19	15.9	31.
43.80	5.0E-05	0.43	11.5	1.53	6	16.4	65.4	81.8	45.4	30	30.0	3.0	0.04	6.4	12.
44.78	5.0E-05	0.29	12.9	2.75	6	18.3	73.2	91.5	51.0	32	30.0	6.0	-0.03	7.2	14.
45.77	5.0E-07	0.15	12.0	4.41	1	17.3	UnDef	UnDef	100.0	UnDef	UnDef	3.0	UnDef	UnDef	UnDe
46.75	5.0E-06	0.21	11.6	3.81	1	16.9	UnDef	UnDef	100.0	UnDef	UnDef	3.0	UnDef	UnDef	UnDe
47.74	5.0E-06	0.19	16.7	3.24	6	23.7	94.8	118.5	48.1	UnDef	UnDef	6.0	UnDef	11.6	23.
48.72	5.0E-06	0.02	37.5	3.86	6	51.0	204.1	255.1	36.3	UnDef	UnDef	6.0	UnDef	25.0	49.
49.70	5.0E-05	0.22	14.4	2.83	6	21.0	84.2	105.2	49.1	32	30.0	6.0	-0.06	8.2	16.
50.69	5.0E-05	0.19	13.9	2.72	6	20.6	82.3	102.8	49.2	32	30.0	6.0	-0.05	8.1	16.
51.67	5.0E-06	0.07	13.3	3.67	1	19.9	UnDef	UnDef	100.0	UnDef	UnDef	6.0	UnDef	UnDef	UnDe
52.66	5.0E-06	0.15	17.2	3.28	6	25.3	101.0	126.3	47.7	UnDef	UnDef	6.0	UnDef	12.4	24.
53.64	1.0E-15	0.03	41.9	4.66	6	58.8	235.3	294.1	37.5	38	52.1	1.0	-0.34	57.6	115.
54.63	5.0E-06	0.02	58.1	4.02	6	81.4	175.2	256.6	30.6	UnDef	UnDef	10.0	UnDef	29.7	69.
55.61	5.0E-03	-0.01	131.9	2.10	7	183.2	60.7	243.9	14.3	44	84.6	1.0	-0.30	8.3	53.
56.59	5.0E-02	0.00	188.7	0.73	9	263.0	0.0	263.0	4.6	44	95.0	1.0	-0.22	0.0	51.
57.58	5.0E-02	0.00	163.5	0.73	9	230.0	2.5	232.4	5.4	44	91.1	1.0	-0.20	0.3	45.
58.56	5.0E-06	0.21	12.9	3.08	4	20.4	81.7	102.1	52.8	UnDef	UnDef	6.0	UnDef	10.0	20.
59.55	5.0E-05	0.30	10.9	1.96	6	17.7	70.9	88.6	49.8	30	30.0	3.0	0.02	6.9	13.
60.53	5.0E-05	0.32	13.5	1.55	6	21.5	86.2	107.7	42.1	32	30.0	6.0	0.01	8.4	16.
61.52	5.0E-05	0.18	14.3	2.72	6	22.9	91.6	114.4	48.6	32	30.0	6.0	-0.06	9.0	17.
62.42	5.0E-05	0.17	13.2	2.93	4	21.4	85.5	106.9	51.5	32	30.0	6.0	-0.05	8.4	16.
63.32	5.0E-05	0.22	12.1	2.80	4	19.9	79.5	99.4	52.7	30	30.0	3.0	-0.03	7.8	15.
64.30	5.0E-05	0.22	13.1	2.85	4	21.5	86.1	107.6	51.2	32	30.0	6.0	-0.04	8.4	16.
65.29	5.0E-05	0.22	13.8	2.61	6	22.6	90.5	113.1	48.8	32	30.0	6.0	-0.04	8.9	17.
66.27	5.0E-05	0.33	12.8	2.23	6	21.3	85.0	106.3	48.2	32	30.0	6.0	-0.01	8.3	16.
67.26	5.0E-06	0.07	35.0	3.99	6	54.3	217.1	271.4	37.9	UnDef	UnDef	6.0	UnDef	26.6	53.
68.24	1.0E-15	-0.02	57.1	4.79	6	87.5	273.1	360.6	33.4	40	63.5	1.0	-0.42	77.1	162.
69.22	1.0E-15	0.00	24.8	5.60	1	39.8	UnDef	UnDef	100.0	34	40.9	1.0	-0.34	UnDef	UnDe
70.21	5.0E-06	0.13	15.6	3.48	4	26.1	104.4	130.5	50.7	UnDef	UnDef	6.0	UnDef	12.8	25.
71.19	5.0E-05	0.16	14.8	2.91	6	25.0	100.0	125.0	49.0	32	30.0	6.0	-0.07	9.8	19.
72.18	5.0E-05	0.21	12.5	2.30	6	21.6	86.5	108.1	49.2	30	30.0	3.0	-0.02	8.5	16.
73.16	5.0E-05	0.17	13.6	2.83	6	23.4	93.8	117.2	50.4	32	30.0	6.0	-0.06	9.2	18.
74.15	5.0E-06	0.17	12.9	3.75	1	22.5	UnDef	UnDef	100.0	UnDef	UnDef	6.0	UnDef	UnDef	UnDe
75.13	5.0E-06	0.19	13.5	3.36	4	23.6	94.6	118.2	53.2	UnDef	UnDef	6.0	UnDef	11.6	23.
76.11	5.0E-06	0.12	15.9	3.48	4	27.4	109.6	137.0	50.3	UnDef	UnDef	6.0	UnDef	13.4	26.
77.10	5.0E-06	0.14	19.7	4.43	1	33.6	UnDef	UnDef	100.0	UnDef	UnDef	6.0	UnDef	UnDef	UnDe
78.08	1.0E-15	0.03	28.3	6.01	1	47.3	UnDef	UnDef	100.0	36	45.8	1.0	-0.42	UnDef	UnDe
79.07	5.0E-06	0.04	20.3	4.89	1	34.9	UnDef	UnDef	100.0	UnDef	UnDef	6.0	UnDef	UnDef	UnDe
80.05	5.0E-05	0.19	9.4	2.89	4	17.8	71.1	88.9	59.1	30	30.0	3.0	-0.01	7.0	13.

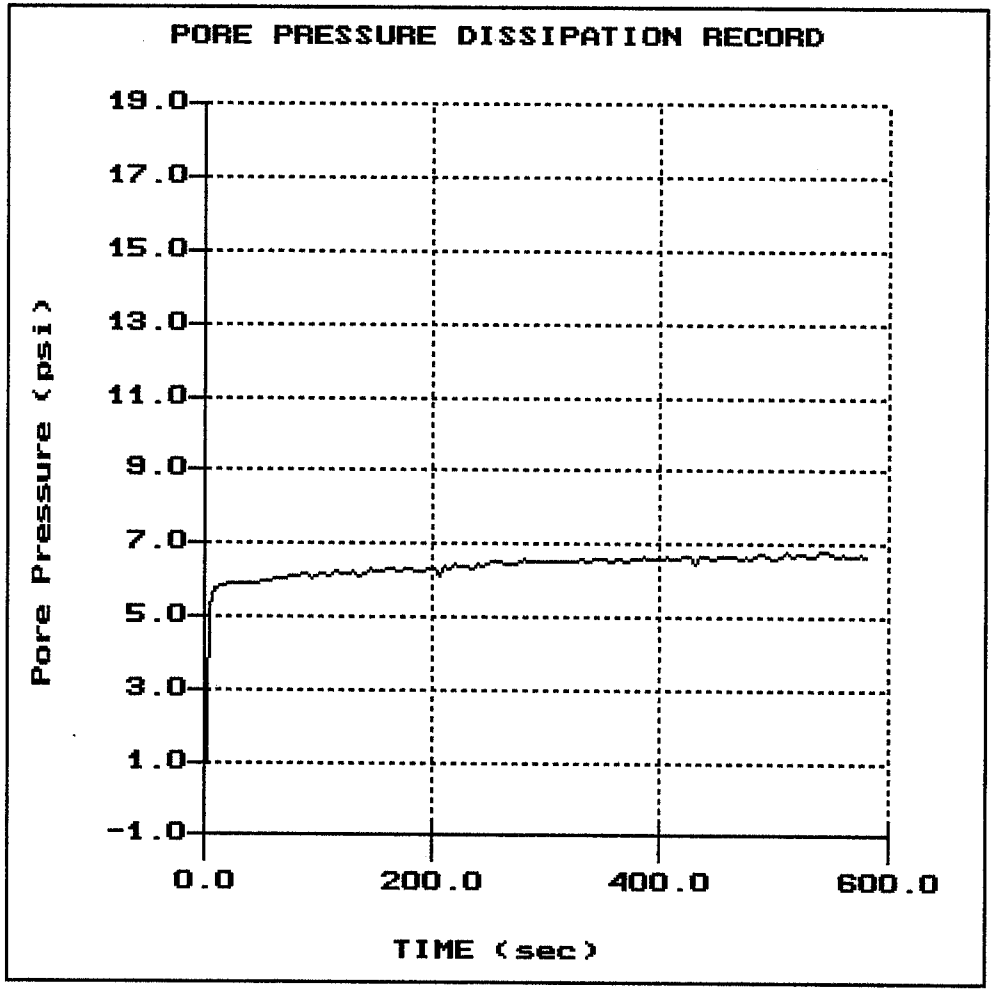
pth (ft)	k (cm/s)	Bq	Qtn	Rfn	SBTn	Qc1N	DeltaQc1N	Qc1Ncs	Fc (%)	Phi (Deg)	Dr (%)	OCR	State Param	Del(n1)60	(N1)60c
81.04	5.0E-05	0.29	9.6	2.50	4	18.1	72.4	90.5	56.4	30	30.0	3.0	0.01	7.1	14.
82.02	5.0E-05	0.17	18.0	3.25	6	31.8	127.1	158.9	46.6	32	34.4	6.0	-0.11	12.4	24.
83.00	5.0E-05	0.16	17.1	2.77	6	30.4	121.8	152.2	45.2	32	33.2	6.0	-0.08	11.9	23.
83.99	5.0E-06	0.05	31.6	4.34	6	54.1	216.3	270.4	40.9	UnDef	UnDef	6.0	UnDef	26.5	52.
84.97	1.0E-15	-0.01	53.3	5.66	1	89.7	UnDef	UnDef	100.0	40	64.2	1.0	-0.53	UnDef	UnDe
85.96	1.0E-15	-0.01	40.4	6.22	1	69.2	UnDef	UnDef	100.0	38	56.7	1.0	-0.57	UnDef	UnDe
86.94	5.0E-06	0.03	14.2	4.54	1	26.4	UnDef	UnDef	100.0	UnDef	UnDef	6.0	UnDef	UnDef	UnDe
87.93	5.0E-05	0.18	13.4	2.34	6	25.1	100.5	125.6	47.8	32	30.0	6.0	-0.04	9.8	19.
88.91	1.0E-15	0.03	41.3	4.70	6	71.6	286.4	358.0	37.8	38	57.7	1.0	-0.34	70.1	140.
89.89	1.0E-15	-0.03	19.0	6.52	1	34.8	UnDef	UnDef	100.0	32	37.0	1.0	-0.41	UnDef	UnDe
90.88	5.0E-05	0.18	8.2	2.43	4	16.8	67.1	83.8	59.8	30	30.0	3.0	0.02	6.6	13.
91.86	5.0E-05	0.27	10.2	2.43	4	20.3	81.2	101.5	54.4	30	30.0	3.0	0.01	7.9	15.
92.85	5.0E-05	0.23	12.4	3.18	4	24.0	96.2	120.2	54.3	30	30.0	3.0	-0.04	9.4	18.
93.83	5.0E-06	0.11	13.7	4.41	1	26.3	UnDef	UnDef	100.0	UnDef	UnDef	6.0	UnDef	UnDef	UnDe
94.82	5.0E-07	0.12	10.1	4.87	1	20.4	UnDef	UnDef	100.0	UnDef	UnDef	3.0	UnDef	UnDef	UnDe
95.80	5.0E-06	0.27	7.3	3.61	1	15.6	UnDef	UnDef	100.0	UnDef	UnDef	3.0	UnDef	UnDef	UnDe
96.78	5.0E-06	0.26	8.0	3.59	1	16.9	UnDef	UnDef	100.0	UnDef	UnDef	3.0	UnDef	UnDef	UnDe
97.77	5.0E-06	0.25	8.6	3.58	1	18.1	UnDef	UnDef	100.0	UnDef	UnDef	3.0	UnDef	UnDef	UnDe
98.75	5.0E-06	0.20	8.7	3.65	1	18.4	UnDef	UnDef	100.0	UnDef	UnDef	3.0	UnDef	UnDef	UnDe

3.3 PORE PRESSURE DISSIPATION PLOTS

CDM

Site: SHERWIN WILLIAMS
Location: CPT-01

Engineer: H. YOUNG
Date:01:29:03 11:54

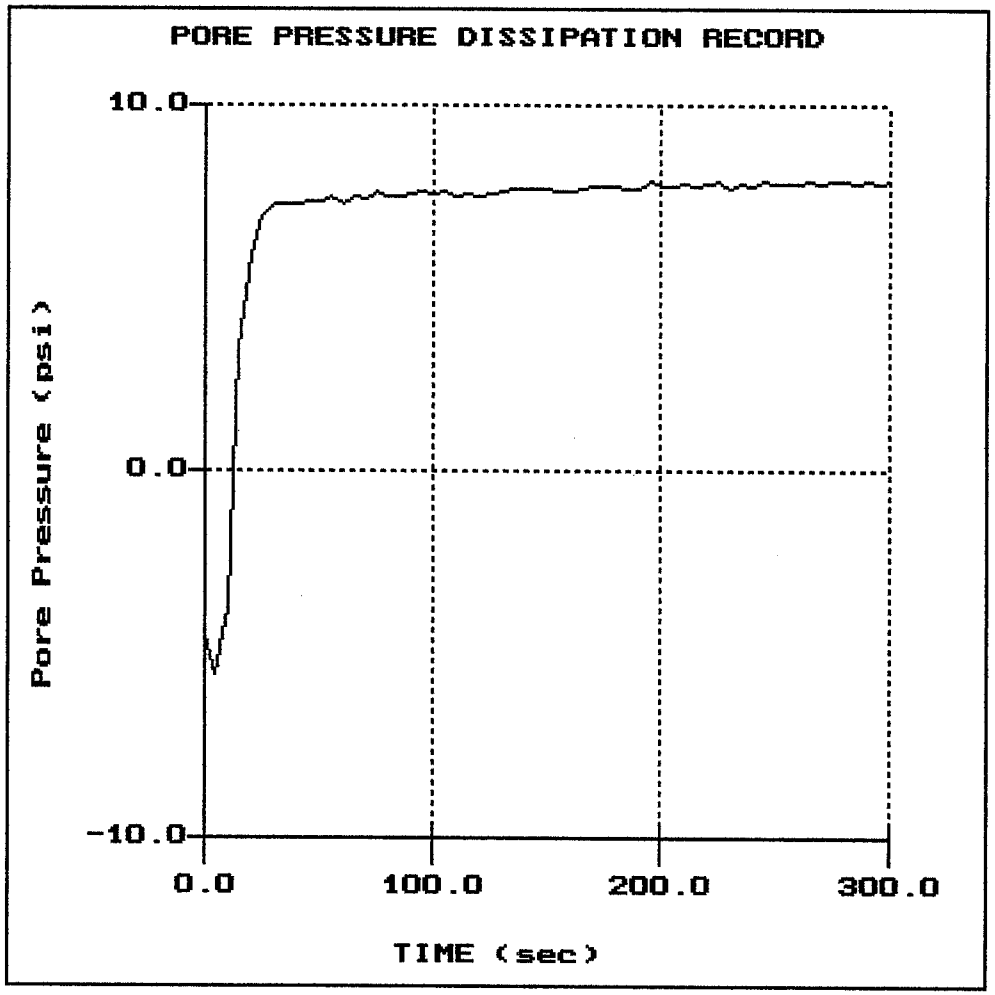


File: 027C01.PPC
Depth (m): 9.30
(ft): 30.51
Duration : 580.0s
U-min: -0.61 0.0s
U-max: 6.77 545.0s

CDM

Site: SHERWIN WILLIAMS
Location: CPT-02

Engineer: H. YOUNG
Date:01:29:03 09:33

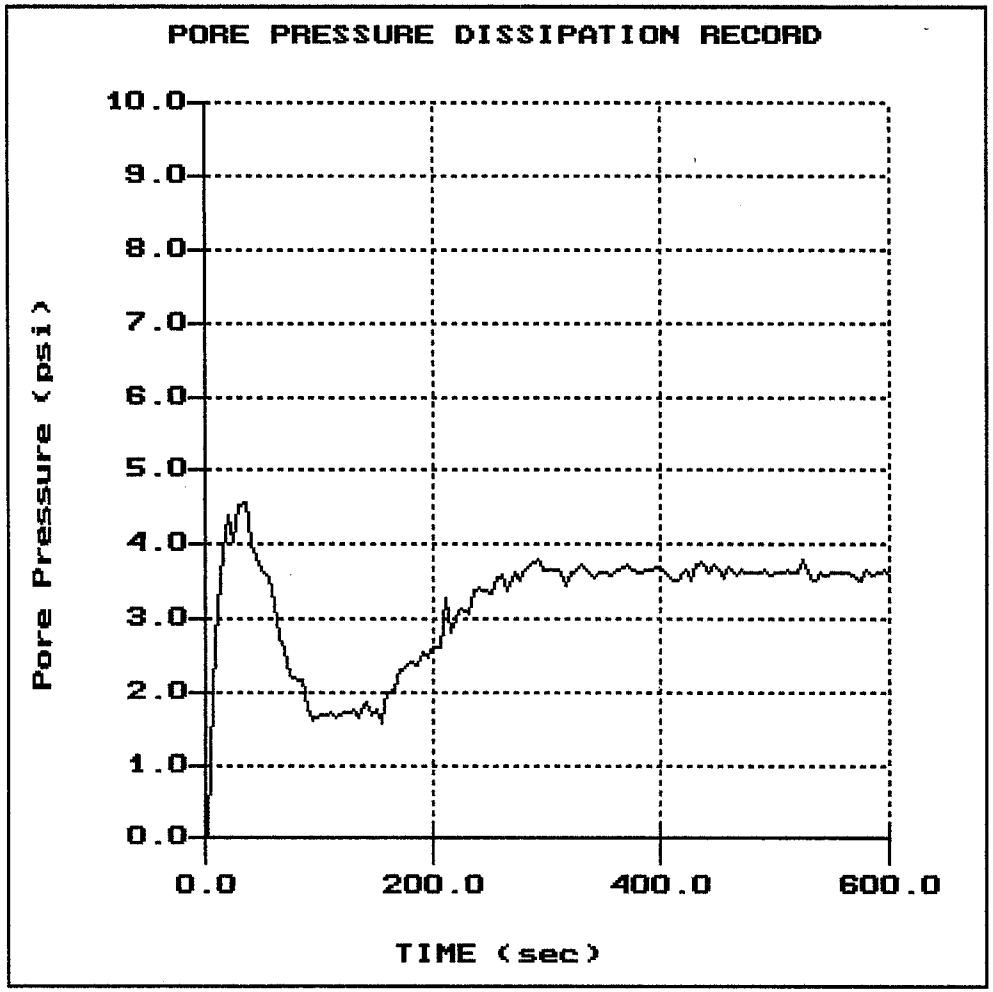


File: 027C02.PPC
Depth (m): 10.30
(ft): 33.79
Duration : 300.0s
U-min: -5.59 5.0s
U-max: 7.93 300.0s

CDM

Site: SHERWIN WILLIAMS
Location: CPT-04

Engineer: H. YOUNG
Date:01:28:03 08:29

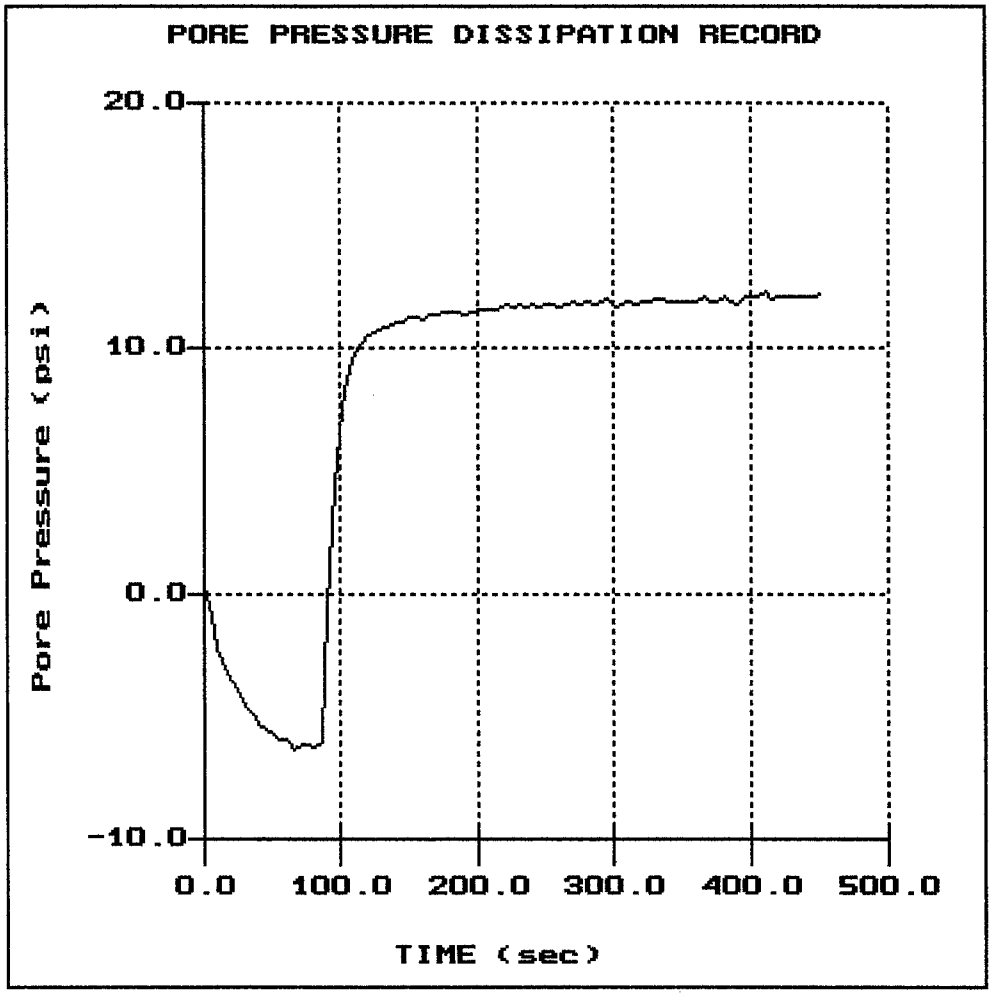


File: 027C04.PPC
Depth (m): 4.85
(ft): 15.91
Duration : 600.0s
U-min: -4.41 0.0s
U-max: 4.54 35.0s

CDM

Site: SHERWIN WILLIAMS
Location: CPT-05

Engineer: H. YOUNG
Date:01:28:03 10:52



File: 027C05.PPC
Depth (m): 10.25
(ft): 33.63
Duration : 450.0s
U-min: -6.35 65.0s
U-max: 12.27 410.0s

GREGG IN SITU CPT Interpretations as of July 31, 2002 (Release 1.20c)

GREGG IN SITU's interpretation routine provides a tabular output of geotechnical parameters based on current published CPT correlations and is subject to change to reflect the current state of practice. The interpreted values are not considered valid for all soil types. The interpretations are presented only as a guide for geotechnical use and should be carefully scrutinized for consideration in any geotechnical design. Reference to current literature is strongly recommended. GREGG IN SITU, Inc. and GREGG DRILLING & TESTING Inc. do not warranty the correctness or the applicability of any of the geotechnical parameters interpreted by the program and can not assume liability for any use of the results in any design or review. Representative hand calculations should be made for any parameter that is critical for design purposes. The end user of the interpreted output should also be fully aware of the techniques and the limitations of any method used in this program. The purpose of this document is to inform the user as to which methods were used and what the appropriate papers and/or publications are for further reference.

The CPT interpretations are based on values of tip, sleeve friction and pore pressure averaged over a user specified interval (e.g. 0.20m). Note that q_t is the recorded tip value, q_c, corrected for pore pressure effects. Since all GREGG IN SITU cones have equal end area friction sleeves, pore pressure corrections to sleeve friction, Fs, are not required.

The tip correction is: $q_t = q_c + (1-a) \bullet u_2$

where: q_t is the corrected tip resistance
q_c is the recorded tip resistance
u_2 is the recorded dynamic pore pressure behind the tip (u_2 position)
a is the Net Area Ratio for the cone (typically 0.85 for GREGG IN SITU cones)

The total stress calculations are based on soil unit weights that have been assigned to the Soil Behavior Type zones, from a user defined unit weight profile or by using a single value throughout the profile. Effective vertical overburden stresses are calculated based on a hydrostatic distribution of equilibrium pore pressures below the water table or from a user defined equilibrium pore pressure profile (this can be obtained from CPT dissipation tests). For over water projects the effects of the column of water have been taken in to account as has the appropriate unit weight of water. How this is done depends on where the instruments were zeroed (i.e. on deck or at mud line).

Details regarding the interpretation methods for all of the interpreted parameters are provided in Table 1. The appropriate references cited in Table 1 are listed in Table 2. Where methods are based on charts or techniques that are too complex to describe in this summary the user should reference to the cited references.

The estimated Soil Behavior Types (normalized and non-normalized) are based on the charts developed by Robertson and Campanella shown in Figures 1 and 2.

Where the results of a calculation/interpretation are declared *'invalid'* the value will be represented by the text strings "-9999" or "-9999.0". Invalid results will occur because of (and not limited to) one or a combination of:

1. Invalid or undefined CPT data (e.g. drilled out section or data gap).

2. Where the interpretation method is inappropriate, for example, drained parameters in an undrained material (and vice versa).

3. Where interpretation input values are beyond the range of the referenced charts or specified limitations of the interpretation method.

4. Where pre-requisite or intermediate interpretation calculations are invalid.

The parameters selected for output from the program are often specific to a particular project. As such, not all of the interpreted parameters listed in Table 1 may be included in the output files delivered with this report.

Table 1
CPT Interpretation Methods

Interpreted Parameter	Description	Equation	Ref
Depth	Mid Layer Depth *(where interpretations are done at each point then Mid Layer Depth = Recorded Depth)*	*Depth (Layer Top) + Depth (Layer Bottom) / 2.0*	
Elevation	Elevation of Mid Layer based on sounding collar elevation supplied by client	Elevation = Collar Elevation - Depth	
Avgqc	Averaged recorded tip value (q_c)	$Avgqc = \frac{1}{n}\sum_{i=1}^{n} q_c$ *n=1 when interpretations are done at each point*	
Avgqt	Averaged corrected tip (q_t) where: $q_t = q_c + (1-a) \bullet u$	$Avgqt = \frac{1}{n}\sum_{i=1}^{n} q_t$ *n=1 when interpretations are done at each point*	
Avgfs	Averaged sleeve friction (f_s)	$Avgfs = \frac{1}{n}\sum_{i=1}^{n} fs$ *n=1 when interpretations are done at each point*	
AvgRf	Averaged friction ratio (Rf) where friction ratio is defined as: $Rf = 100\% \bullet \frac{fs}{qt}$	$AvgRf = 100\% \bullet \frac{Avgfs}{Avgqt}$ *n=1 when interpretations are done at each point*	
Avgu	Averaged dynamic pore pressure *(u)*	$Avgu = \frac{1}{n}\sum_{i=1}^{n} u_i$ *n=1 when interpretations are done at each point*	
AvgRes	Averaged Resistivity (this data is not always available since it is a specialized test requiring an additional module)	$Avgu = \frac{1}{n}\sum_{i=1}^{n} RESISTIVITY_i$ *n=1 when interpretations are done at each point*	
AvgUVIF	Averaged UVIF ultra-violet induced fluorescence (this data is not always available since it is a specialized test requiring an additional module)	$Avgu = \frac{1}{n}\sum_{i=1}^{n} UVIF_i$ *n=1 when interpretations are done at each point*	
AvgTemp	Averaged Temperature (this data is not always available since it is a specialized test)	$Avgu = \frac{1}{n}\sum_{i=1}^{n} TEMPERATURE_i$ *n=1 when interpretations are done at each point*	
AvgGamma	Averaged Gamma Counts (this data is not always available since it is a specialized test requiring an additional module)	$Avgu = \frac{1}{n}\sum_{i=1}^{n} GAMMA_i$ *n=1 when interpretations are done at each point*	
SBT	Soil Behavior Type as defined by Robertson and Campanella	See Figure 1	2, 5
U.Wt.	Unit Weight of soil determined from one of the following user selectable options: 1) uniform value 2) value assigned to each SBT zone 3) user supplied unit weight profile	See references	5
T. Stress σ_v	Total vertical overburden stress at Mid Layer Depth. *A layer is defined as the averaging interval specified by the user. For data interpreted at each point the Mid Layer Depth is the same as the recorded depth.*	$TStress = \sum_{i=1}^{n} \gamma_i h_i$ *where* γ_i is layer unit weight h_i is layer thickness	

CPT Interpretations

Interpreted Parameter	Description	Equation	Ref
E. Stress σ_v'	Effective vertical overburden stress at Mid Layer Depth	*Estress = Tstress - u_{eq}*	
Ueq	Equilibrium pore pressure determined from one of the following user selectable options: 1) hydrostatic from water table depth 2) user supplied profile	For hydrostatic option: $u_{eq} = \gamma_w \bullet (D - D_{wt})$ where u_{eq} is equilibrium pore pressure γ_w is unit weight of water D is the current depth D_{wt} is the depth to the water table	
Cn	SPT N_{60} overburden correction factor	$Cn=(\sigma_v')^{-0.5}$ where σ_v' *is in tsf* $0.5 < C_n < 2.0$	
N_{60}	SPT N value at 60% energy calculated from qt/N ratios assigned to each SBT zone. This method has abrupt N value changes at zone boundaries.	*See Figure 1*	4, 5
N_{60} (Ic)	SPTN Value at 60% energy. This method is a slight modification of the Jefferies and Davies technique whereby the qt/N ratio varies across soil classification zones based on the Ic parameter. This techniques is limited to zones 2 through 7 on the normalized Soil Behavior Type Chart	*See Figure 1*	5, 8
$(N_1)_{60}$	SPT N_{60} value corrected for overburden pressure	$(N_1)_{60} = Cn \bullet N_{60}$	4
$\Delta(N_1)_{60}$	Equivalent Clean Sand Correction to $(N_1)_{60}$	$\Delta(N_1)_{60} = \frac{K_{SPT}}{1 - K_{SPT}} \bullet (N_1)_{60}$ Where: K_{SPT} is defined as: 0.0 for FC < 5% 0.0167 • (FC - 5) for 5% < FC < 35% 0.5 for FC > 35% FC - Fines Content in %	4
$(N_1)_{60cs}$	Equivalent Clean Sand $(N_1)_{60}$	$(N1)_{60cs} = (N1)_{60} + \Delta(N1)_{60}$	4
Su	Undrained shear strength - N_{kt} is user selectable	$Su = \frac{qt - \sigma_v}{N_{kt}}$	1, 5
k	Coefficient of permeability (assigned to each SBT zone)		5
Bq	Pore pressure parameter	$Bq = \frac{\Delta u}{qt - \sigma_v}$ *where:* $\Delta u = u - u_{eq}$ *and u = dynamic pore pressure* *u_{eq} = equilibrium pore pressure*	1, 5
Q_t	Normalized q_t for Soil Behavior Type classification as defined by Robertson, 1990	$Qt = \frac{qt - \sigma_v}{\sigma_v'}$	2, 5
F_r	Normalized Friction Ratio for Soil Behavior Type classification as defined by Robertson, 1990	$Fr = 100\% \bullet \frac{fs}{qt - \sigma_v}$	2, 5
SBTn	Normalized Soil Behavior Type as defined by Robertson and Campanella	See Figure 2	2, 5

CPT Interpretations

Interpreted Parameter	Description	Equation	Ref
q_{c1}	q_t normalized for overburden stress used for seismic analysis	$q_{c1} = q_t \bullet (Pa/\sigma_v')^{0.5}$ where: Pa = atm. Pressure q_t is in MPa	3
q_{c1N}	q_{c1} in dimensionless form used for seismic analysis	$q_{c1N} = q_{c1} / Pa$ where: Pa = atm. pressure	3
K_c	Equivalent clean sand correction for q_{c1N}	*$K_c = 1.0$ for $I_c \leq 1.64$* *$K_c = f(I_c)$ for $I_c > 1.64$ (see reference)* *$K_c = 1.0$ for $1.64 < I_c < 2.36$ and $Fc < 0.5\%$*	3
q_{c1Ncs}	Clean Sand equivalent q_{c1N}	$q_{c1Ncs} = q_{c1N} \bullet K_c$	3
I_c	Soil index for estimating grain characteristics	$Ic = [(3.47 - \log_{10}Q)^2 + (\log_{10} Fr + 1.22)^2]^{0.5}$ *Where:* $Q = \left(\frac{qt - \sigma_v}{P_{a2}}\right)\left(\frac{P_a}{\sigma_v'}\right)^n$ *And* *Fr is in percent* *P_a = atmospheric pressure* *P_{a2} = atmospheric pressure* *n varies from 0.5 to 1.0 and is selected in an iterative manner based on the resulting I_c*	3, 8
FC	Apparent fines content (%)	*$FC = 1.75(Ic^{3.25}) - 3.7$* *$FC = 100$ for $Ic > 3.5$* *$FC = 0$ for $Ic < 1.26$* *$FC = 5\%$ if $1.64 < Ic < 2.6$ AND $F_r < 0.5$*	3
Ic Zone	This parameter is the Soil Behavior Type zone based on the Ic parameter (valid for zones 2 through 7 on SBTn chart)	Ic < 1.31 Zone = 7 1.31 < Ic < 2.05 Zone = 6 2.05 < Ic < 2.60 Zone = 5 2.60 < Ic < 2.95 Zone = 4 2.95 < Ic < 3.60 Zone = 3 Ic > 3.60 Zone = 2	3
PHI ϕ	Friction Angle determined from one of the following user selectable options: a) Campanella and Robertson b) Durgunoglu and Mitchel c) Janbu	See reference	5
Dr	Relative Density determined from one of the following user selectable options: a) Ticino Sand b) Hokksund Sand c) Schmertmann 1976 d) Jamiolkowski - All Sands	See reference	5
OCR	Over Consolidation Ratio – 2 methods available	a) Based on Schmertmann's method involving a plot of $S_u/\sigma_v' / (S_u/\sigma_v')_{NC}$ and OCR b) Based on $OCR = K \bullet \left(\frac{qt - \sigma_v}{\sigma_v'}\right)$ where an average value of k=0.3 is used	5
State Parameter	The state parameter is used to describe whether a soil is contractive (SP is positive) or dilative (SP is negative) at large strains based on the work by Been and Jefferies	See reference	9, 7, 5

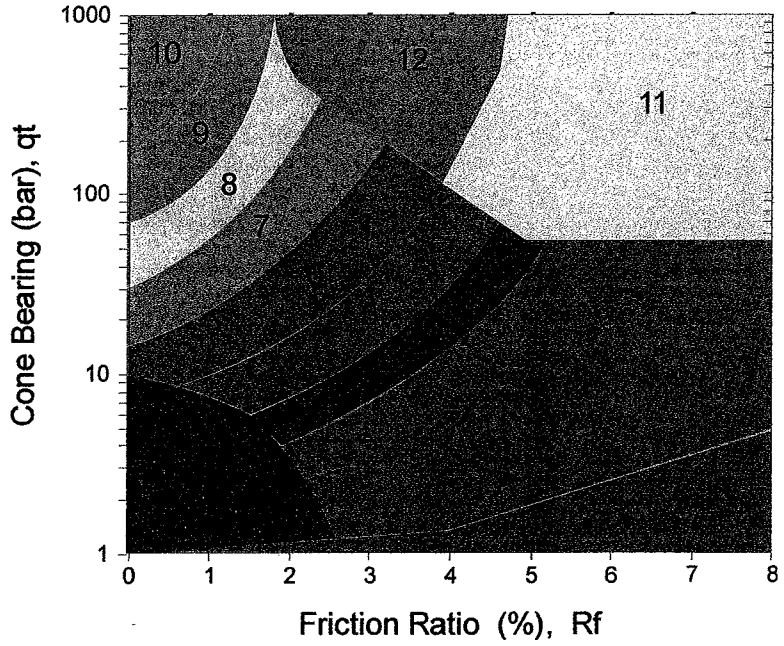
CPT Interpretations

Interpreted Parameter	Description	Equation	Ref
CRR	Cyclic Resistance Ratio (for M=7.5)	*For* $(q_{c1N})_{cs} < 160$: $CRR = 93 \bullet \left(\frac{(q_{c1N})cs}{1000}\right)^3 + 0.08$ *For* $(q_{c1N})_{cs} < 50$: $CRR = 0.833 \bullet \left(\frac{(q_{c1N})cs}{1000}\right)^3 + 0.05$	5
Youngs Modulus E	Youngs Modulus based on the work by Baldi. There are three types of sands considered in this technique. The user selects the approriate type for the site from: a) OC Sands b) Aged NC Sands c) Recent NC Sands Each sand type has a family of curves that depend on mean normal stress. The program calculates mean normal stress and linearly interpolates between the two extremes provided in Baldi's chart.	Mean normal stress is evaluated from: $\sigma'_m = \frac{1}{3} \bullet (\sigma'_v + \sigma'_h + \sigma'_h)$ where σ_v'= vertical effective stress σ_h'= horizontal effective stress and $\sigma_h = K_o * \sigma_v'$ with Ko assumed to be 0.5	5
K_o	Coefficient of lateral earth pressure at rest.	$K_o = 0.1 \bullet \left(\frac{q_t - \sigma_{v0}}{\sigma'_v}\right)$	5

Savannah River Site Specific Parameters

Interpreted Parameter	Description	Equation	Ref
Ic	Ic based on normalized data at the Savannah River Site; developed by Frank Syms and SGS	$Ic = [(1.95 - \log_{10}Q)^2 + (\log_{10} Fr + 1.78)^2]^{0.5}$ *Where: Q is the normalized tip resistance And Fr is the normalized friction ratio*	10
FC	Fines content based on the normalized Savannah River Site Ic parameter; developed by Frank Syms and SGS	$FC = (5.31 * (Ic)^{2.31}) + 9.61$ For FC > 100 and q_t < 15 tsf the material is flagged as a soft zone	10
FC	Fines Content directly from non-normalized data at the Savannah River Site; developed by Frank Syms and SGS	$FC = [(3.58 - \log_{10}(qtsf))^2 + (1.43 + \log_{10}(Rf))^2]^{1.8}$ For FC > 100 and q_t < 15 tsf the material is flagged as a soft zone *Where: qtsf is the non-normalized tip resistance in tsf Rf is the non-normalized friction ratio*	11

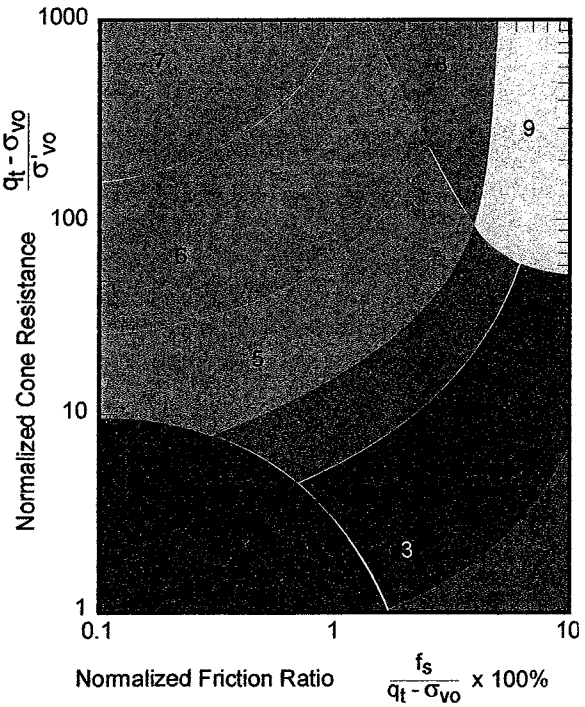
Figure 1
Non-Normalized Behavior Type Classification Chart



Zone	qt / N	Soil Behavior Type
1	2	sensitive fine grained
2	1	organic material
3	1	clay
4	1.5	silty clay to clay
5	2	clayey silt to silty clay
6	2.5	sandy silt to clayey silt
7	3	silty sand to sandy silt
8	4	sand to silty sand
9	5	sand
10	6	gravelly sand to sand
11	1	very stiff fine grained *
12	2	sand to clayey sand *

* overconsolidated or cemented

Figure 2
Normalized Behavior Type Classification Chart



Zone	Normalized Soil Behavior Type
1	sensitive fine grained
2	organic material
3	clay to silty clay
4	clayey silt to silty clay
5	silty sand to sandy silt
6	clean sands to silty sands
7	gravelly sand to sand
8	very stiff sand to clayey sand
9	very stiff fine grained

GREGG

Table 2
References

No.	References
1	Robertson, P.K., Campanella, R.G., Gillespie, D. and Greig, J., 1986, "Use of Piezometer Cone Data", Proceedings of InSitu 86, ASCE Specialty Conference, Blacksburg, Virginia.
2	Robertson, P.K., 1990, "Soil Classification Using the Cone Penetration Test", Canadian Geotechnical Journal, Volume 27.
3	Robertson, P.K. and Fear, C.E., 1998, "Evaluating cyclic liquefaction potential using the cone penetration test", Canadian Geotechnical Journal, 35: 442-459.
4	Robertson, P.K. and Wride, C.E., 1998, "Cyclic Liquefaction and its Evaluation Based on SPT and CPT", NCEER Workshop Paper, January 22, 1997
5	Lunne, T., Robertson, P.K. and Powell, J. J. M., 1997, " Cone Penetration Testing in Geotechnical Practice," Blackie Academic and Professional.
6	GREGG IN SITU Internal Report
7	Plewes, H.D., Davies, M.P. and Jefferies, M.G., 1992, "CPT Based Screening Procedure for Evaluating Liquefaction Susceptibility", 45th Canadian Geotechnical Conference, Toronto, Ontario, October 1992.
8	Jefferies, M.G. and Davies, M.P., 1993. "Use of CPTu to Estimate equivalent N_{60}", Geotechnical Testing Journal, 16(4): 458-467.
9	Been, K. and Jefferies, M.P., 1985, "A state parameter for sands", Geotechnique, 35(2), 99-112.
10	Frank Syms, Bechtel Corp (Savannah River Site), 2001, "CPTU Fines Content Determination", Calculation No. K-CIC-G-00065 Revision 0.
11	Frank Syms, Bechtel Corp (Savannah River Site) – personal communication

Appendix C
Geotechnical Laboratory Test Results

SMITH-EMERY COMPANY
The Full Service Independent Testing Laboratory, Established 1904

Hunters Point Shipyard, Bldg. 114
P. O. Box 880550
San Francisco, California 94188
(415) 330-3000 Fax (415) 330-3030

GEOSERVICES DIVISION

791 East Washington Blvd.
Los Angeles, California 90021-3043
(213) 749-3411
Fax (213) 746-7228

MAR 1 3 2003

March 11, 2003

SECo File No. 2058
SECo Report No. 03-135

One Walnut Creek Center
100 Pringle Avenue, Sulte 300
Walnut Creek, California 94596

Attn: Mr. Michael Gray

Re: CDM Project No. 13452-35952-TK16.Design
Sherwin-Williams SB-11 and SB-12

SUBJECT: REPORT OF TESTS

TEST STANDARDS: ASTM D2216 (Moisture Content), ASTM D2937 (Dry Unit Weight), ASTM D4318 (Atterberg Limits), ASTM D422 (Sieve Analysis), ASTM D3080 (Direct Shear Test), and ASTM D2435 (Consolidation Test)

SOURCE: Soil boring samples from the Sherwin-Williams Geotechnical Investigation were submitted to our laboratory by your representative on February 6, 2003.

REPORT OF TESTS

In compliance with the request of your authorized representative, we have conducted the subject tests, as per your requirements for the above referenced project. Test results for the moisture content, dry unit weight, and Atterberg Limits are presented on the following table. The Sieve Analysis, Atterberg Limits, Direct Shear, and Consolidation test results/graphs are attached.

Respectfully submitted,
SMITH-EMERY COMPANY

Patrick Morrison

PATRICK MORRISON, R.G. #7174
Registered Geologist
Geoservices Division Manager, SF

Attachments: Sieve Analysis, Atterberg Limits, Direct Shear, and Consolidation test results/graphs

Cc: 2-Addressee

ALL REPORTS ARE SUBMITTED AS THE CONFIDENTIAL PROPERTY OF CLIENTS. AUTHORIZATION FOR PUBLICATION OF OUR REPORT, CONCLUSIONS, OR EXTRACTS FROM OR REGARDING THEM IS RESERVED PENDING OUR WRITTEN APPROVAL AS A MUTUAL PROTECTION TO CLIENTS, THE PUBLIC AND OURSELVES.

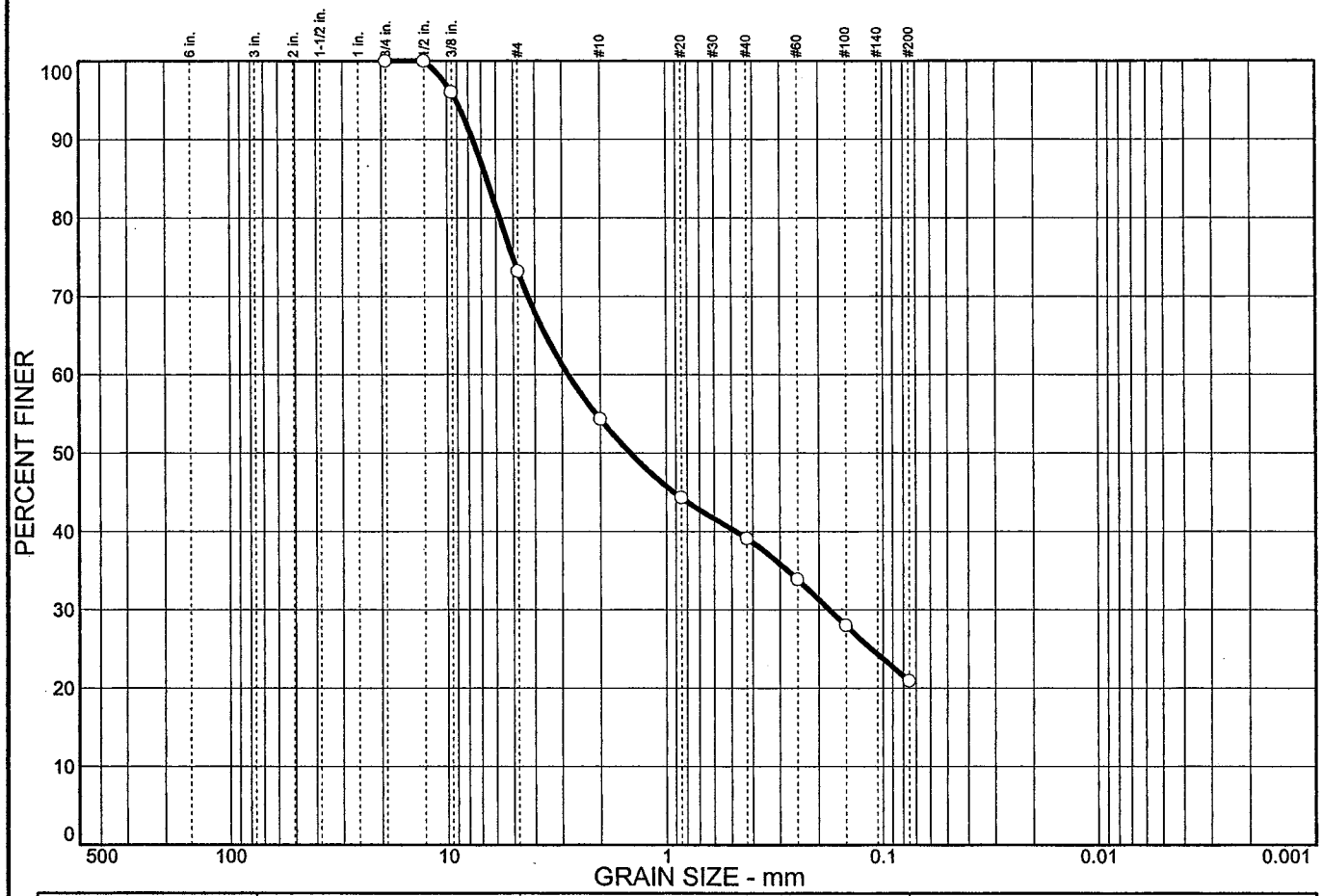
Re: CDM Project No. 13452-35952-TK16.Design
Sherwin Williams SB-11 and SB-12

REPORT OF TESTS

Boring No.	Depth (ft)	Dry Unit Weight (pcf)	Moisture Content (%)	Liquid Limit	Plastic Limit	Plasticity Index	Reports/Graphs Attached
SB-11	18.5	--	--	34	15	19	Plasticity Chart, Direct Shear
SB-11	21	--	--	--	--	--	Sieve Analysis
SB-11	25	97.6	25.0	--	--	--	--
SB-11	27	--	--	30	14	16	Plasticity Chart, Direct Shear
SB-11	30	--	--	--	--	--	Sieve Analysis
SB-11	35	102.6	24.2	--	--	--	Consolidation
SB-11	40			36	16	20	Plasticity Chart
SB-11	45	113.3	18.0	33	15	18	Plasticity Chart, Direct Shear
SB-11	55	118.9	16.2	--	--	--	--
SB-11	65	--	--	39	20	19	Plasticity Chart, Consolidation
SB-12	15	--	--	31	15	16	Plasticity Chart, Direct Shear
SB-12	25	--	--	46	13	33	Plasticity Chart, Consolidation
SB-12	30	--	--	49	22	27	Plasticity Chart, Direct Shear
SB-12	35	--	--	--	--	--	Sieve Analysis
SB-12	40	111.0	18.5	--	--	--	Consolidation
SB-12	45	--	--	33	15	18	Plasticity Chart
SB-12	60	99.8	25.8	70	16	54	Plasticity Chart
SB-12	65	--	--	47	16	31	Plasticity Chart
SB-12	70	114.3	17.5	--	--	--	--

SIEVE ANALYSIS RESULTS / GRAPHS

Particle Size Distribution Report



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	26.8	18.9	15.2	18.2	20.9	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
.75 in.	100.0		
.50 in.	100.0		
.375 in.	96.0		
#4	73.2		
#10	54.3		
#20	44.3		
#40	39.1		
#60	33.9		
#100	28.0		
#200	20.9		

* (no specification provided)

Soil Description

Gray clayey gravelly Sand

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 6.60 D_{60}= 2.82 D_{50}= 1.46
D_{30}= 0.179 D_{15}= D_{10}=
C_u= C_c=

Classification

USCS= SM AASHTO=

Remarks

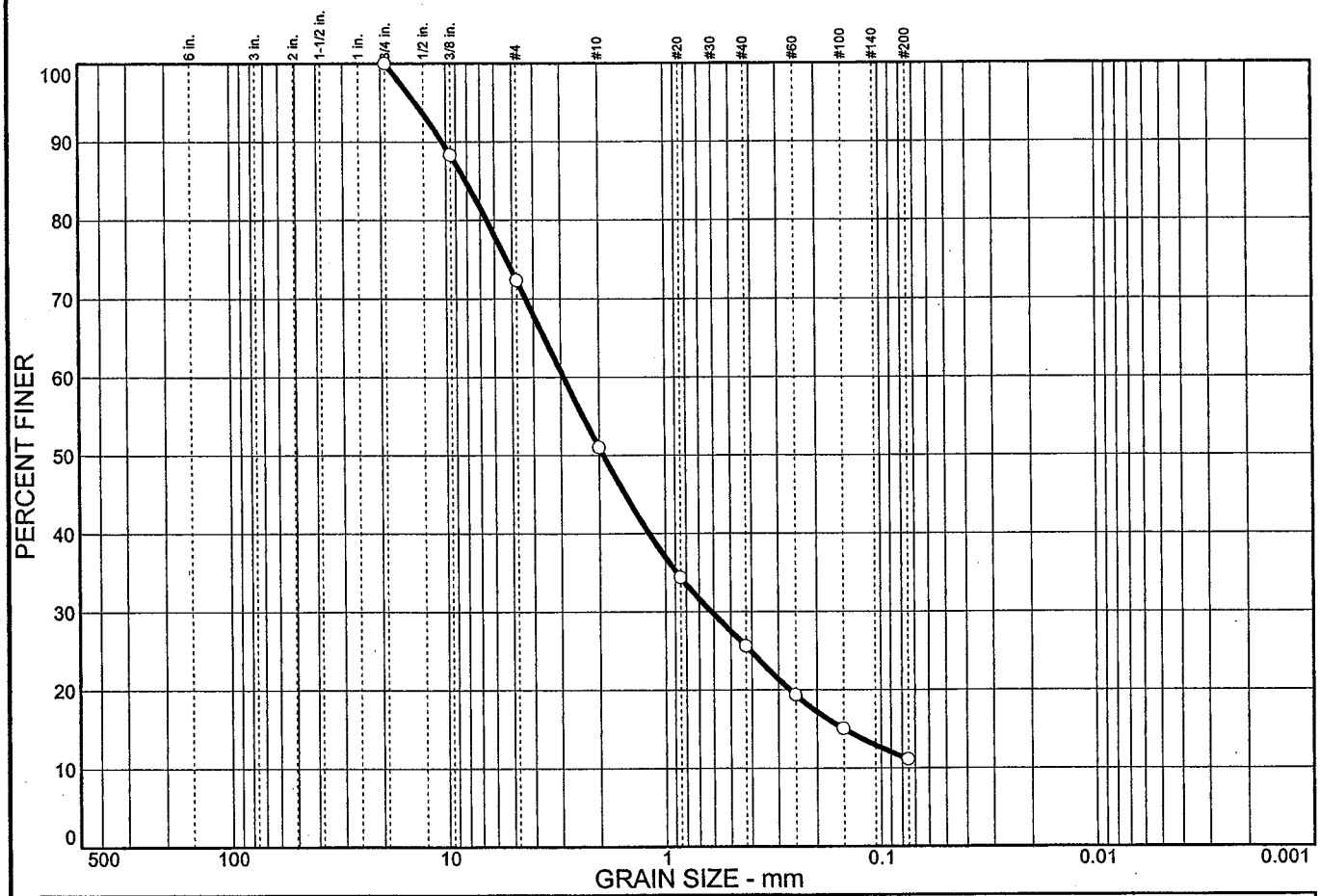
Sample No.: SB-11 **Source of Sample:** CDM-Sherwin Williams **Date:** 2-24-03
Location: **Elev./Depth:** 21

Smith-Emery Company

Client: CDM Inc.
Project: Sherwin Williams (CDM Project No. 13452-35952-TK16.Design)

Project No: 2058-2 **Plate** 1

Particle Size Distribution Report



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	27.7	21.3	25.4	14.5	11.1	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
.75 in.	100.0		
.375 in.	88.3		
#4	72.3		
#10	51.0		
#20	34.4		
#40	25.6		
#60	19.3		
#100	15.0		
#200	11.1		

* (no specification provided)

Soil Description

Brown gravelly Sand with silt

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 8.12 D_{60}= 2.91 D_{50}= 1.91
D_{30}= 0.614 D_{15}= 0.150 D_{10}=
C_u= C_c=

Classification

USCS= SP-SM AASHTO=

Remarks

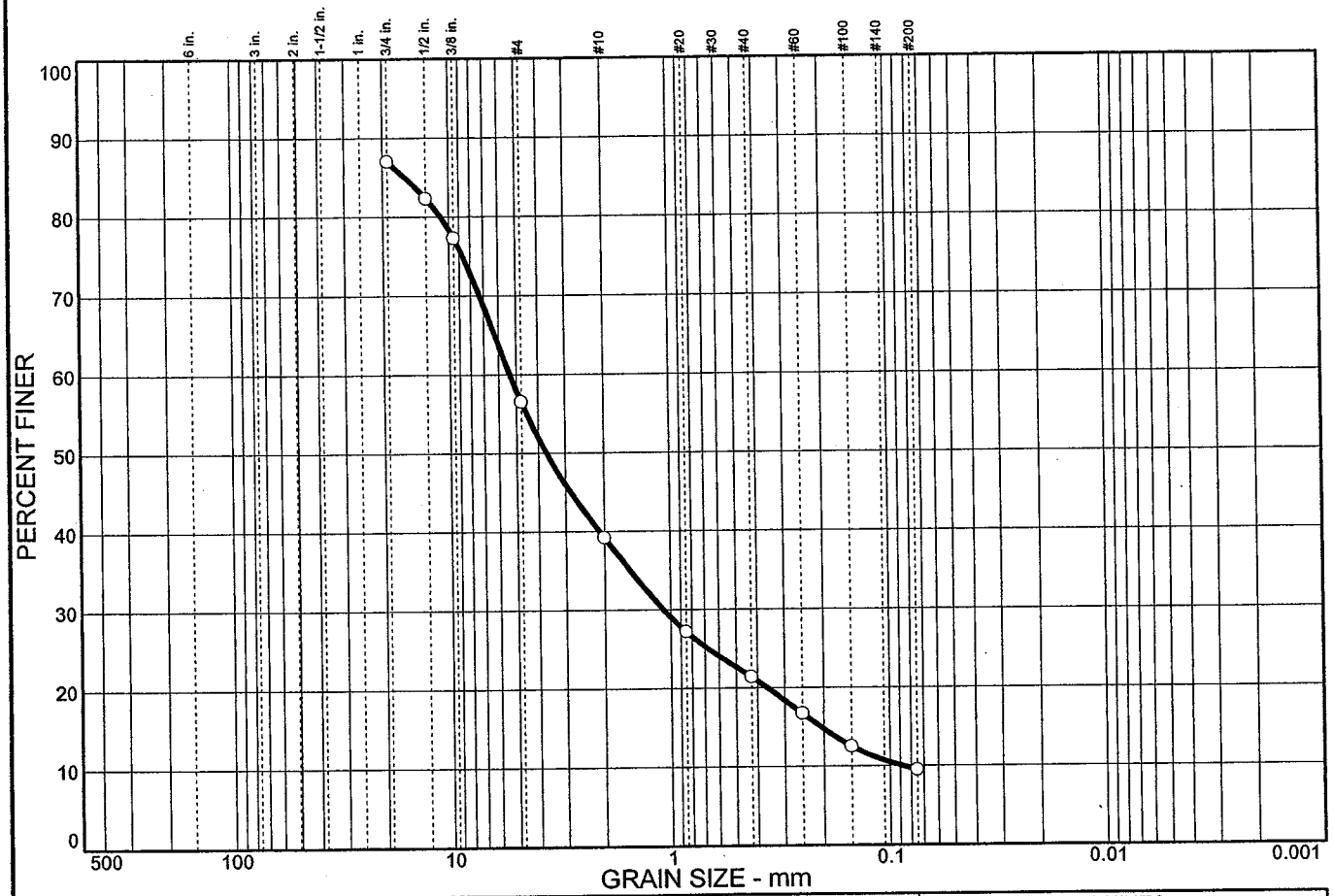
Sample No.: SB-11 **Source of Sample:** CDM-Sherwin Williams **Date:** 2-24-03
Location: **Elev./Depth:** 30

Smith-Emery Company

Client: CDM Inc.
Project: Sherwin Williams (CDM Project No. 13452-35952-TK16.Design)

Project No: 2058-2 **Plate** 2

Particle Size Distribution Report



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
		30.5	17.3	17.8	11.9	9.5	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
.75 in.	87.0		
.50 in.	82.3		
.375 in.	77.3		
#4	56.5		
#10	39.2		
#20	27.2		
#40	21.4		
#60	16.7		
#100	12.5		
#200	9.5		

* (no specification provided)

Soil Description

Brown gravelly Sand with silt

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 15.8 D_{60}= 5.34 D_{50}= 3.66
D_{30}= 1.08 D_{15}= 0.207 D_{10}= 0.0874
C_u= 61.12 C_c= 2.48

Classification

USCS= SW-SM AASHTO=

Remarks

Sample No.: SB-12 **Source of Sample:** CDM-Sherwin Williams **Date:** 2-24-03
Location: **Elev./Depth:** 35

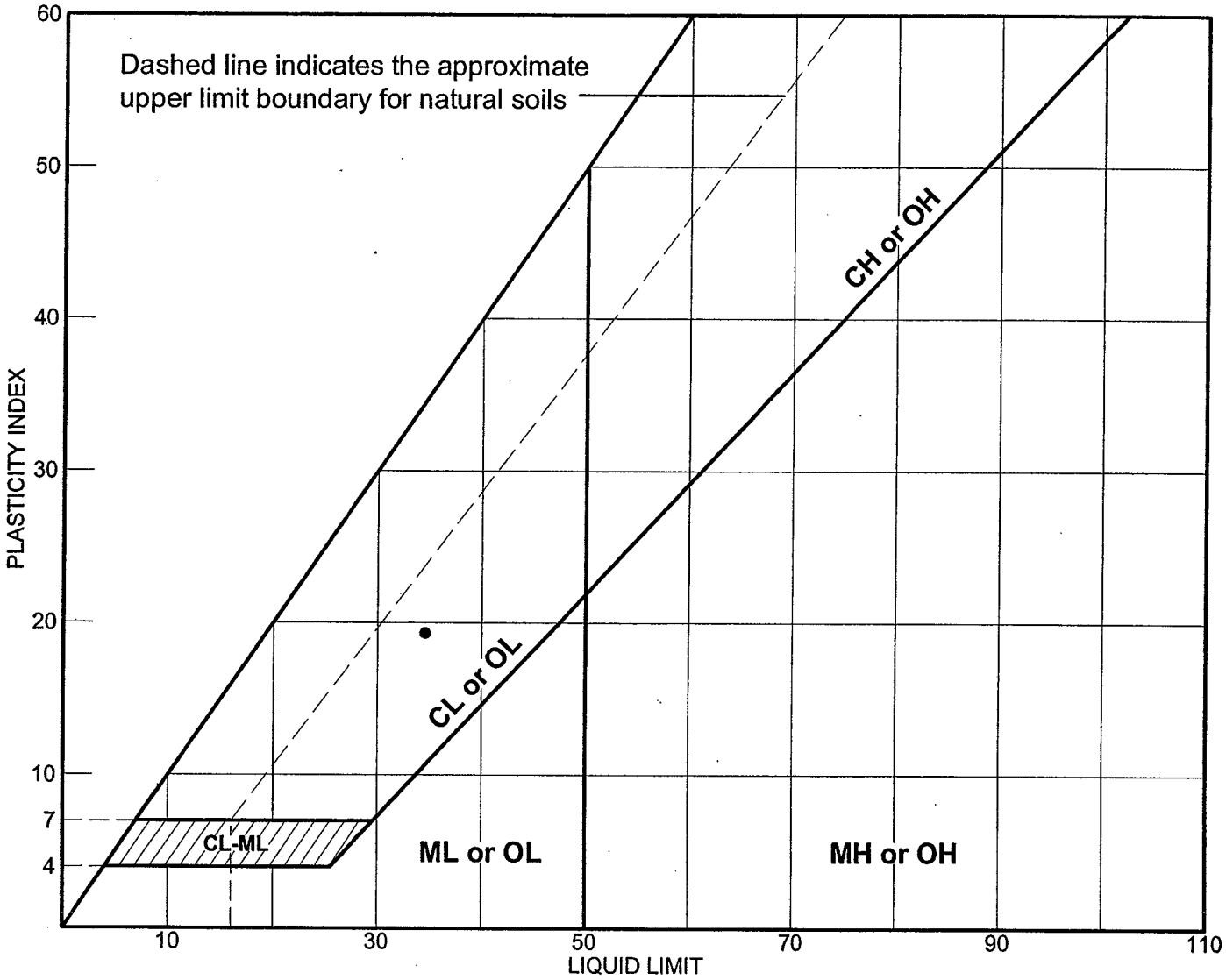
Smith-Emery Company

Client: CDM Inc.
Project: Sherwin Williams (CDM Project No. 13452-35952-TK16.Design)

Project No: 2058-2 **Plate** 3

ATTERBERG LIMITS PLASTICITY CHARTS

LIQUID AND PLASTIC LIMITS TEST REPORT



SOIL DATA								
SYMBOL	SOURCE	SAMPLE NO.	DEPTH (ft.)	NATURAL WATER CONTENT (%)	PLASTIC LIMIT (%)	LIQUID LIMIT (%)	PLASTICITY INDEX (%)	USCS
●	CDM-Sherwin Williams	SB-11	18.5		15.3	34.6	19.3	

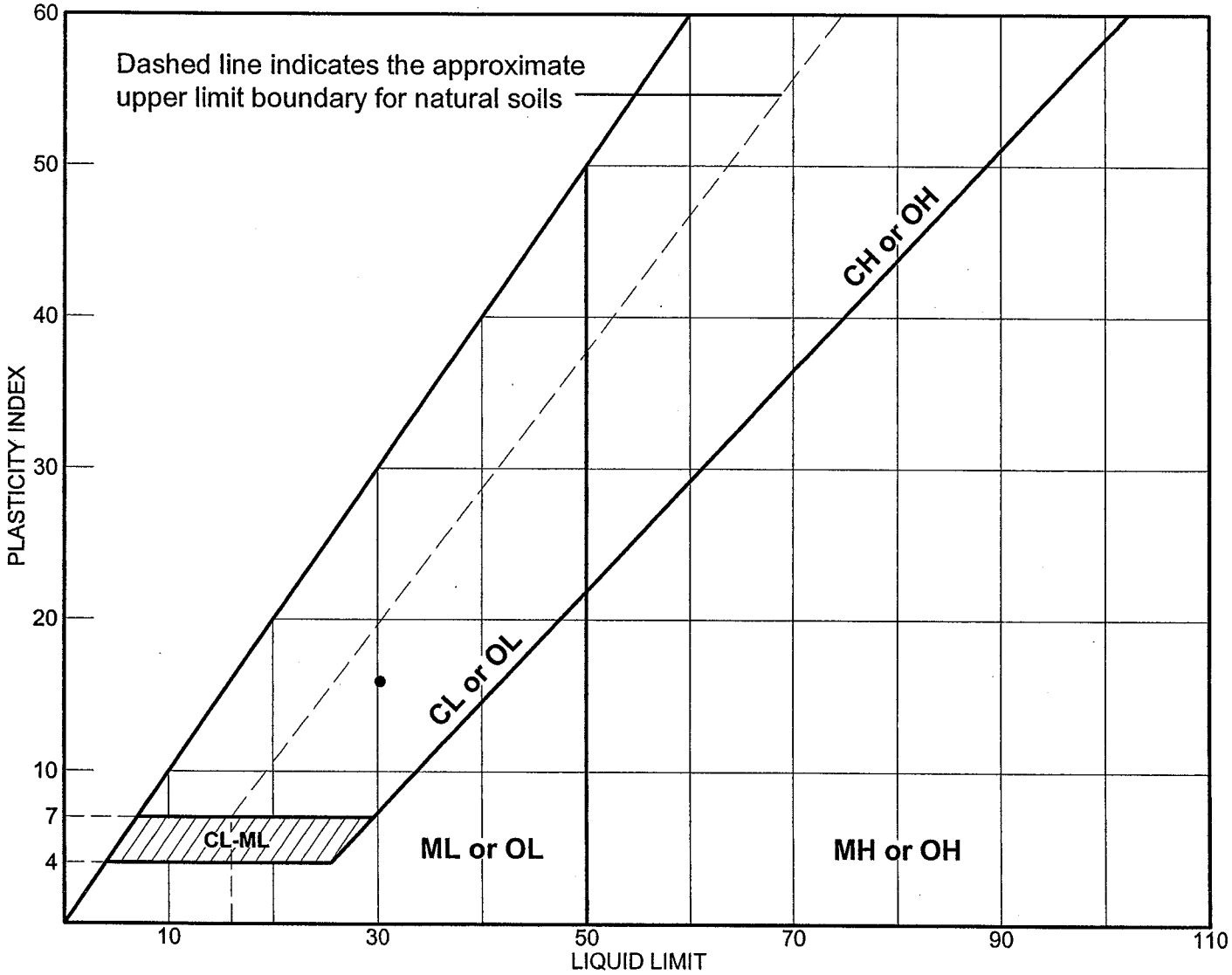
Smith-Emery Company

Client: CDM Inc.

Project: Sherwin Williams (CDM Project No. 13452-35952-TK16.Design)

Project No.: 2058-2 **Plate** 4

LIQUID AND PLASTIC LIMITS TEST REPORT



SOIL DATA								
SYMBOL	SOURCE	SAMPLE NO.	DEPTH (ft.)	NATURAL WATER CONTENT (%)	PLASTIC LIMIT (%)	LIQUID LIMIT (%)	PLASTICITY INDEX (%)	USCS
●	CDM-Sherwin Williams	SB-11	27		14.4	30.3	15.9	

Smith-Emery Company

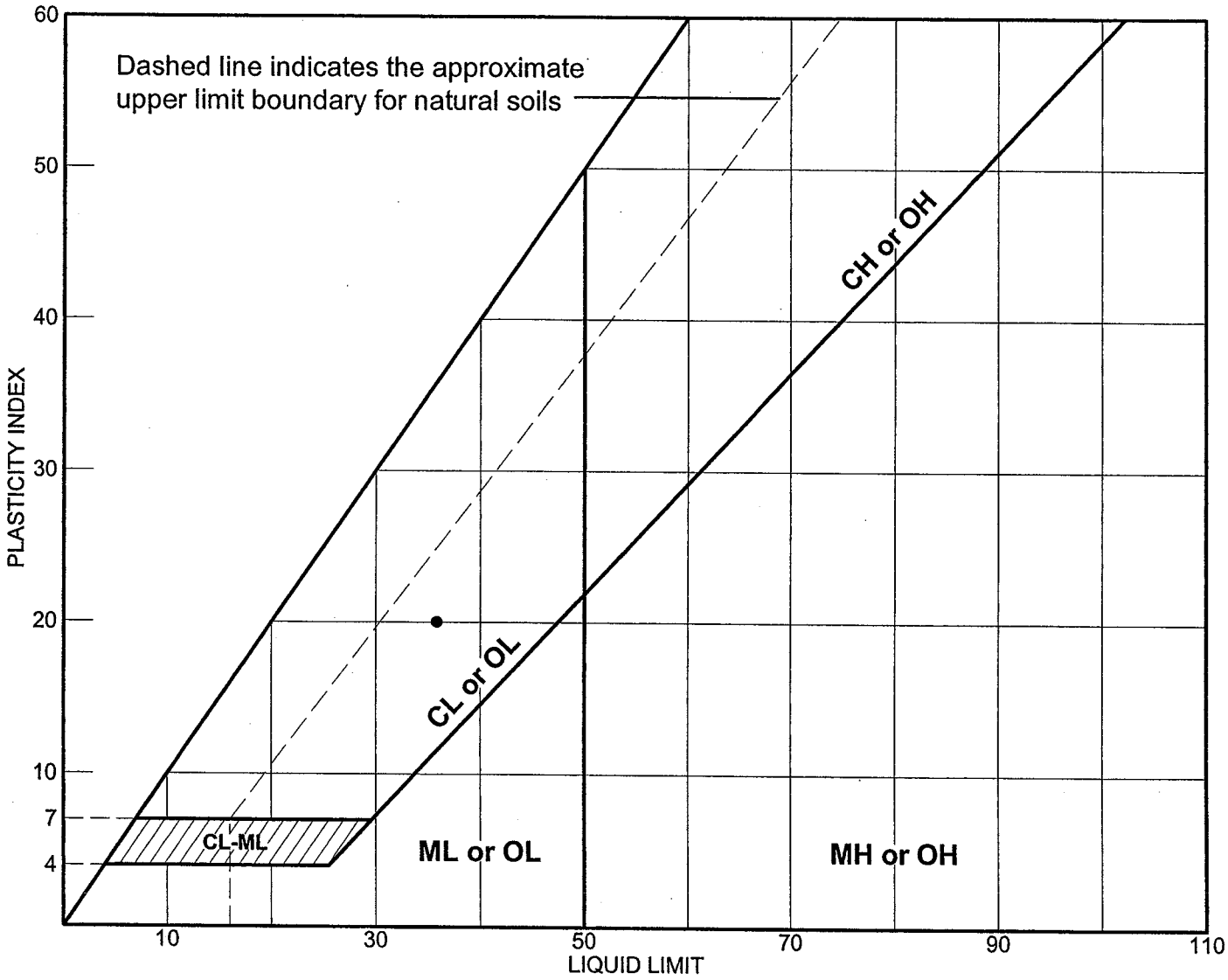
Client: CDM Inc.

Project: Sherwin Williams (CDM Project No. 13452-35952-TK16.Design)

Project No.: 2058-2

Plate 5

LIQUID AND PLASTIC LIMITS TEST REPORT



SOIL DATA								
SYMBOL	SOURCE	SAMPLE NO.	DEPTH (ft.)	NATURAL WATER CONTENT (%)	PLASTIC LIMIT (%)	LIQUID LIMIT (%)	PLASTICITY INDEX (%)	USCS
●	CDM-Sherwin Williams	SB-11	40		15.9	35.9	20.0	

Smith-Emery Company

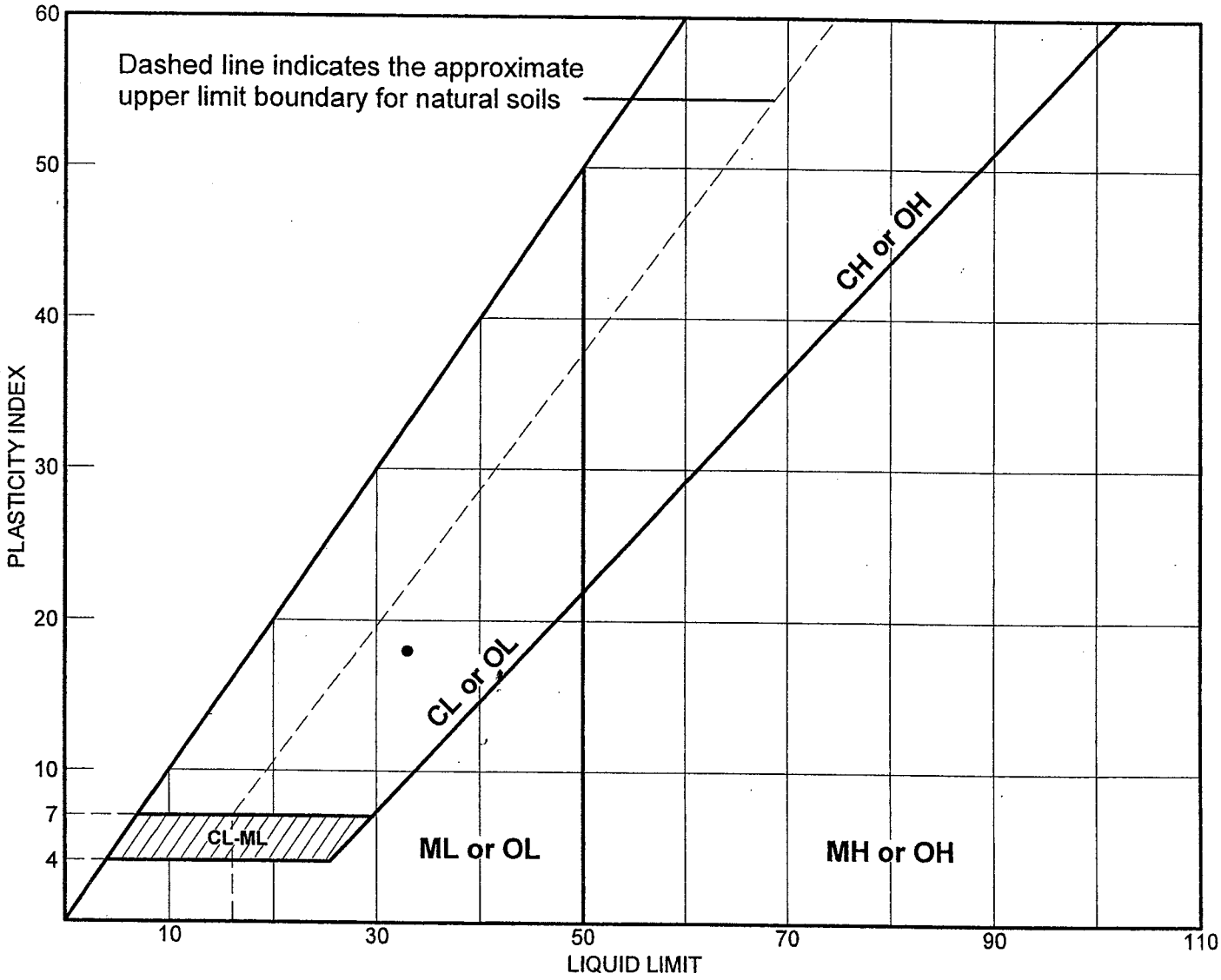
Client: CDM Inc.

Project: Sherwin Williams (CDM Project No. 13452-35952-TK16.Design)

Project No.: 2058-2

Plate 6

LIQUID AND PLASTIC LIMITS TEST REPORT



SOIL DATA								
SYMBOL	SOURCE	SAMPLE NO.	DEPTH (ft.)	NATURAL WATER CONTENT (%)	PLASTIC LIMIT (%)	LIQUID LIMIT (%)	PLASTICITY INDEX (%)	USCS
●	Sherwin	SB11-45	45 ft.		15	33	18	CL

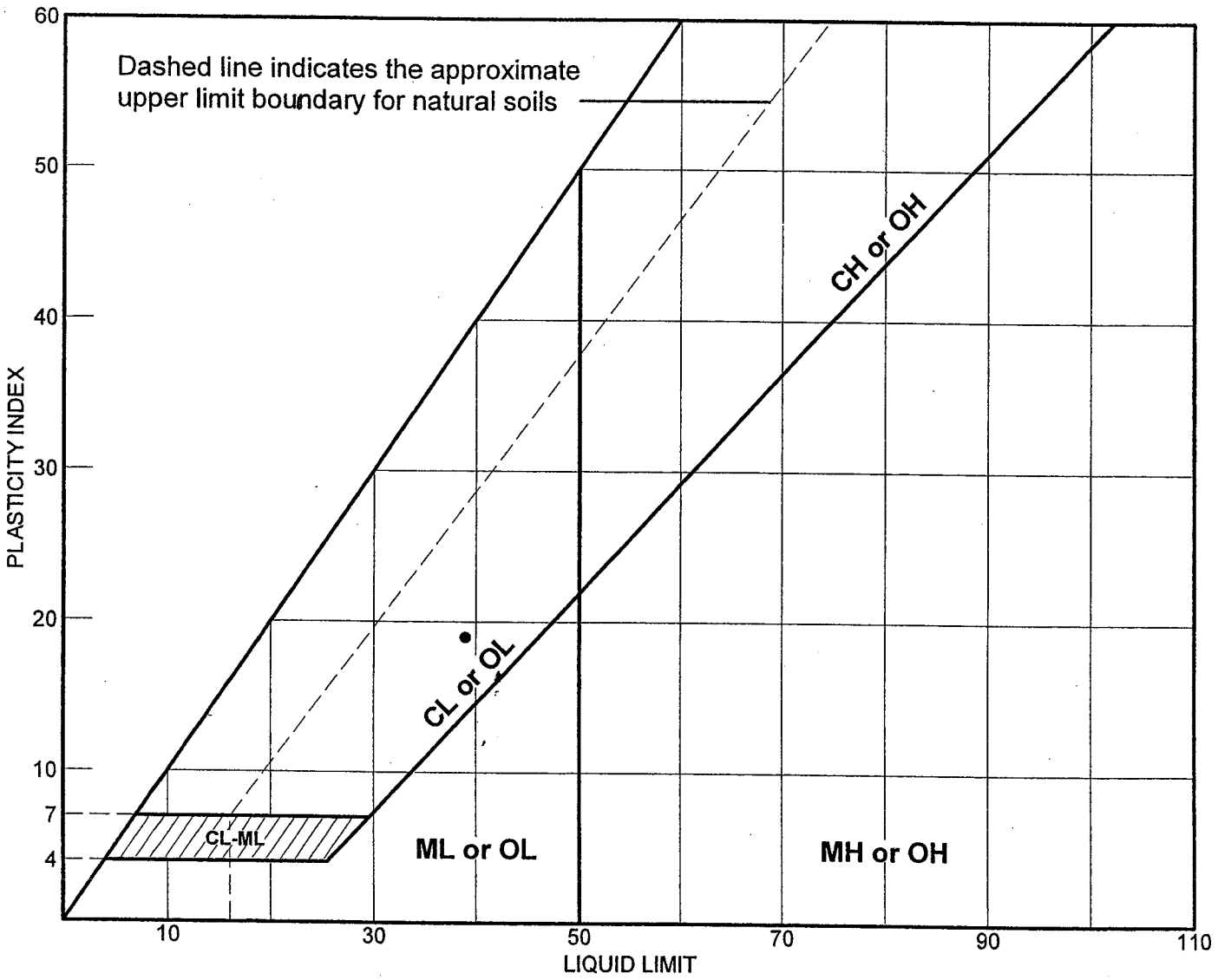
Smith-Emery Company

Client: SHERWIN WILLIAMS
Project: 13452-35952-TK16.DESIGN

Project No.: 2058-2

Plate 7

LIQUID AND PLASTIC LIMITS TEST REPORT



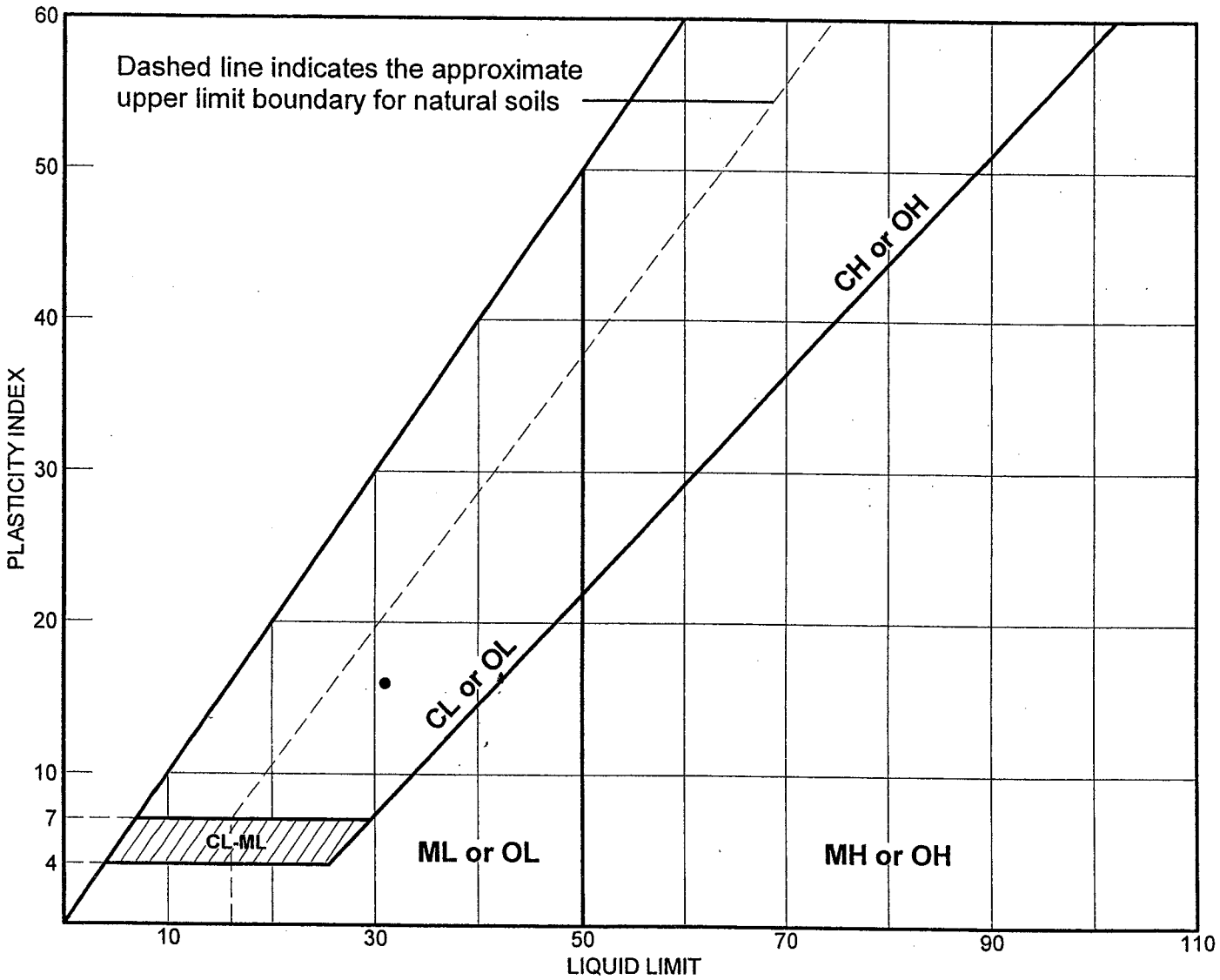
SOIL DATA								
SYMBOL	SOURCE	SAMPLE NO.	DEPTH (ft.)	NATURAL WATER CONTENT (%)	PLASTIC LIMIT (%)	LIQUID LIMIT (%)	PLASTICITY INDEX (%)	USCS
●	Sherwin	SB11-65	65 ft.		20	39	19	CL

Smith-Emery Company

Client: SHERWIN WILLIAMS
Project: 13452-35952-TK16.DESIGN

Project No.: 2058-2 **Plate** 8

LIQUID AND PLASTIC LIMITS TEST REPORT



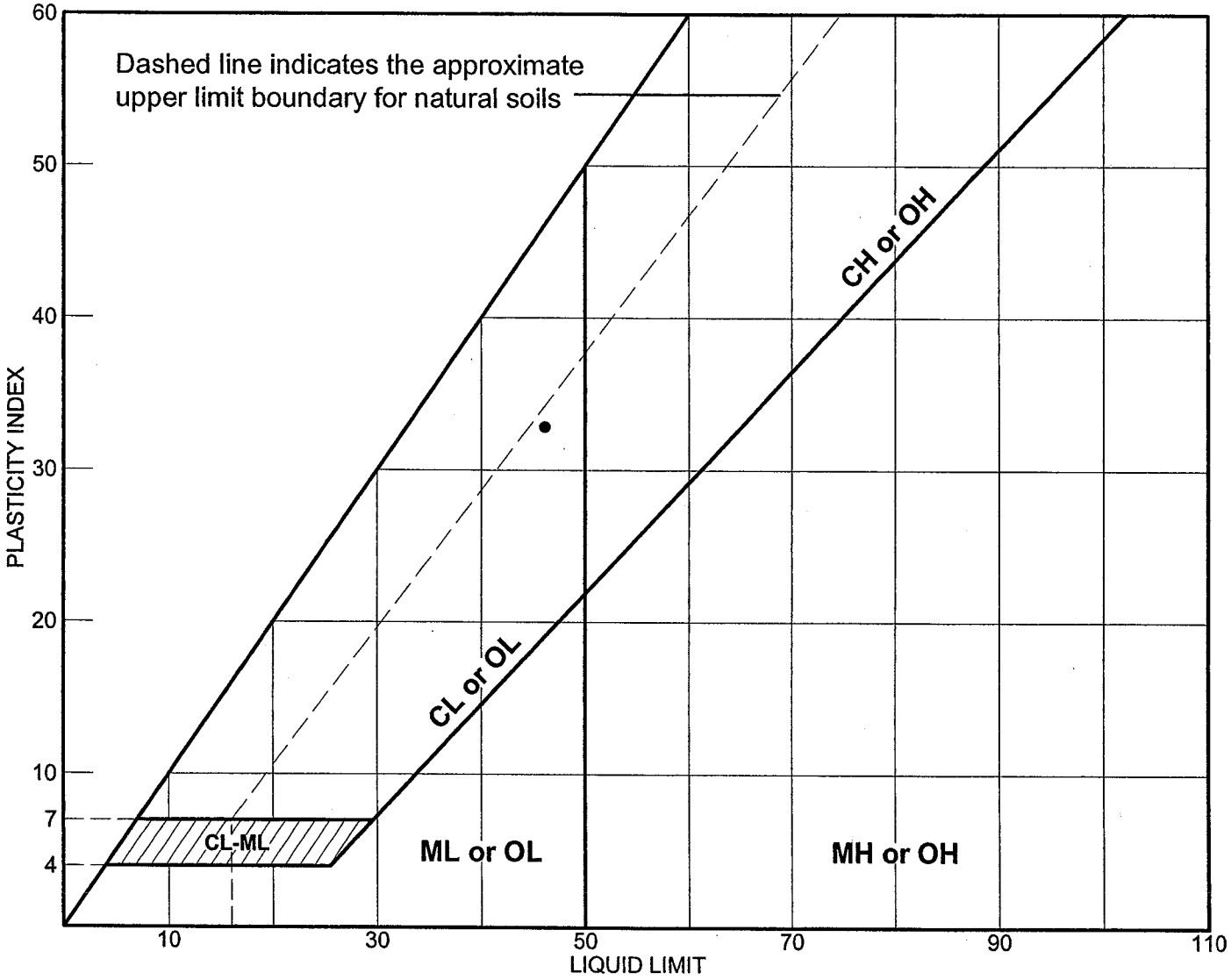
SOIL DATA								
SYMBOL	SOURCE	SAMPLE NO.	DEPTH (ft.)	NATURAL WATER CONTENT (%)	PLASTIC LIMIT (%)	LIQUID LIMIT (%)	PLASTICITY INDEX (%)	USCS
●	Sherwin	SB12-15	15 ft.		15	31	16	CL

Smith-Emery Company

Client: SHERWIN WILLIAMS
Project: 13452-35952-TK16.DESIGN
Project No.: 2058-2

Plate 9

LIQUID AND PLASTIC LIMITS TEST REPORT



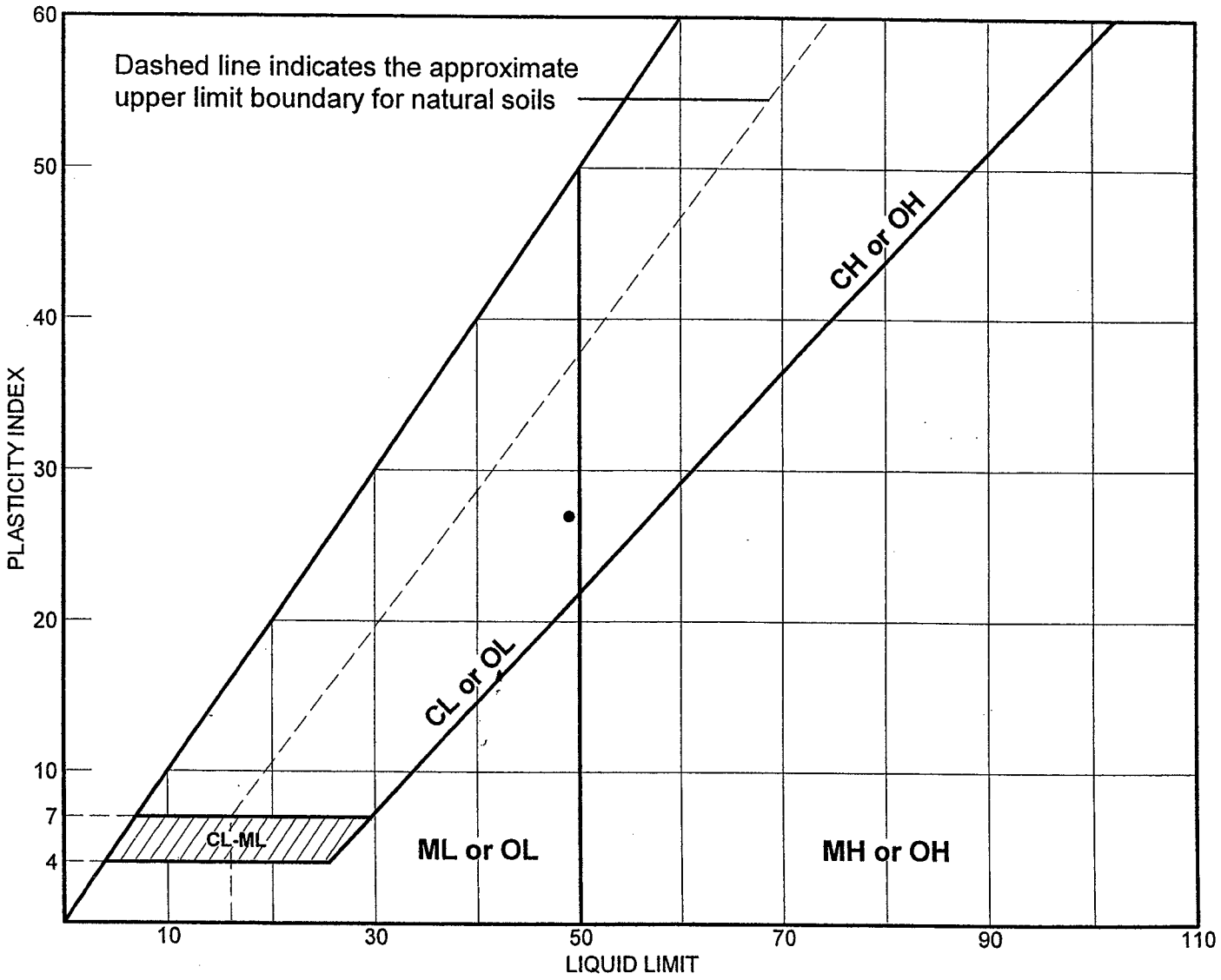
SOIL DATA								
SYMBOL	SOURCE	SAMPLE NO.	DEPTH (ft.)	NATURAL WATER CONTENT (%)	PLASTIC LIMIT (%)	LIQUID LIMIT (%)	PLASTICITY INDEX (%)	USCS
●	CDM-Sherwin Williams	SB-12	25		13.4	46.2	32.8	

Smith-Emery Company

Client: CDM Inc.
Project: Sherwin Williams (CDM Project No. 13452-35952-TK16.Design)

Project No.: 2058-2 **Plate** 10

LIQUID AND PLASTIC LIMITS TEST REPORT



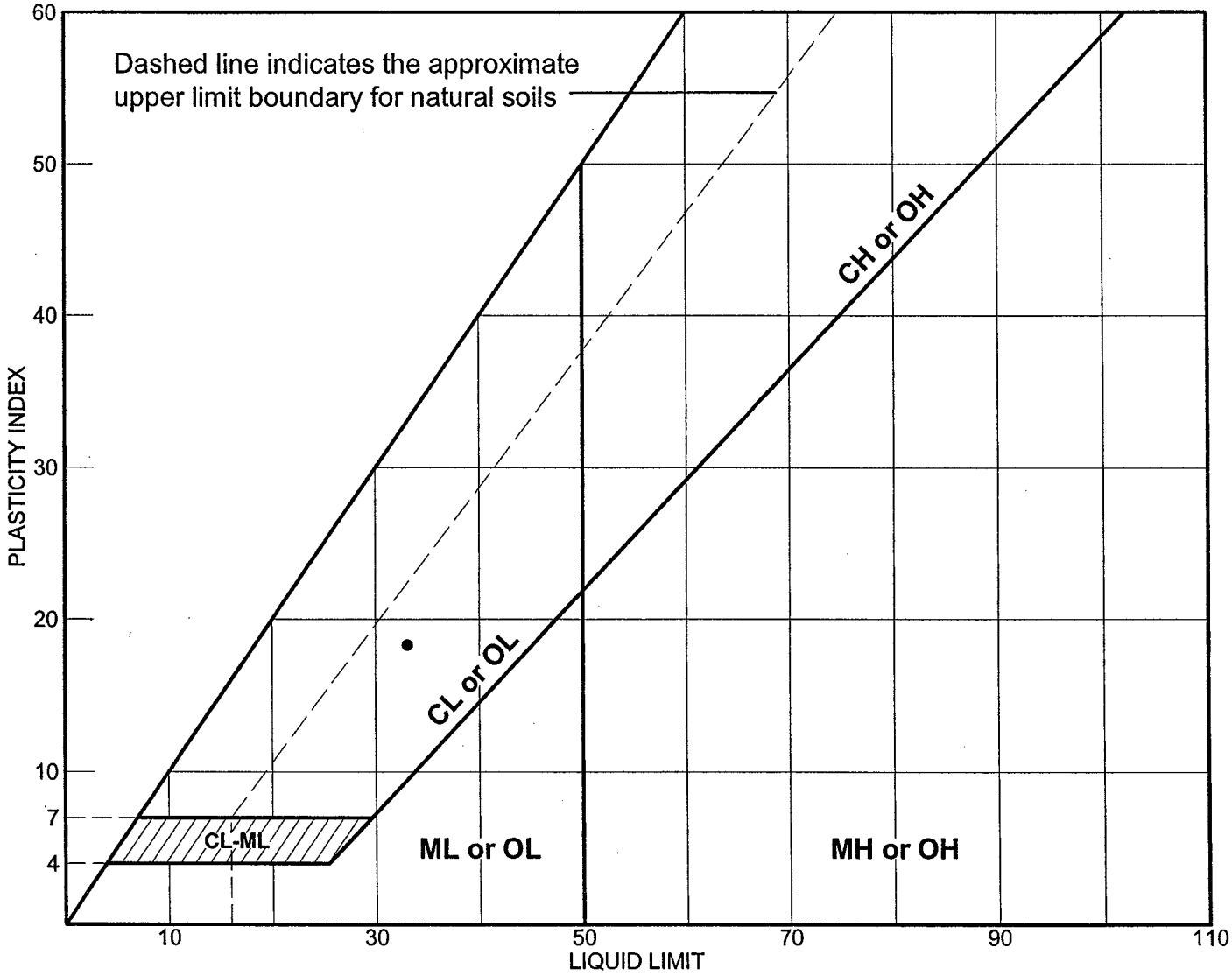
SOIL DATA								
SYMBOL	SOURCE	SAMPLE NO.	DEPTH (ft.)	NATURAL WATER CONTENT (%)	PLASTIC LIMIT (%)	LIQUID LIMIT (%)	PLASTICITY INDEX (%)	USCS
●	Sherwin	SB12-30	30 ft.		22	49	27	CL

Smith-Emery Company

Client: SHERWIN WILLIAMS
Project: 13452-35952-TK16.DESIGN

Project No.: 2058-2 **Plate** 11

LIQUID AND PLASTIC LIMITS TEST REPORT



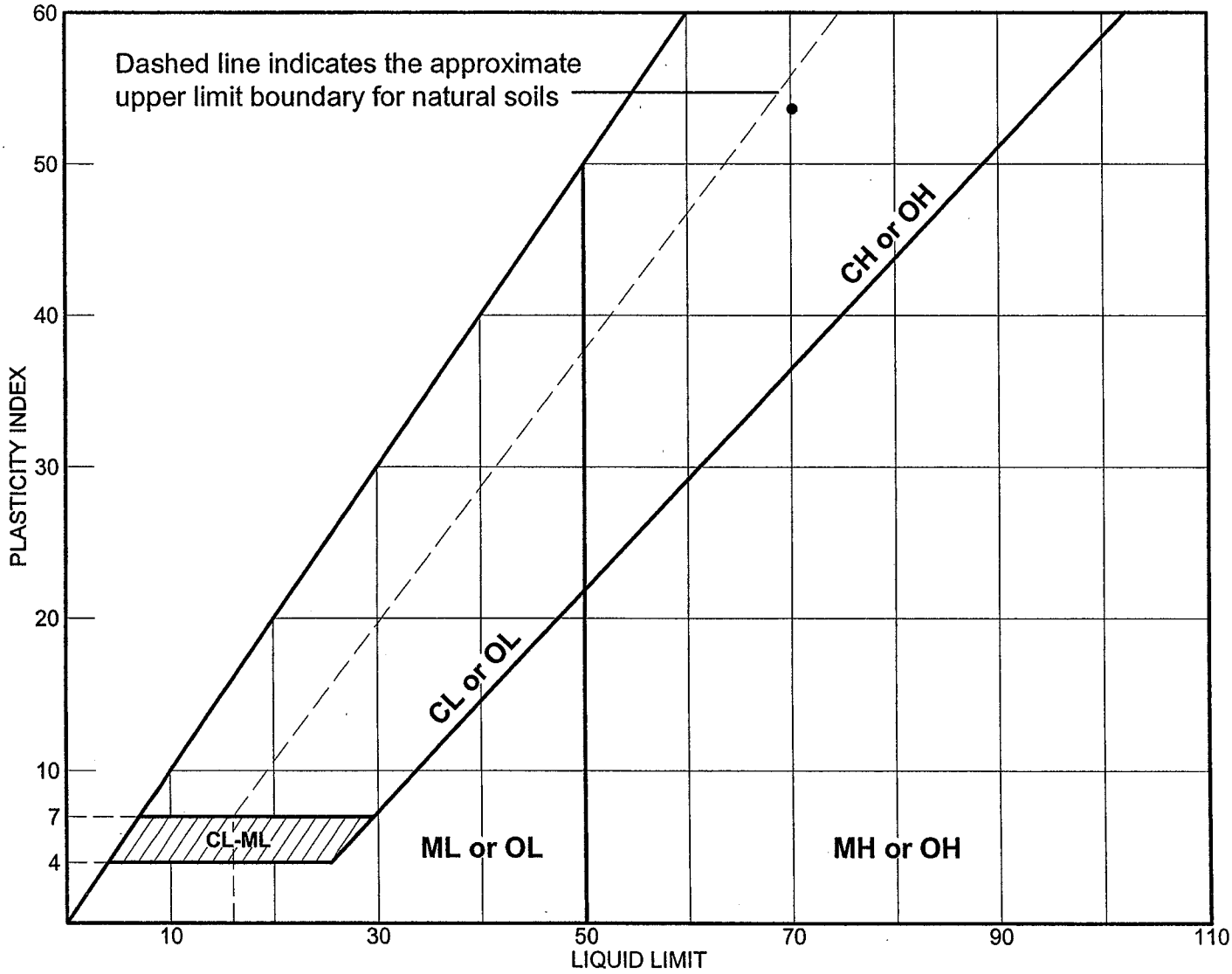
SOIL DATA								
SYMBOL	SOURCE	SAMPLE NO.	DEPTH (ft.)	NATURAL WATER CONTENT (%)	PLASTIC LIMIT (%)	LIQUID LIMIT (%)	PLASTICITY INDEX (%)	USCS
●	CDM-Sherwin Williams	SB-12	45		14.8	33.1	18.3	

Smith-Emery Company

Client: CDM Inc.
Project: Sherwin Williams (CDM Project No. 13452-35952-TK16.Design)

Project No.: 2058-2 **Plate** 12

LIQUID AND PLASTIC LIMITS TEST REPORT



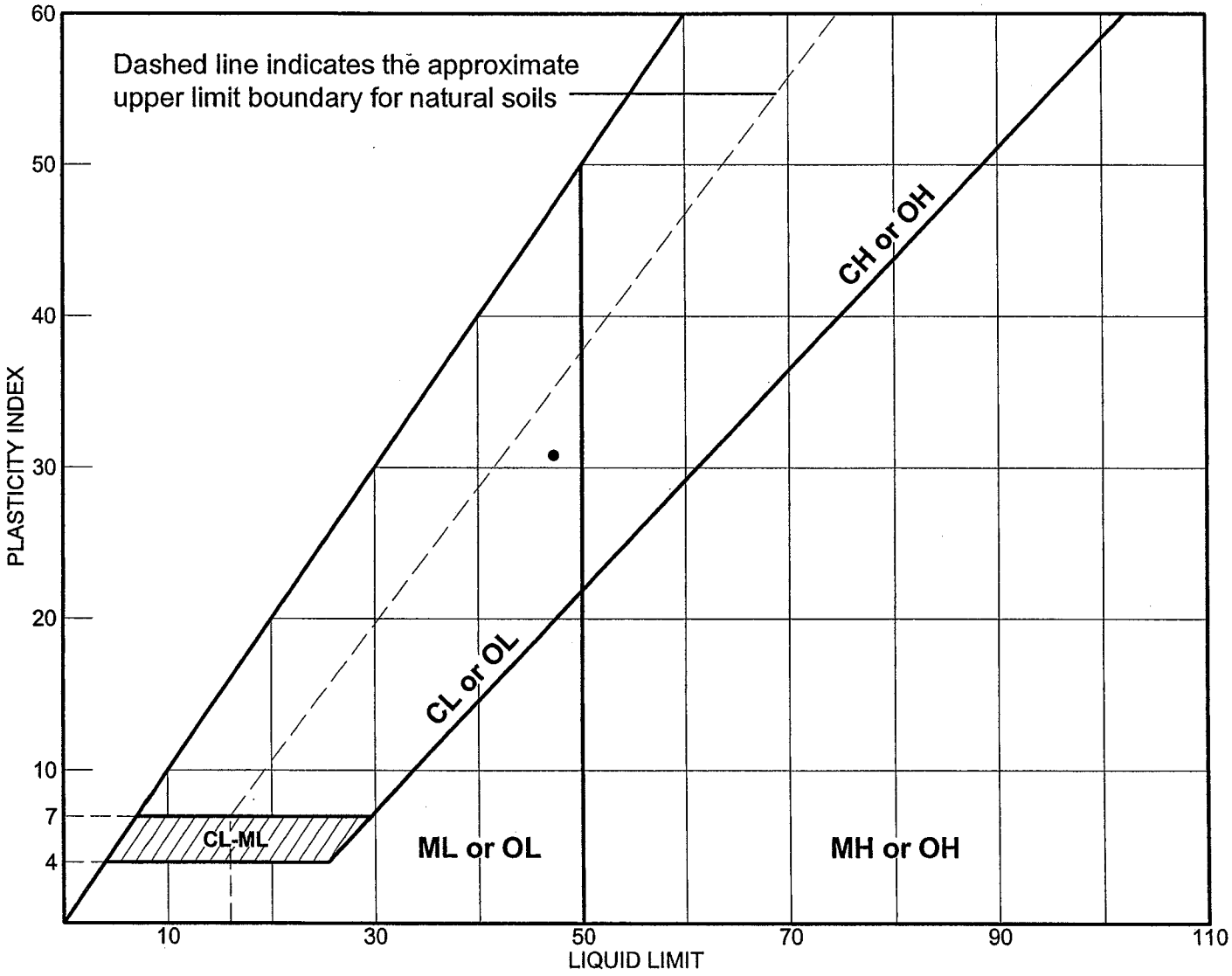
SOIL DATA								
SYMBOL	SOURCE	SAMPLE NO.	DEPTH (ft.)	NATURAL WATER CONTENT (%)	PLASTIC LIMIT (%)	LIQUID LIMIT (%)	PLASTICITY INDEX (%)	USCS
●	CDM-Sherwin Williams	SB-12	60		16.6	70.2	53.6	

Smith-Emery Company

Client: CDM Inc.
Project: Sherwin Williams (CDM Project No. 13452-35952-TK16.Design)

Project No.: 2058-2 **Plate** 13

LIQUID AND PLASTIC LIMITS TEST REPORT



SOIL DATA								
SYMBOL	SOURCE	SAMPLE NO.	DEPTH (ft.)	NATURAL WATER CONTENT (%)	PLASTIC LIMIT (%)	LIQUID LIMIT (%)	PLASTICITY INDEX (%)	USCS
●	CDM-Sherwin Williams	SB-12	65		16.5	47.3	30.8	

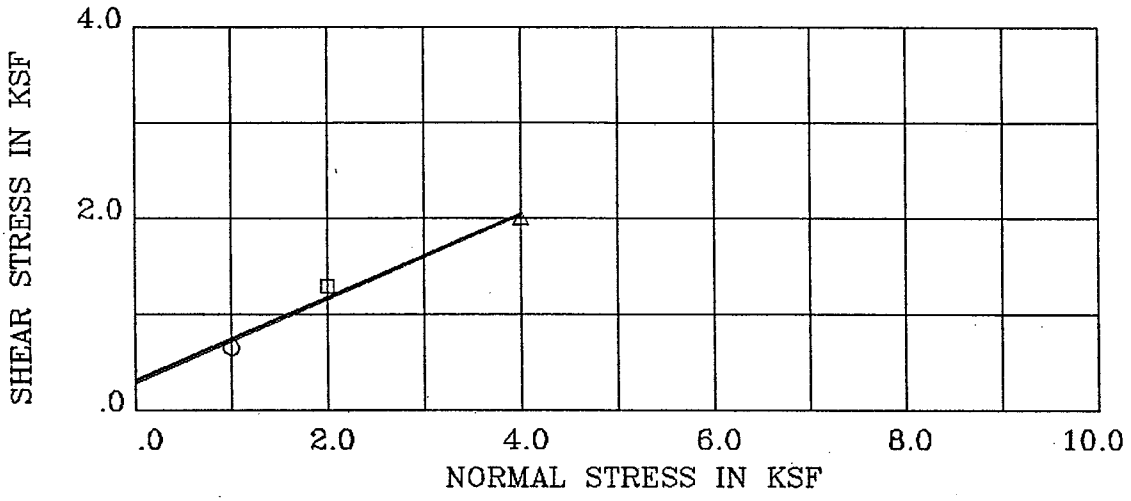
Smith-Emery Company

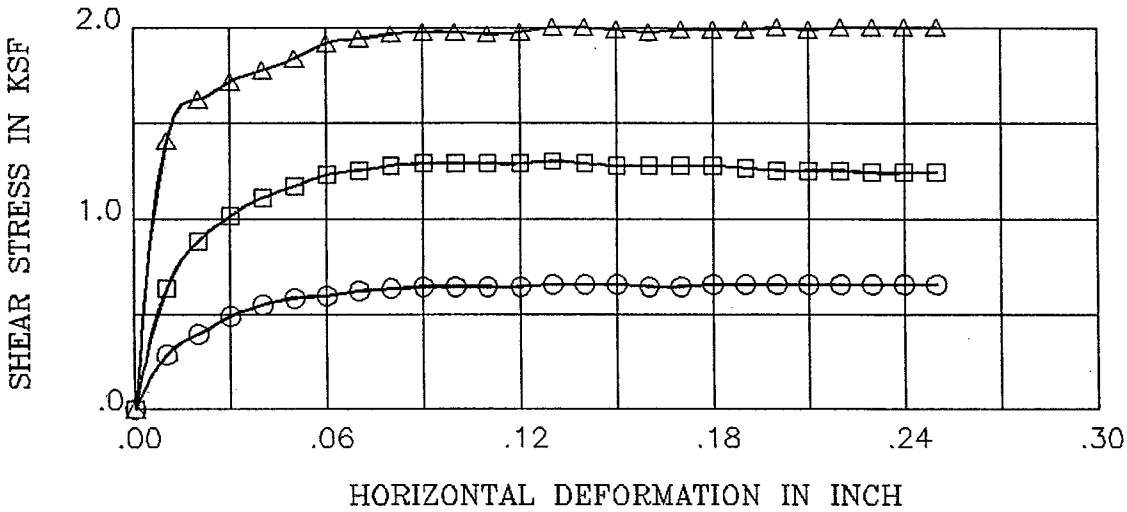
Client: CDM Inc.

Project: Sherwin Williams (CDM Project No. 13452-35952-TK16.Design)

Project No.: 2058-2 **Plate** 14

DIRECT SHEAR TESTS



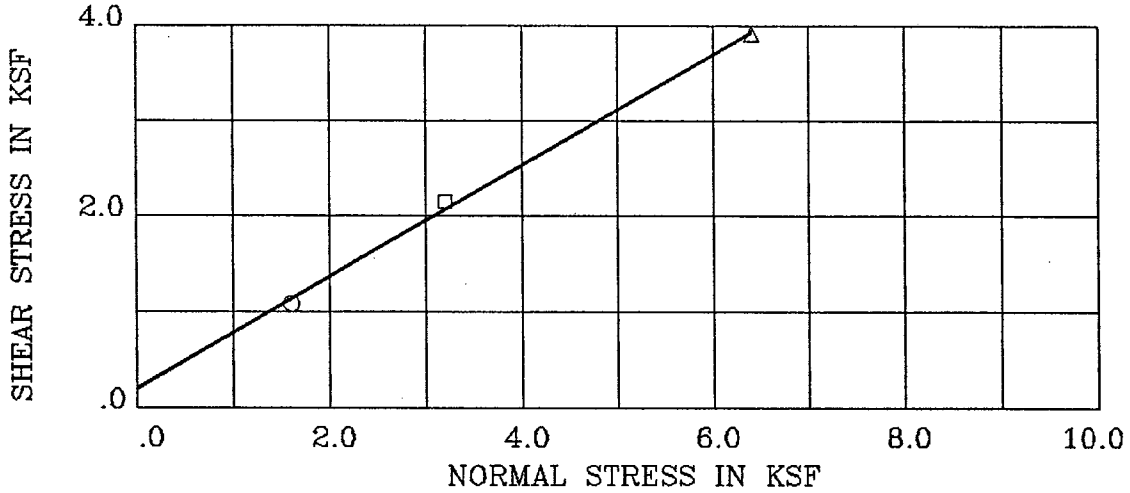


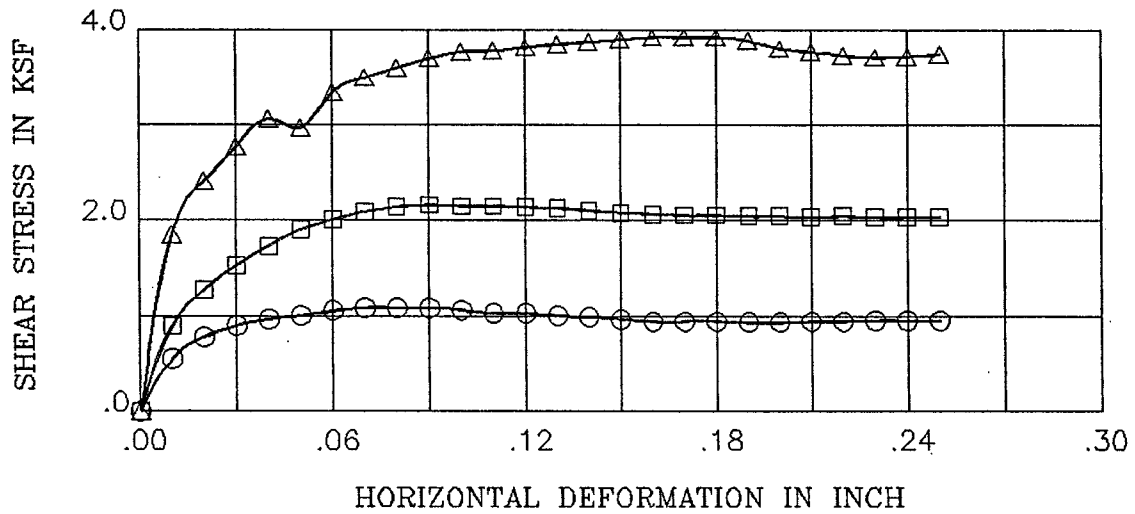
BORING/SAMPLE : SB11-18.5/ DEPTH (ft) : 18.5
DESCRIPTION : GRAY CLAYEY SILT
STRENGTH INTERCEPT (C) : .303 KSF
FRICTION ANGLE (PHI) : 23.5 DEG
(PEAK STRENGTH)

SYMBOL	MOISTURE CONTENT (%)	DRY DENSITY (pcf)	VOID RATIO	NORMAL STRESS (ksf)	PEAK SHEAR (ksf)	RESIDUAL SHEAR (ksf)
○	25.8	102.5	.644	1.00	.66	.65
□	25.0	103.8	.623	2.00	1.30	1.24
△	27.3	100.7	.673	4.00	2.00	1.98

Remark : INUNDATED

Project No.2058-2	Project Name:S.WILLIAMS 13452-35952-TK16.DESIGN
Smith-Emery Company	DIRECT SHEAR TEST Plate No.: 15



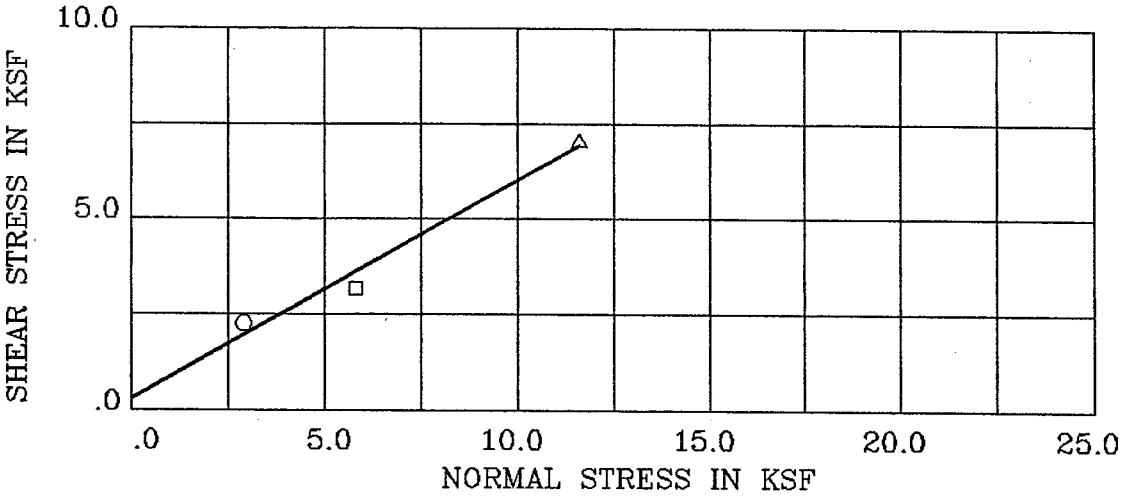


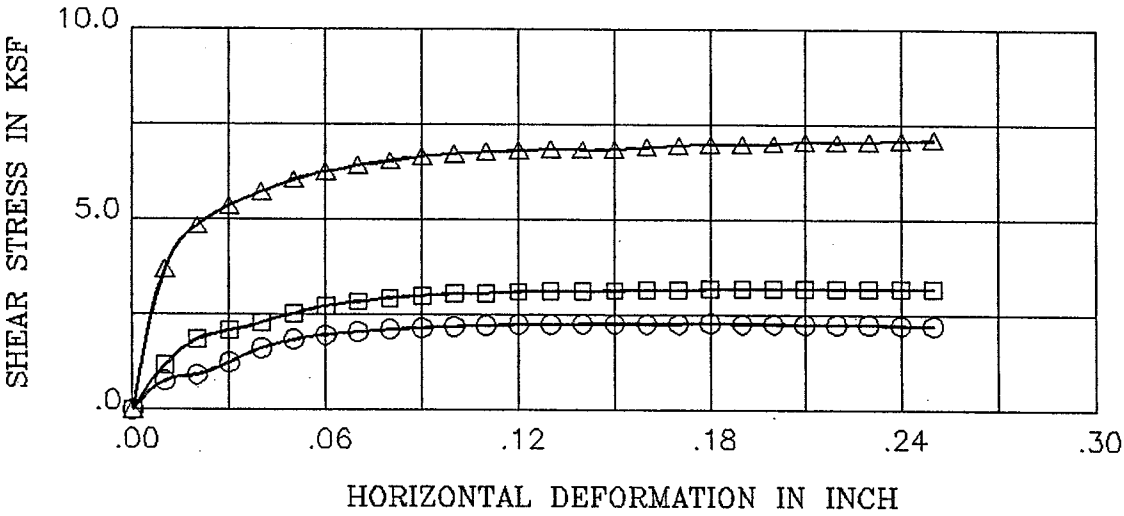
BORING/SAMPLE : SB11-27 / DEPTH (ft) : 27.0
DESCRIPTION : BROWN CLAYEY SAND
STRENGTH INTERCEPT (C) : .204 KSF
FRICTION ANGLE (PHI) : 30.3 DEG
(PEAK STRENGTH)

SYMBOL	MOISTURE CONTENT (%)	DRY DENSITY (pcf)	VOID RATIO	NORMAL STRESS (ksf)	PEAK SHEAR (ksf)	RESIDUAL SHEAR (ksf)
○	19.8	103.6	.626	1.60	1.09	.93
□	19.9	103.8	.623	3.20	2.15	2.02
△	20.8	104.5	.612	6.40	3.92	3.70

Remark : INUNDATED

Project No.2058-2	Project Name:S.WILLIAMS 13452-35952-TK16.DESIGN
Smith-Emery Company	DIRECT SHEAR TEST Plate No.: 16



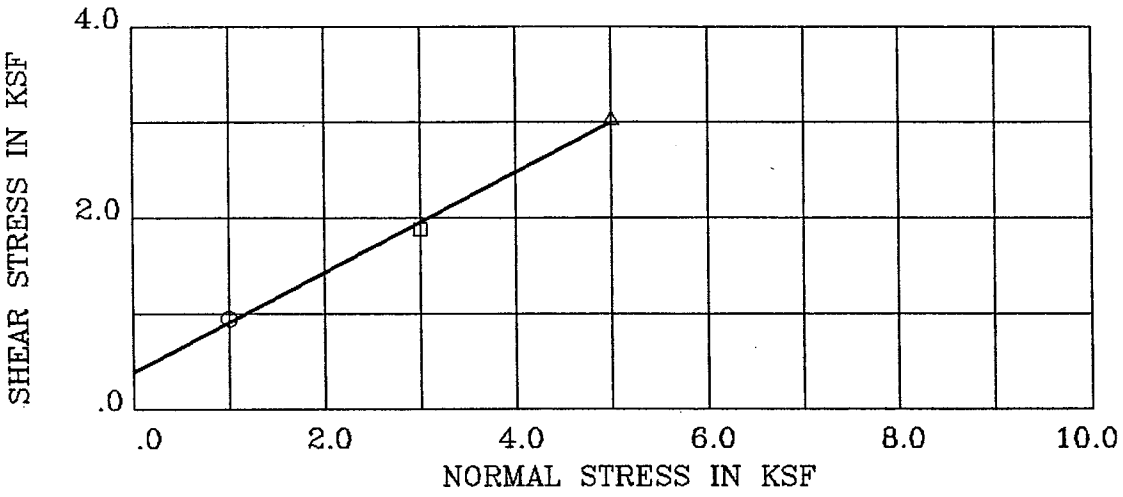


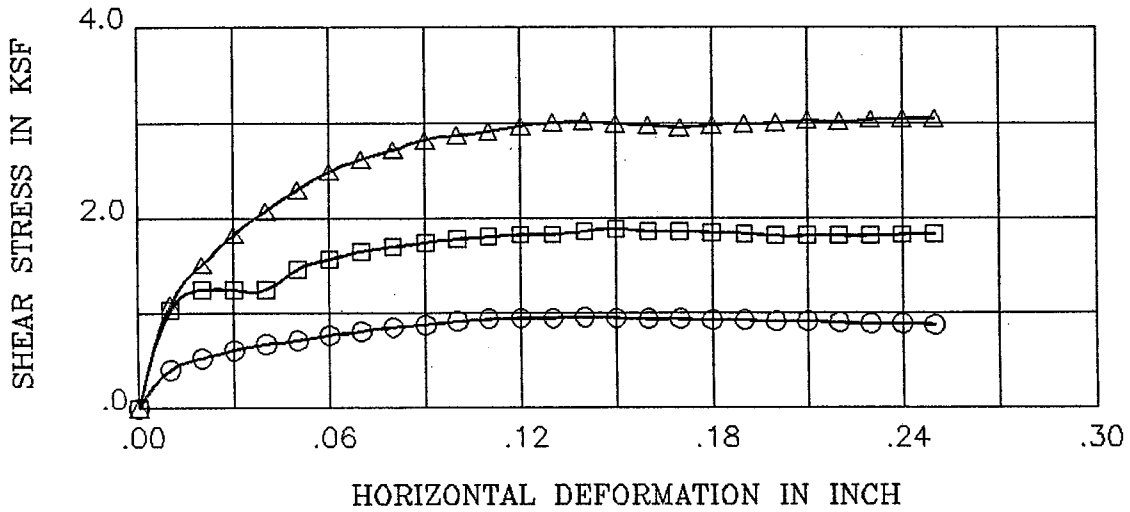
BORING/SAMPLE : SB11-45 / DEPTH (ft) : 45.0
DESCRIPTION : BROWN SILTY CLAY WITH GRAVEL
STRENGTH INTERCEPT (C) : .298 KSF
FRICTION ANGLE (PHI) : 29.8 DEG
(PEAK STRENGTH)

SYMBOL	MOISTURE CONTENT (%)	DRY DENSITY (pcf)	VOID RATIO	NORMAL STRESS (ksf)	PEAK SHEAR (ksf)	RESIDUAL SHEAR (ksf)
○	20.2	108.7	.550	2.90	2.26	2.20
□	19.8	110.0	.532	5.80	3.17	3.15
△	14.2	121.1	.391	11.60	7.09	7.09

Remark : INUNDATED

Project No.2058-2	Project Name:S.WILLIAMS 13452-35952-TK16.DESIGN
Smith-Emery Company	DIRECT SHEAR TEST Plate No.: 17



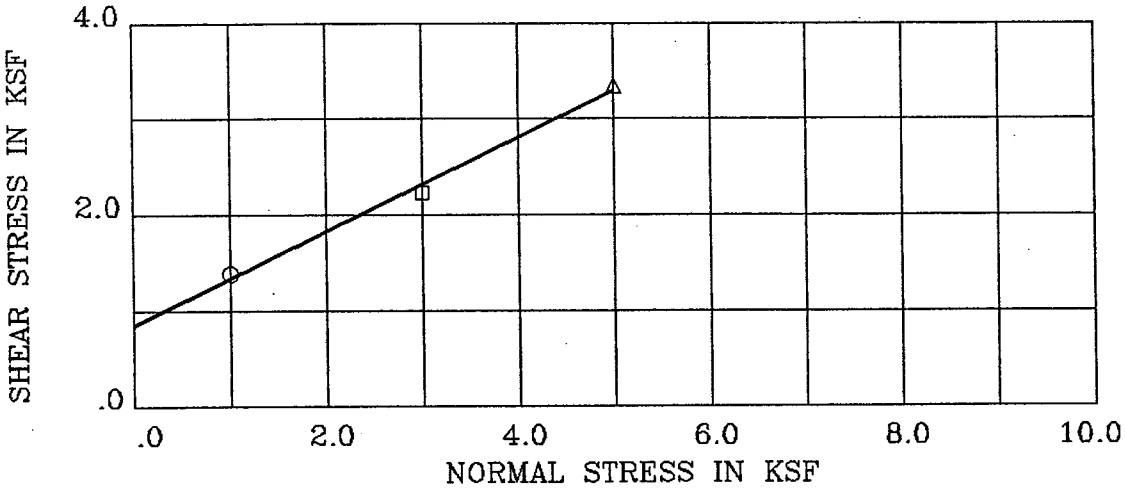


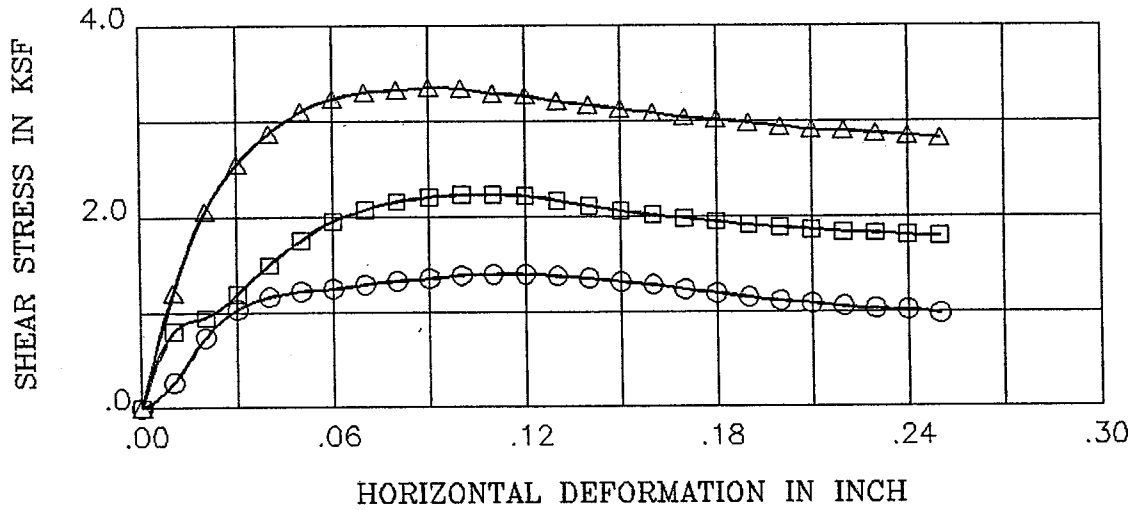
BORING/SAMPLE : SB12-15 / DEPTH (ft) : 15.0
DESCRIPTION : BROWN SILTY CLAY
STRENGTH INTERCEPT (C) : .388 KSF
FRICTION ANGLE (PHI) : 27.7 DEG
(PEAK STRENGTH)

SYMBOL	MOISTURE CONTENT (%)	DRY DENSITY (pcf)	VOID RATIO	NORMAL STRESS (ksf)	PEAK SHEAR (ksf)	RESIDUAL SHEAR (ksf)
○	20.9	107.2	.572	1.00	.95	.87
□	21.7	106.7	.579	3.00	1.88	1.81
△	20.9	107.7	.565	5.00	3.05	3.05

Remark : INUNDATED

Project No.2058-2	Project Name:S.WILLIAMS 13452-35952-TK16.DESIGN
Smith-Emery Company	DIRECT SHEAR TEST Plate No.: 18





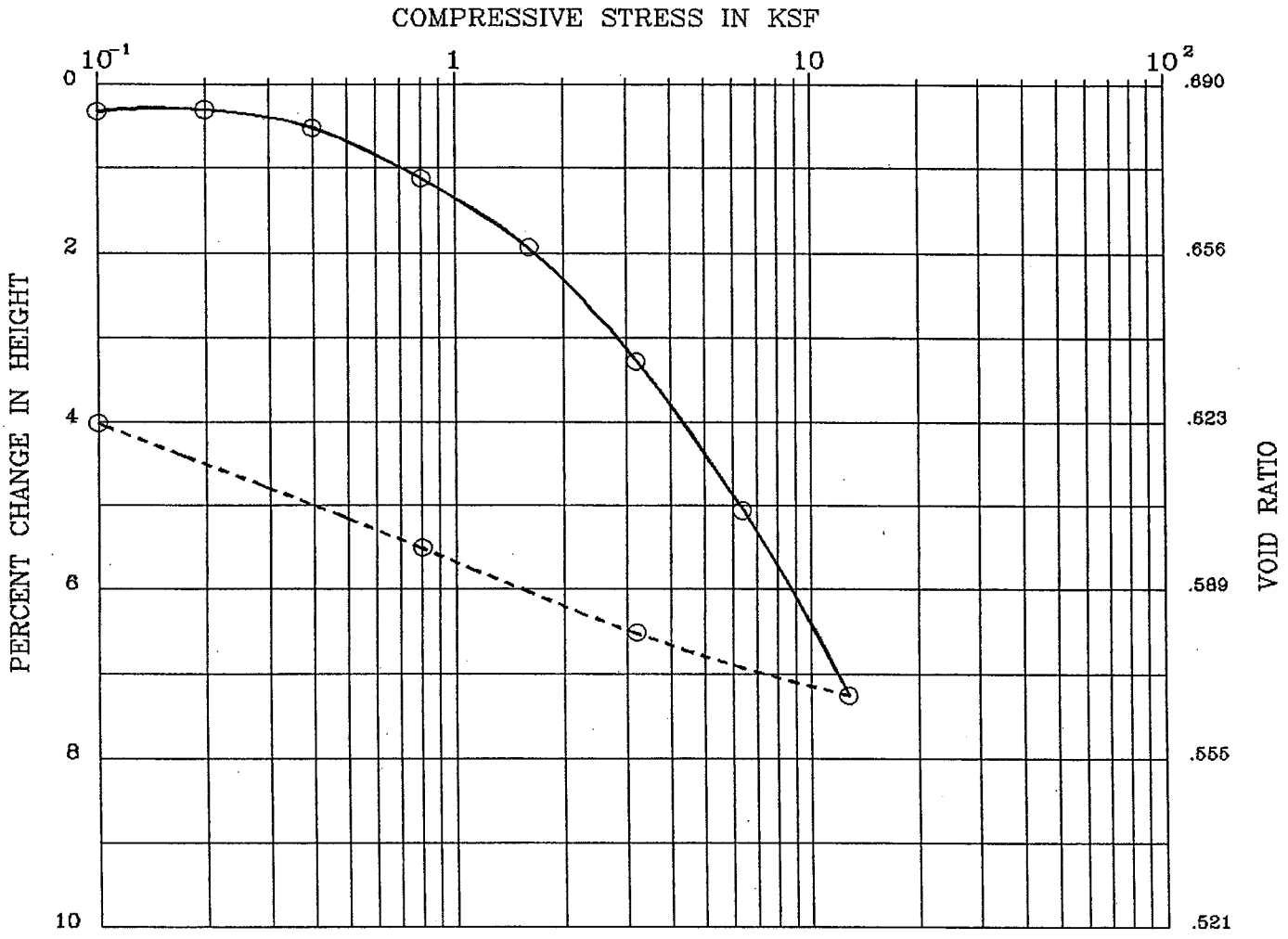
BORING/SAMPLE : SB12-30 / DEPTH (ft) : 30.0
DESCRIPTION : BROWN SILTY CLAY
STRENGTH INTERCEPT (C) : .859 KSF
FRICTION ANGLE (PHI) : 26.0 DEG
(PEAK STRENGTH)

SYMBOL	MOISTURE CONTENT (%)	DRY DENSITY (pcf)	VOID RATIO	NORMAL STRESS (ksf)	PEAK SHEAR (ksf)	RESIDUAL SHEAR (ksf)
○	24.8	102.0	.651	1.00	1.39	.98
□	22.9	104.3	.616	3.00	2.23	1.79
△	22.5	105.1	.603	5.00	3.35	2.82

Remark : INUNDATED

Project No.2058-2	Project Name:S.WILLIAMS 13452-35952-TK16.DESIGN
Smith-Emery Company	DIRECT SHEAR TEST Plate No.: 19

CONSOLIDATION TESTS

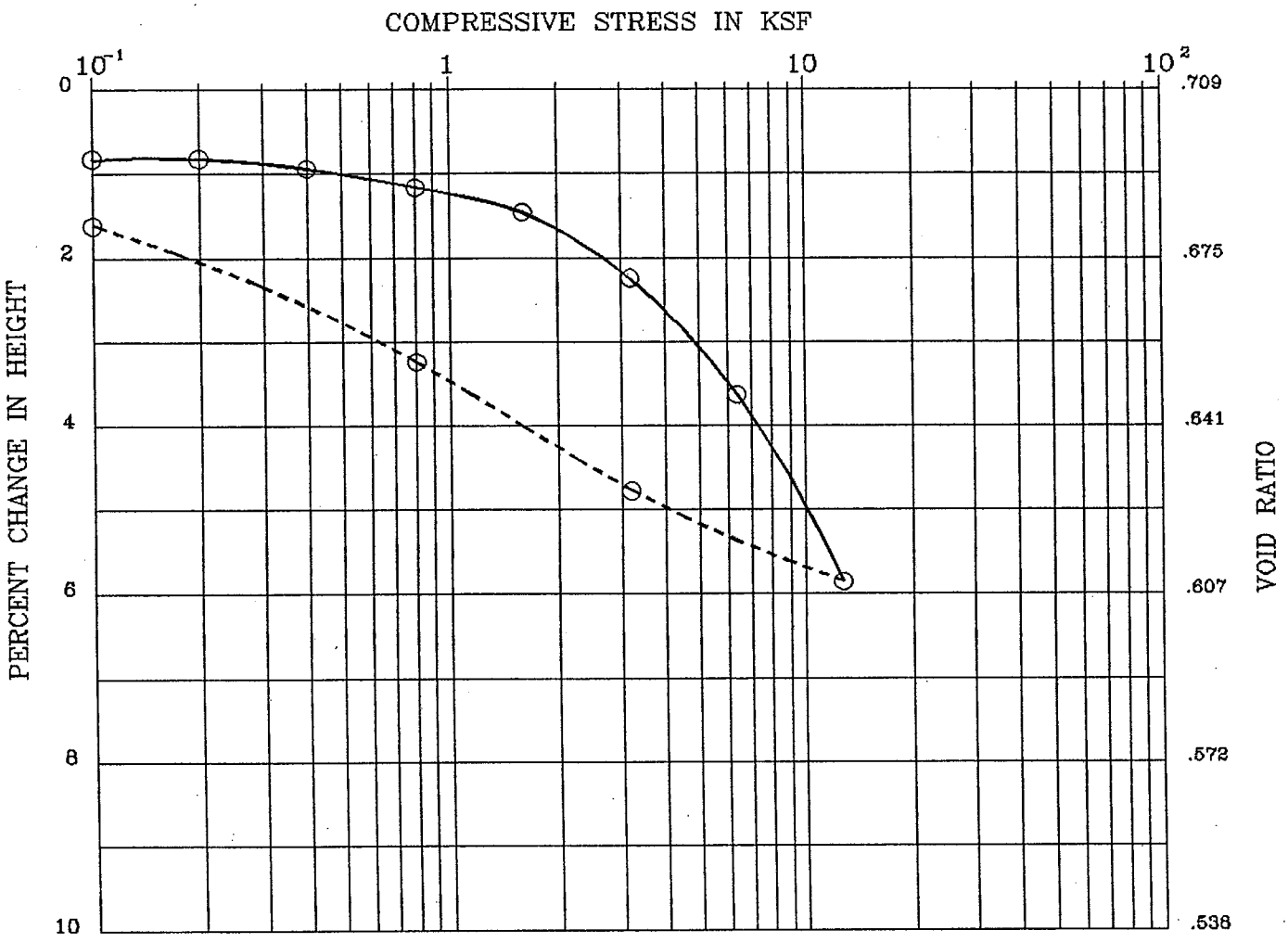


BORING	: SB11-35 /	DESCRIPTION	: BROWN CLAYEY SILT
DEPTH (ft)	: 35.0	LIQUID LIMIT	:
SPEC. GRAVITY	: 2.78	PLASTIC LIMIT	:

	MOISTURE CONTENT (%)	DRY DENSITY (pcf)	PERCENT SATURATION	VOID RATIO
INITIAL	24.2	102.6	98	.690
FINAL	22.4	106.9	100	.623

Remark : INUNDATED AT 0.1 KSF

Project No.2058-2	S.WILLIAMS 13452-35952-TK16.DESN
SMITH EMERY	CONSOLIDATION TEST Plate No. 20



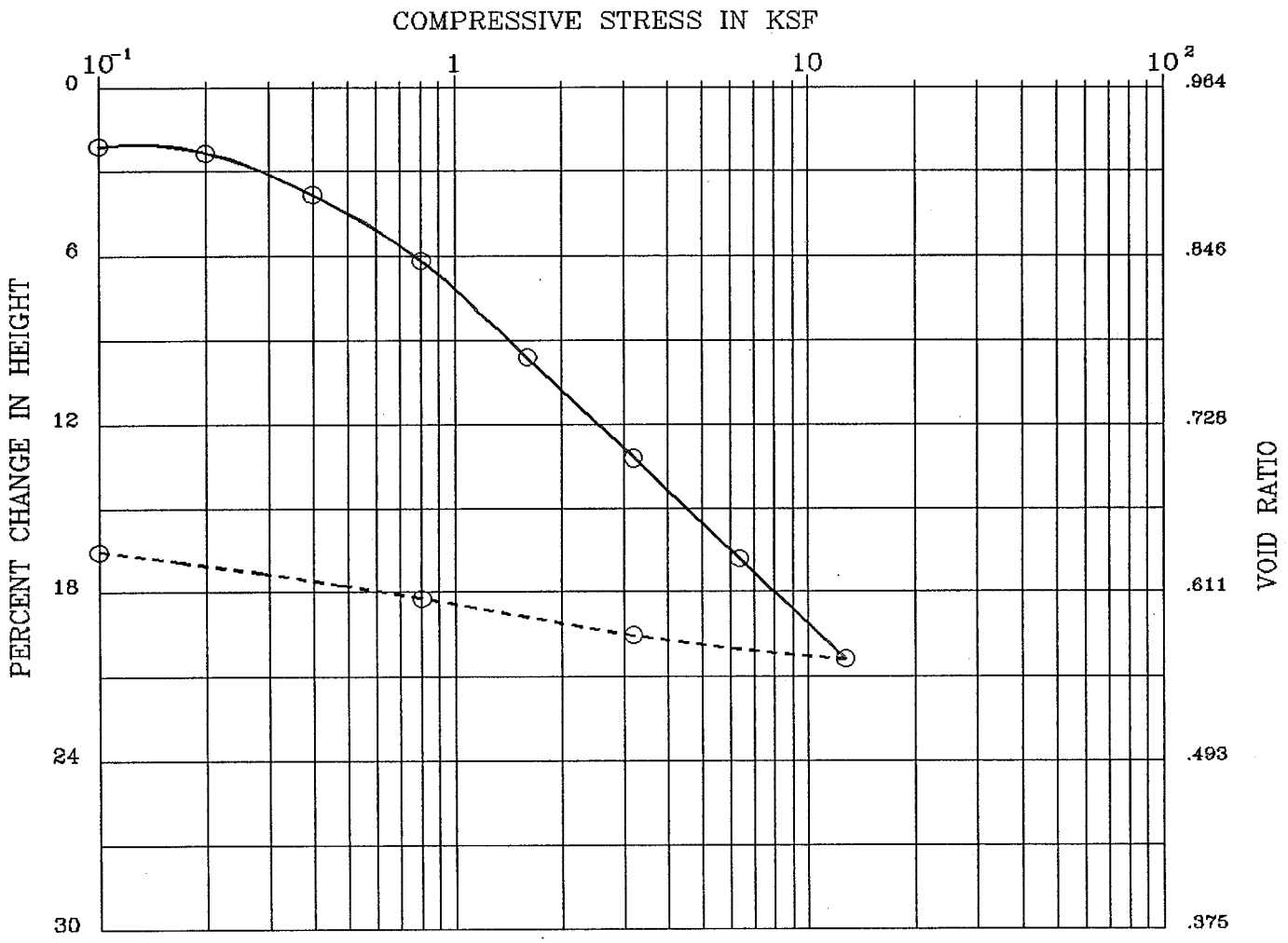
BORING : SB11-65 /
DEPTH (ft) : 65.0
SPEC. GRAVITY : 2.81

DESCRIPTION : BRN SILTY CLAY
LIQUID LIMIT :
PLASTIC LIMIT :

	MOISTURE CONTENT (%)	DRY DENSITY (pcf)	PERCENT SATURATION	VOID RATIO
INITIAL	24.0	102.7	95	.709
FINAL	24.2	104.4	100	.682

Remark : INUNDATED AT 0.1 KSF

Project No.2058-2	S.WILLIAMS 13452-35952-TK16.DESN
SMITH EMERY	CONSOLIDATION TEST Plate No. 21



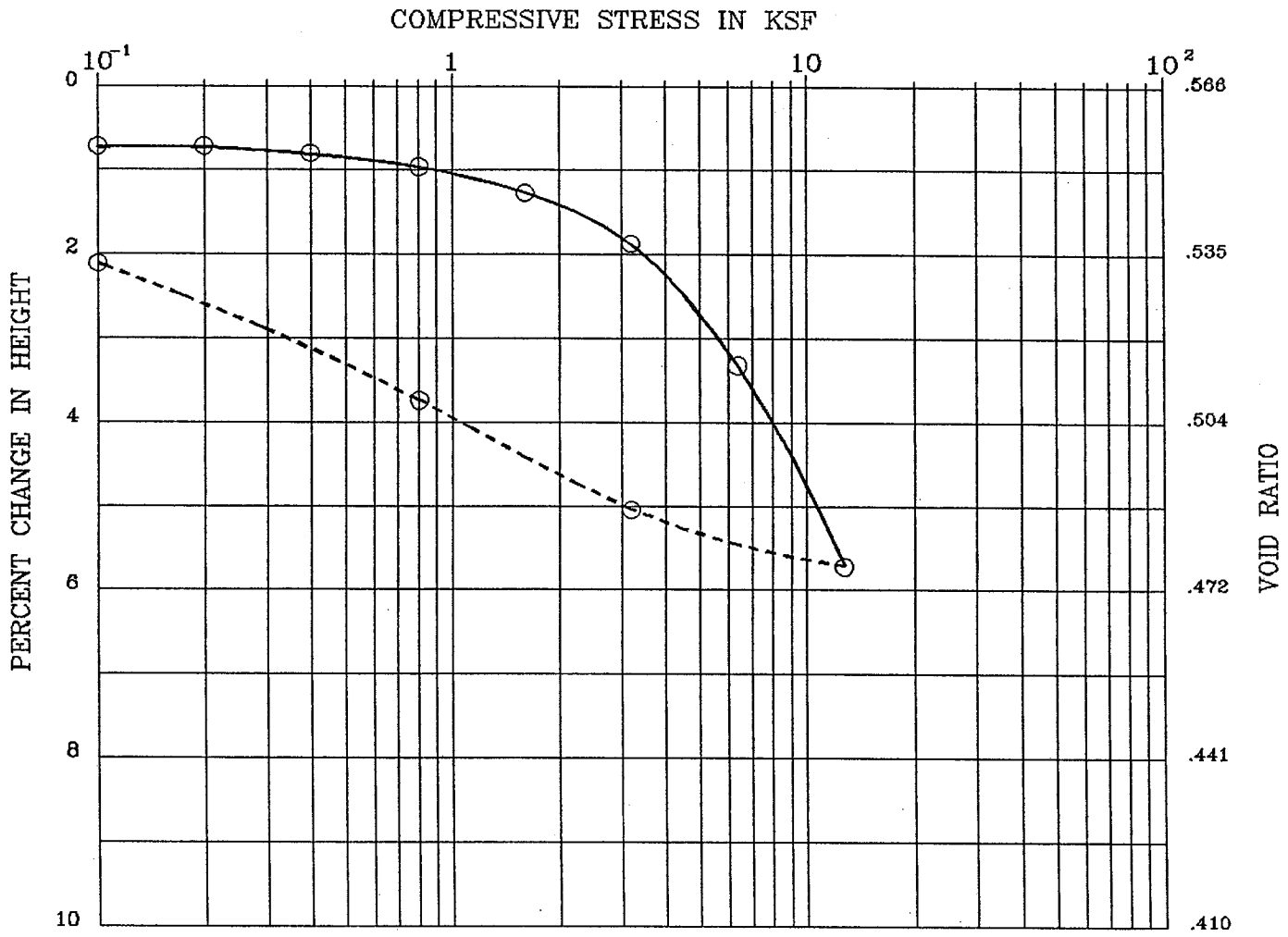
BORING : SB12-25 /
DEPTH (ft) : 25.0
SPEC. GRAVITY : 2.70

DESCRIPTION : BROWN SILTY CLAY
LIQUID LIMIT :
PLASTIC LIMIT :

	MOISTURE CONTENT (%)	DRY DENSITY (pcf)	PERCENT SATURATION	VOID RATIO
INITIAL	34.3	85.9	96	.964
FINAL	23.1	102.9	98	.640

Remark : INUNDATED AT 0.8 KSF

Project No.2058-2	SHERWIN WILLIAMS .
SMITH EMERY	CONSOLIDATION TEST Plate No. 22



BORING	: SB12-40 /	DESCRIPTION	: BRN SILTY CLAY
DEPTH (ft)	: 40.0	LIQUID LIMIT	:
SPEC. GRAVITY	: 2.77	PLASTIC LIMIT	:

	MOISTURE CONTENT (%)	DRY DENSITY (pcf)	PERCENT SATURATION	VOID RATIO
INITIAL	18.7	110.3	92	.566
FINAL	19.2	112.7	100	.533

Remark : INUNDATED AT 0.1 KSF

Project No.	S.WILLIAMS 13452-35952-TK16.DESN
SMITH EMERY	CONSOLIDATION TEST Plate No. 23

****
* *
* E Q F A U L T *
* *
* Version 3.00 *
* *
****

DETERMINISTIC ESTIMATION OF
PEAK ACCELERATION FROM DIGITIZED FAULTS

JOB NUMBER: 13452

DATE: 04-17-2003

JOB NAME: s-w

CALCULATION NAME: Preliminary Sample Run Analysis

FAULT-DATA-FILE NAME: CDMGFLTE.DAT

SITE COORDINATES:
SITE LATITUDE: 37.8343
SITE LONGITUDE: 122.2872

SEARCH RADIUS: 70 mi

ATTENUATION RELATION: 23) Abrahamson & Silva (1995b/1997) Horiz.- Soil
UNCERTAINTY (M=Median, S=Sigma): M Number of Sigmas: 0.0
DISTANCE MEASURE: clodis
SCOND: 0
Basement Depth: 5.00 km Campbell SSR: Campbell SHR:
COMPUTE PEAK HORIZONTAL ACCELERATION

FAULT-DATA FILE USED: CDMGFLTE.DAT

MINIMUM DEPTH VALUE (km): 0.0

EQFAULT SUMMARY

DETERMINISTIC SITE PARAMETERS

Page 1

	APPROXIMATE	ESTIMATED MAX. EARTHQUAKE EVENT		
ABBREVIATED FAULT NAME	DISTANCE mi (km)	MAXIMUM EARTHQUAKE MAG.(Mw)	PEAK SITE ACCEL. g	EST. SITE INTENSITY MOD.MERC.
HAYWARD (Total Length)	3.1(5.0)	7.1	0.434	X
HAYWARD (North)	3.1(5.0)	6.9	0.420	X
HAYWARD (South)	11.0(17.7)	6.9	0.197	VIII
CALAVERAS (No.of Calaveras Res)	14.0(22.5)	6.8	0.158	VIII
SAN ANDREAS (Peninsula)	15.4(24.8)	7.1	0.161	VIII
SAN ANDREAS (1906)	15.4(24.8)	7.9	0.209	VIII
CONCORD - GREEN VALLEY	16.8(27.0)	6.9	0.141	VIII
SAN ANDREAS (North Coast)	16.8(27.0)	7.6	0.178	VIII
RODGERS CREEK	17.8(28.6)	7.0	0.139	VIII
SAN GREGORIO	18.4(29.6)	7.3	0.150	VIII
GREENVILLE	21.2(34.1)	6.9	0.116	VII
WEST NAPA	22.9(36.9)	6.5	0.093	VII
GREAT VALLEY 6	25.7(41.3)	6.7	0.112	VII
MONTE VISTA - SHANNON	27.5(44.2)	6.8	0.110	VII
GREAT VALLEY 5	28.6(46.0)	6.5	0.094	VII
POINT REYES	30.8(49.5)	6.8	0.100	VII
HAYWARD (SE Extension)	33.2(53.4)	6.4	0.063	VI
GREAT VALLEY 4	34.4(55.3)	6.6	0.083	VII
CALAVERAS (So.of Calaveras Res)	38.6(62.2)	6.2	0.044	VI
GREAT VALLEY 7	39.5(63.6)	6.7	0.076	VII
HUNTING CREEK - BERRYESSA	43.1(69.3)	6.9	0.062	VI
SAN ANDREAS (Santa Cruz Mtn.)	48.0(77.2)	7.0	0.060	VI
SARGENT	51.6(83.1)	6.8	0.050	VI
ZAYANTE-VERGELES	54.3(87.4)	6.8	0.048	VI
MAACAMA (South)	55.8(89.8)	6.9	0.049	VI

GREAT VALLEY 3 | 56.5(91.0)| 6.8 | 0.058 | VI
MONTEREY BAY - TULARCITOS | 63.8(102.6)| 7.1 | 0.061 | VI
GREAT VALLEY 8 | 63.8(102.6)| 6.6 | 0.046 | VI
ORTIGALITA | 67.2(108.1)| 6.9 | 0.042 | VI
COLLAYOMI | 68.7(110.6)| 6.5 | 0.032 | V
SAN ANDREAS (Pajaro) | 68.8(110.8)| 6.8 | 0.038 | V
****

-END OF SEARCH- 31 FAULTS FOUND WITHIN THE SPECIFIED SEARCH RADIUS.

LARGEST MAXIMUM-EARTHQUAKE SITE ACCELERATION: 0.4335 g

14432 SE Eastgate Way, Suite 100
Bellevue, Washington 98007-6493
Telephone: +1 425 519-8300
Facsimile: +1 425 746-0197

November 7, 2012

Mr. Larry Mencin
The Sherwin-Williams Company
101 Prospect Avenue, N.W.
Cleveland, Ohio 44115

Subject: 2012 Update – Geotechnical Results and
Conceptual Geotechnical Engineering Recommendations
Sherwin-Williams Company Emeryville, CA Manufacturing Site

Dear Mr. Mencin:

This letter presents CDM Smith Inc.'s (CDM Smith) additional geotechnical exploration results and updates the geotechnical engineering recommendations in our Technical Memorandum of June 10, 2005 titled: "*Summary of Geotechnical Results and Conceptual Geotechnical Engineering Recommendations for The Sherwin-Williams Company Emeryville, CA Manufacturing Facility*" (2005 Technical Memorandum). A copy of the 2005 Technical Memorandum is appended.

Purpose and Scope

The purpose of this document is to amend the 2005 Technical Memorandum based on additional geotechnical exploration results and information on construction activities performed in 2011 and 2012. These activities implemented remedial actions (the Installed Remedial Features) by the Sherwin-Williams Company Emeryville (S-W) in conjunction with the Department of Toxic Substances Control (DTSC).

The additional data includes:

- Documentation of the excavation of contaminated soils and backfilling per specified procedure;
- Information on the breaching of the existing slurry wall at three locations;
- Boring logs from eight groundwater monitoring wells installed in March 2012; and
- Results of geotechnical laboratory testing.

Proposed Future Development

The proposed future development plan has not been finalized. For this study the intended land use and design assumptions are considered to be the same as described in the 2005 Technical Memorandum. As an overall site consideration, this evaluation is based on the condition that final site grading will be minimal and that the first floor of all structures will be essentially at grade or embedded no more than 5 feet below the existing grade.

Major Installed Remedial Features are shown on **Figure 1** including contaminated soil excavation and replacement with zones of varying permeability backfill, slurry wall breaches, a slurry wall extension and surface cap, and an interceptor trench with membrane barrier leading to a zone of high permeability backfill. The Installed Remedial features also include the remaining portions of slurry walls installed as part of prior remedial activities.

Activities that may disturb, alter, and/or remove the Installed Remedial Features shall not be permitted on the Property without prior written approval by the DTSC and S-W. All uses and development of the Property shall preserve the integrity or effectiveness of the Installed Remedial Features. The Installed Remedial Features were documented in the Remedy Implementation Completion Report (RICR; CDM Smith, 2012), which presented the modifications to the project's Remedial Action Plan (RAP; CDM, 2010") and Remedial Design Implementation Plan (RDIP; CDM, 2011). The RAP and RDIP were developed in accordance with the project's Remedial Investigation (RI; ENTRIX, 2002), Human Health Risk Assessment (HHRA; Gradient, 2005), and Feasibility Study (FS; CDM, 2009).

Existing Site Conditions

The project site, subsequently referred to as site, is located at 1450 Sherwin Avenue in Emeryville, California and encompasses about 8 acres. The 2005 Technical Memorandum describes the existing site conditions in 2005[1]. Since then, several construction activities have been executed, including the demolition and removal of manufacturing structures used to manufacture paint products, the removal of the raised cap in an area of known soil contamination, and site remediation. The remediation implementation activities included excavation of contaminated soils and the subsequent backfilling of the excavation with soil materials of specified engineering properties (structural fill). In addition, existing groundwater extraction wells were decommissioned and the groundwater flow was re-directed by breaching the existing slurry wall at three locations and extending the slurry wall at another location.

[1] All elevations in this report are in feet based on the North American Vertical Datum of 1988 (NAVD 88). Boring elevations in the 2005 Technical Memorandum report are based on National Geodetic Vertical Datum (NGVD 29). Elevation 2.71 ft (NAVD 88) = 0.00 ft (NGVD 29).

Several new monitoring wells were installed for monitoring groundwater conditions. At seven of these wells, the geotechnical conditions encountered were recorded and boring logs generated. The boring locations are shown on **Figure 1**.

Additional Geotechnical Borings and Laboratory Testing

CDM Smith's additional geotechnical exploration consisted of geotechnical logging and sampling of the seven groundwater monitoring well borings. These borings were performed by Gregg Drilling and Testing, Inc. between March 8 and 12, 2012 using the hollow stem auger method. Three borings – CDM-101, CDM-103, and CDM-104 – were drilled within the area of soil excavation and subsequent placement of structural fill, while four borings – CDM-110, CDM-111, CDM-113, and CDM-114 – were drilled west and south of that area. The geotechnical borings were monitored in the field by a CDM Smith representative.

Sample collection was performed by Standard Penetration Test (SPT) in general accordance with American Society of Testing Method (ASTM) D1586. A 140 pound hydraulically driven auto-hammer was used to drive the split spoon sampler 18-inches. The blow count for each six-inch driven interval was recorded, which allows determination of the penetration resistance (SPT N-Value) as the sum of the second and third six-inch penetration blow counts. Samples were collected continuously in 18-inch intervals and the retained sample material was placed in sealed plastic bags for transport to the laboratory.

Water levels in the test borings were estimated from the condition of the samples obtained and by the observed water levels within the borehole at the time of drilling, if any. All seven borings were drilled to an approximate El. -2, resulting in borehole depths between 17 feet and 21 feet.

Laboratory tests were performed by Cooper Testing Labs, Inc. of Palo Alto, California on samples selected by CDM Smith from all seven borings. The following analyses were conducted to characterize material index properties:

- Moisture Content per ASTM D2937;
- Grain Size Distribution per ASTM D422; and
- Atterberg Limits per ASTM D4318.

A summary of the subsurface conditions encountered by the exploratory borings is included in **Table 1**. The borings logs are included as **Attachment A**.

A summary of the results of laboratory testing is included in **Table 2**. The laboratory test reports are included as **Attachment B**.

Soil and Groundwater Conditions

The subsurface conditions encountered in previous explorations are described in the 2005 Technical Memorandum in terms of five distinct units:

- Layer 1: Silty/clayey gravel with sand
- Layer 2: Black sandy clay
- Layer 3: Clayey sand/Silty sand
- Layer 4: Sandy clay
- Layer 5: Sand/Gravelly sand/Silty gravel

The excavation and backfill activities performed since and the additional exploratory borings drilled in that area require adding another unit:

- Unit B: Sand and gravel (compacted structural fill)

The seven new geotechnical borings encountered Layers 1, 2, and Unit B, summarized as follows.

Layer 1

Soils designated as fill (Layer 1 – Silty/clayey gravel with sand) were encountered by the borings drilled outside the backfill area of Unit B – CDM-110, CDM-111, CDM-113, and CDM 114 – as the topmost layer. The thickness of Layer 1 ranged from 4 feet (CDM-110) to more than 7 feet (CDM-114). Layer 1 includes gravel, sand and silt as well as concrete layers and debris. The Unified Soil Classification System (USCS) description of Layer 1 includes GP and SM. The SPT N-Values collected in this layer indicate a wide range of density from loose to dense.

Layer 2

Layer 2 soils consist of mostly fine-grained soils containing organic compounds (Layer 2 – Black sandy clay) with interbeds of coarser grained soils. At the boring locations outside the backfill area of Unit B – CDM-110, CDM-111, CDM-113, and CDM 114 – Layer 2 soils were encountered beneath the Layer 1 soils to the bottom of the borings at El. -2. Layer 2 consists of black, gray and brown clay, partly with amounts of silt, sand and fine gravel, with interbedded layers of silt, sand and gravel. The USCS classification includes predominantly CL but also ML, SP, SW, SC and GP. SPT N-Values collected in this layer indicate the fine grained soils are mostly soft, partly very soft or medium stiff, and the coarse grained interbeds are generally very loose or loose.

At all four boring locations, Layer 2 soils encountered at depths ranging from 4 ft to 16 ft are described as having a petroleum-like odor.

Unit B

Soils placed and compacted in the excavation area (Unit B – Sand and gravel (compacted structural fill)) were encountered by Borings CDM-101, CDM-103, and CDM 104. The backfill material is predominantly silty sand with varying amounts of clay and gravel. Boring CDM-104 also encountered fine to medium sand. At and near the ground surface, the backfill includes gravel layers. These soil materials are classified as SM, SP, and GP per USCS. The SPT N-Values collected in these materials indicate mostly medium dense and dense conditions with a few loose or very loose interbeds. While borings CDM-103 and CDM-104 appear to end within Unit B, the deepest part of boring CDM-101 (20 to 21 feet) shows an interlayering of silt and sand layers, indicating either soils underlying Unit B or backfill material different from what has been otherwise encountered.

Table 1 provides a summary of the unit thicknesses encountered.

Assessment of Geologic Hazards

The CDM Technical Memorandum of June 10, 2005 provides an assessment of specific geologic hazards in a seismic event – surface fault rupture and liquefaction. This assessment has not been updated and remains applicable.

Installed Remedial Measures

The 2005 Technical Memorandum describes planned future site remediation measures which have been implemented as described above. The replacement of excavated contaminated soil with compacted structural fill in the areas shown on **Figure 1** allows consideration of shallow foundation options for future buildings without basements, as described in more detail in the subsequent sections. It should be noted that foundation design for structures spanning the transition from compacted structural fill (Unit B) to areas underlain by the highly compressible natural soils (Layer 2) will require special attention with respect to differential settlement.

In general, development activities which involve surficial site improvements and installation of shallow foundations and concrete slabs-on-grade will result in minimal or limited disturbance, alteration, or removal of the Installed Remedial Features. Widened or thickened footings and floor slabs may be required to span over slurry wall, slurry wall breach, or interceptor trench locations. Deep foundations consisting of driven piles will generally be acceptable provided they do not alter the groundwater flow pattern. Deep foundations utilizing drilled shafts or drilled piles will have additional specific requirements to prevent creation of temporary or permanent vertical groundwater flow paths.

A soil and groundwater management plan must be submitted for written approval by the DTSC and S-W prior to any site investigative drilling or and other activities that otherwise disturb the site. Any contaminated site soils encountered during construction will have special requirements including, but not limited to, specific health and safety procedures and soil disposal methods. It should be noted that during logging of four borings outside the area of compacted structural fill a petroleum-like odor was recorded at different depths in Layer 2 soils (**Attachment A**).

Conceptual Geotechnical Design Recommendations

The 2005 Technical Memorandum provides recommendations based on conceptual geotechnical engineering evaluations. These recommendations remain valid other than as amended herein to take into account the additional data and changes in site conditions.

Low and Mid Rise Buildings – Conceptual Foundation Design

The low-rise (up to two stories) and some of the mid-rise (up to five stories) buildings can be supported on spread footings or on mat foundations bearing on suitable foundation bearing soils. Suitable foundation bearing soils consist of Layers 3, 4, 5, and Unit B (compacted structural fill), unsuitable soils include Layers 1 and 2. With the replacement of unsuitable soils by compacted structural fill in the areas shown on **Figures 1 and 2**, the area suitable for shallow foundation options has been extended. For final design of buildings, the thickness of suitable foundation bearing soils beneath the foundation subgrade level and the presence of slurry walls, slurry wall breaches, and the interceptor trench all need to be taken into account. A minimum thickness of suitable soil is required for adequate bearing capacity and for limiting settlement and differential settlement. If a portion of a building spans a remediation trench feature, the foundation and slabs may need to be strengthened to limit bearing pressures and differential movement. If a portion of a building extends into an area with unsuitable soils near the foundation subgrade level, these soils should be overexcavated and replaced with compacted structural fill to the minimum required depth. Overexcavation should not extend into the remediation trench features.

The minimum thickness of structural fill should be determined based on the dead and life foundation loads. For the lateral extent of the overexcavation and replacement, refer to the below section Construction Considerations, Compacted Fill. The deep foundation options discussed in the next section can be used as an alternative to soil replacement. If different foundation systems are used for the same building, differences in settlement behavior need to be taken into account.

Please refer to the 2005 Technical Memorandum for other aspects of foundation design, including maximum allowable bearing pressure and settlement estimates.

High Rise Buildings – Conceptual Foundation Design

The proposed high-rise buildings (over five stories) or mid-rise buildings with heavy loads should be supported on deep foundations bearing in Layers 3, 4 and/or 5. Applicable common deep foundation options include driven piles or deep-drilled shafts. Alternatively, it may be feasible and more economical to support some high-rise structures on an intermediate pile-raft foundation system.

Please refer to the 2005 Technical Memorandum for other aspects of deep foundation design, including achievable pile capacities.

Construction Considerations

Deep Foundation Construction

The following issues need to be addressed when installing deep foundations:

- Potential for contaminant migration during installation of deep foundations through contaminated soil: Although contaminated soils have been excavated and replaced with compacted structural fill in the area shown on **Figure 2**, limited contaminated soils remain on site and are undergoing long-term, natural attenuation. Construction means and methods will need to minimize the risk of contaminant migration, as outlined in the 2005 Technical Memorandum.
- Driving piles through stabilized soils: Driving displacement piles through stabilized soils such as the compacted structural fill placed in the area shown on **Figure 2** can result in damage to the piles, particularly concrete piles. Pre-drilling through these stabilized soils may be required prior to pile driving.

Excavation Support

No further deep excavations are foreseen. If overexcavation is considered for extending the compacted structural fill in order to implement shallow foundation options, sloping is likely the most economic measure. If site constraints require excavation support measures, the information provided in the 2005 Technical Memorandum remain applicable.

Compacted Fill

All imported structural fills and backfills shall be predominantly granular, less than 3 inches in any dimensions, free of organic and inorganic debris and other deleterious materials, with less than 35 percent passing the No. 200 sieve. All fill and backfill materials should be observed and tested by the geotechnical engineer prior to their use in order to evaluate suitability.

Granular structural fill should be placed in loose layers no thicker than 8 inches and compacted with a self-propelled vibratory roller. Each layer of fill should be compacted to at least 95 percent of the maximum dry density as determined by ASTM D1557. Lift thicknesses should be reduced to 4 inches in confined areas accessible only to hand guided compaction equipment.

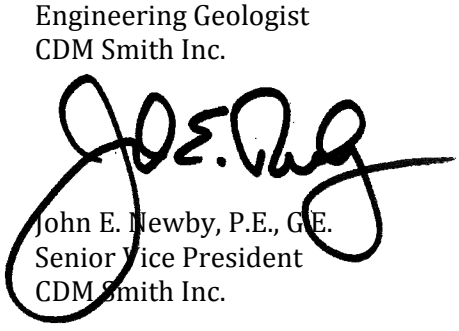
Structural fill placed below foundations should extend at least 3 feet beyond the edge of foundations, then outward and downward at a slope of 1 horizontal to 1 vertical (1H:1V).

Closure

The recommendations contained herein are considered suitable for conceptual design level evaluations associated with the proposed future development of the Sherwin-Williams Company manufacturing facility site in Emeryville, California as understood at this time and described herein. These recommendations have been prepared in accordance with generally accepted engineering practices. No other warranty, expressed or implied, is made. In the event that changes in the design or locations of the structures occur, the conclusions and recommendations contained herein should not be considered valid unless verified in writing by CDM Smith.

Very truly yours,

Ulf Gwildis
Engineering Geologist
CDM Smith Inc.



John E. Newby, P.E., G.E.
Senior Vice President
CDM Smith Inc.

cc: Pawn Sharma, CDM Smith
Randy Smith, CDM Smith

Attachments

References

Tables

Figures

Attachment A – Boring Logs

Attachment B – Laboratory Test Reports

Appendix:

Summary of Geotechnical Results and
Conceptual Geotechnical Engineering Recommendations for
The Sherwin-Williams Company Emeryville, CA Manufacturing Facility

References

CDM, 2009. *Feasibility Study, Sherwin-Williams Company, Emeryville, California*. Camp Dresser & McKee Inc. April 1, 2009.

CDM, 2010. *Final Remedial Action Plan, Sherwin-Williams Company, Emeryville, California*. Camp Dresser & McKee Inc. June 14, 2010.

CDM, 2011. *Final Remedial Design Implementation Plan, Sherwin-Williams Company, Emeryville, California*. Camp Dresser & McKee Inc. June 29, 2011.

CDM Smith, 2012. *Remedy Implementation Completion Report, Sherwin-Williams Company, Emeryville, California*. CDM Smith Inc. July 25, 2012.

ENTRIX, 2002. *Remedial Investigation, Sherwin-Williams Site, Emeryville, California*. ENTRIX. March 8, 2002.

Gradient, 2005. *Human Health Risk Assessment for 1450 Sherwin Avenue, Emeryville, California*. Gradient Corporation. February 11, 2005.

Tables

Sherwin-Williams
1450 Sherwin Avenue
Emeryville, California

Table 1
SUMMARY OF GEOTECHNICAL BORINGS (MARCH 2012)

Boring	Approximate Ground Surface Elevation [1]	Total Drilling Depth (ft)	Layer Thickness (ft)						Approximate Depth to Groundwater [2] (ft)
			Layer 1	Layer 2	Layer 3	Layer 4	Layer 5	Unit B	
CDM-101	19	21	2	NE	NE	NE	NE	~ 18	17
CDM-103	18	20	1	NE	NE	NE	NE	≥ 19	10
CDM-104	16	18	2	NE	NE	NE	NE	≥ 14	6.25
CDM-110	16	17.5	4	≥ 13.5	NE	NE	NE	NE	5.5
CDM-111	15	17	6.5	≥ 10.5	NE	NE	NE	NE	6.5
CDM-113	16	18	4.5	≥ 13.5	NE	NE	NE	NE	5.5
CDM-114	15.5	17.5	≥ 7.25/≤10	≥ 7.5	NE	NE	NE	NE	8.5

Notes:
[1] Vertical Datum: NAVD 88
[2] Depth to groundwater is reported at the time of drilling

Abbreviations:
NE Not Encountered

Sherwin-Williams
1450 Sherwin Avenue
Emeryville, California

Table 2
SUMMARY OF GEOTECHNICAL LABORATORY TEST RESULTS

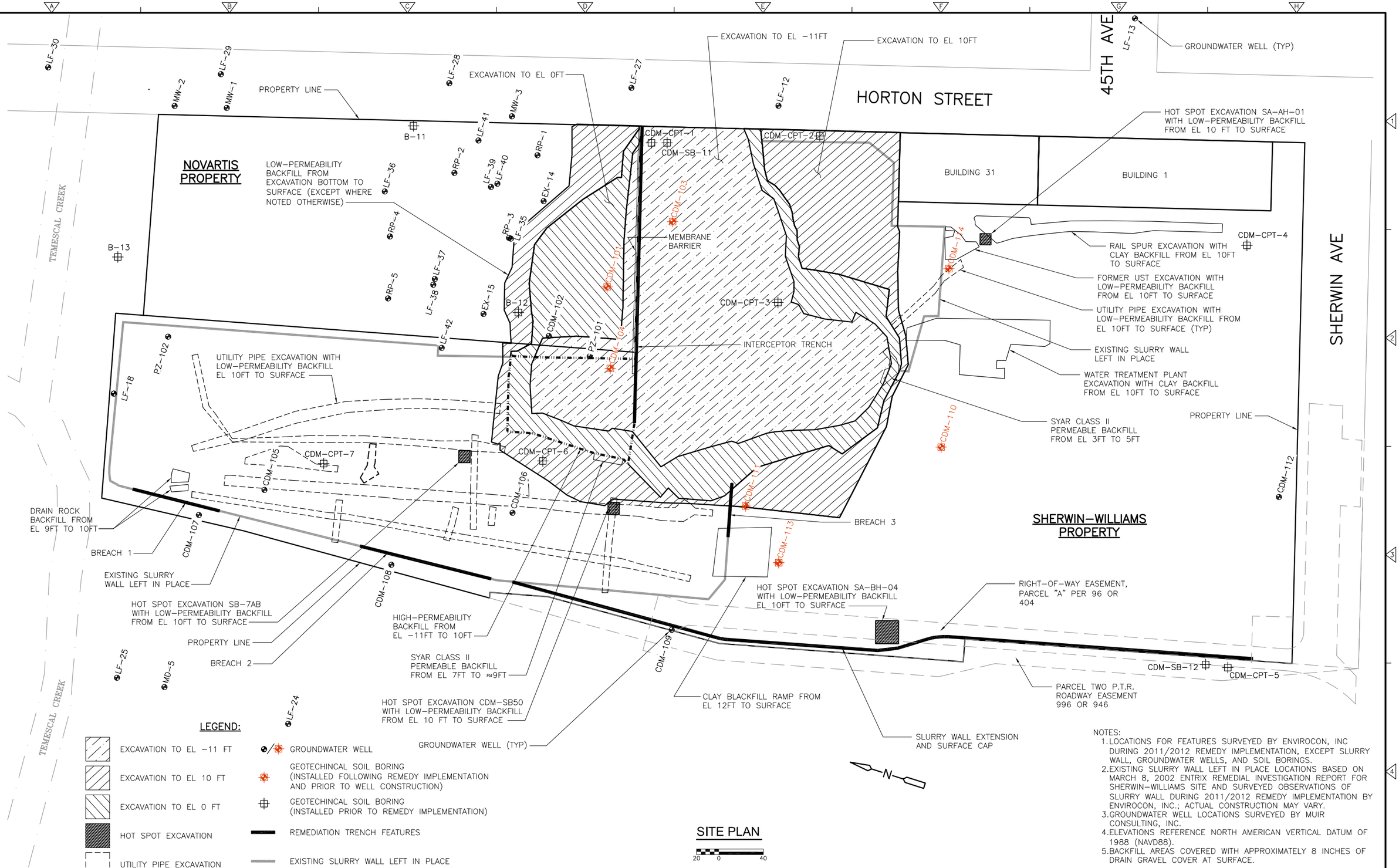
Boring	Sample Depth (ft)	Layer/Unit	Grain Size Analysis [1]			Atterberg Limits [2]			Moisture Content [3] (%)	USCS Classification
			Gravel (%)	Sand (%)	Fines (%)	LL (%)	PL (%)	PI (%)		
CDM-101	2 - 3.5								16.3	
CDM-101	3.5 - 5		13.0	47.8	39.2	27.8	23.8	4.0	13.5	SM
CDM-101	5 - 6.5								11.1	
CDM-101	6.5 - 8								14.1	
CDM-101	8 - 9.5								13.5	
CDM-101	9.5 - 11		18.0	40.4	41.6	27.5	22.4	5.1	13.3	SC - SM
CDM-101	11 - 12.5								13.8	
CDM-101	12.5 - 14								20.9	
CDM-101	14 - 15.5								16.0	
CDM-101	15.5 - 17								12.6	
CDM-101	18.5 - 20		14.6	53.5	31.9					
CDM-103	1 - 2.5								13.2	
CDM-103	2.5 - 4								14.7	
CDM-103	4 - 5.5								16.4	
CDM-103	5.5 - 7								13.7	
CDM-103	7 - 8.5		24.8	37.2	38.0	27.7	22.2	5.5	13.7	SC - SM
CDM-103	8.5 - 10								13.6	
CDM-103	19 - 20		7.1	49.6	43.3					
CDM-104	2 - 3.5								16.1	
CDM-104	3.5 - 5								17.2	
CDM-104	6.5 - 8		0	87.3	12.7					
CDM-104	14 - 15.5		0	86.4	13.6					
CDM-110	11.5 - 13		4.3	37.1	58.6					
CDM-111	6.5 - 8		1.5	30.2	68.3					
CDM-111	12.5 - 14		2.3	33.3	64.4					
CDM-111	16 - 17					35.2	20.4	14.8		
CDM-113	9.5 - 11					38.1	19.0	19.1		
CDM-113	15.5 - 17					41.6	21.2	20.4		
CDM-114 [4]	16 - 17.5					24.1	19.8	4.3		

Notes:
[1] Grain size analysis tests were performed in accordance with ASTM D422
[2] Atterberg Limit tests were performed in accordance with ASTM D4318
[3] Moisture content tests were performed in accordance with ASTM D2937
[4] Boring and sample designations CDM-114 and PZ-102 refer to the same location

Abbreviations:

LL	Liquid Limit
PL	Plastic Limit
PI	Plasticity Index
SC	Clayey Sand
SM	Silty Sand
USCS	Unified Soil Classification System

Figures



NOTES:
1. LOCATIONS FOR FEATURES SURVEYED BY ENVIROCON, INC DURING 2011/2012 REMEDY IMPLEMENTATION, EXCEPT SLURRY WALL, GROUNDWATER WELLS, AND SOIL BORINGS.
2. EXISTING SLURRY WALL LEFT IN PLACE LOCATIONS BASED ON MARCH 8, 2002 ENTRIX REMEDIAL INVESTIGATION REPORT FOR SHERWIN–WILLIAMS SITE AND SURVEYED OBSERVATIONS OF SLURRY WALL DURING 2011/2012 REMEDY IMPLEMENTATION BY ENVIROCON, INC.; ACTUAL CONSTRUCTION MAY VARY.
3. GROUNDWATER WELL LOCATIONS SURVEYED BY MUIR CONSULTING, INC.
4. ELEVATIONS REFERENCE NORTH AMERICAN VERTICAL DATUM OF 1988 (NAVD88).
5. BACKFILL AREAS COVERED WITH APPROXIMATELY 8 INCHES OF DRAIN GRAVEL COVER AT SURFACE.

REV. NO.	DATE	DRWN	CHKD	REMARKS

DESIGNED BY: x
DRAWN BY: x
SHEET CHK'D BY: x
CROSS CHK'D BY: x
APPROVED BY:
DATE: NOVEMBER 2012

CDM Smith
100 Pringle Avenue, Suite 300
Walnut Creek, CA 94596
Tel: (925) 933-2900

VERIFY SCALE
THIS BAR IS ONE INCH LONG AT FULL SCALE

SHERWIN-WILLIAMS COMPANY

EMERYVILLE, CALIFORNIA

FIGURE 1
BORING LOCATION MAP

PROJECT NO. 13452–81494
FILE NAME: GEOTECH MEMO FIG 1

P:\13452 Sherwin–Williams\81494 Emeryville\Completion Report\CAD\ GEOTECH MEMO FIG 1 10/31/12 12:29 talbotwk XREFS: CDM_2234–D, swexutil, swextopo, swexbndy, XR–SLRY–WALL, WELLS, (2011–04–14)SW topo, ACAD–WELLS, Aerialtoposh01
© CDM SMITH ALL RIGHTS RESERVED.
REUSE OF DOCUMENTS: THESE DOCUMENTS AND DESIGNS PROVIDED BY PROFESSIONAL SERVICE, INCORPORATED HEREIN, ARE THE PROPERTY OF CDM SMITH AND ARE NOT TO BE USED, IN WHOLE OR PART, FOR ANY OTHER PROJECT WITHOUT THE WRITTEN AUTHORIZATION OF CDM SMITH.

P:\13452 Sherwin-Williams\81494 Emeryville\Completion Report\CAD\ GEOTECH MEMO FIG 2 11/05/12 10:14 talbotwk XREFS: CDM_2234-D, swexutil, swextopo, swexbndy, XR-SLRY-WALL, WELLS, (2011-04-14)SW topo, ACAD-WELLS, Aerialtoposh01
© CDM SMITH ALL RIGHTS RESERVED.
REUSE OF DOCUMENTS: THESE DOCUMENTS AND DESIGNS PROVIDED BY PROFESSIONAL SERVICE, INCORPORATED HEREIN, ARE THE PROPERTY OF CDM SMITH AND ARE NOT TO BE USED, IN WHOLE OR PART, FOR ANY OTHER PROJECT WITHOUT THE WRITTEN AUTHORIZATION OF CDM SMITH.

PROPERTY LINE

NOVARTIS PROPERTY

TEMESCAL CREEK

HORTON STREET

45TH AVE

SHERWIN AVE

BUILDING 31

BUILDING 1

SHERWIN–WILLIAMS PROPERTY

EXCAVATION TO EL 10FT

EXCAVATION TO EL 0FT

EXCAVATION TO EL –11FT

LOW–PERMEABILITY BACKFILL FROM EXCAVATION BOTTOM TO SURFACE (EXCEPT WHERE NOTED OTHERWISE)

MEMBRANE BARRIER

INTERCEPTOR TRENCH

UTILITY PIPE EXCAVATION WITH LOW–PERMEABILITY BACKFILL EL 10FT TO SURFACE

FORMER UST EXCAVATION WITH LOW–PERMEABILITY BACKFILL FROM EL 10FT TO SURFACE

HOT SPOT EXCAVATION SA–AH–01 WITH LOW–PERMEABILITY BACKFILL FROM EL 10 FT TO SURFACE

RAIL SPUR EXCAVATION WITH CLAY BACKFILL FROM EL 10FT TO SURFACE

UTILITY PIPE EXCAVATION WITH LOW–PERMEABILITY BACKFILL FROM EL 10FT TO SURFACE (TYP)

EXISTING SLURRY WALL LEFT IN PLACE

WATER TREATMENT PLANT EXCAVATION WITH CLAY BACKFILL FROM EL 10FT TO SURFACE

SYAR CLASS II PERMEABLE BACKFILL FROM EL 3FT TO 5FT

DRAIN ROCK BACKFILL FROM EL 9FT TO 10FT

BREACH 1

BREACH 2

BREACH 3

EXISTING SLURRY WALL LEFT IN PLACE

HOT SPOT EXCAVATION SB–7AB WITH LOW–PERMEABILITY BACKFILL FROM EL 10FT TO SURFACE

HIGH–PERMEABILITY BACKFILL FROM EL –11FT TO 10FT

SYAR CLASS II PERMEABLE BACKFILL FROM EL 7FT TO ≈9FT

HOT SPOT EXCAVATION CDM–SB50 WITH LOW–PERMEABILITY BACKFILL FROM EL 10 FT TO SURFACE

GROUNDWATER WELL (TYP)

HOT SPOT EXCAVATION SA–BH–04 WITH LOW–PERMEABILITY BACKFILL EL 10FT TO SURFACE

RIGHT–OF–WAY EASEMENT, PARCEL "A" PER 96 OR 404

CLAY BLACKFILL RAMP FROM EL 12FT TO SURFACE

PARCEL TWO P.T.R. ROADWAY EASEMENT 996 OR 946

SLURRY WALL EXTENSION AND SURFACE CAP

RP–BH–009 (5)
B–11(7)
LF–31(12)
LF–34(5)
LF–32(5)
RP–BH–005(9)
RP–BH–010(8)
RP–BH–004(6)
LF–35(8)
B–13 (14)
RP–BH–018 (13)
RP–BH–11(10)
LF–33(6)
RP–BH–09(2)
RP–BH–08(13)
B–12(8)
CT–3(–7)
LF–B6(–12)
LF–B2(–14)
IS–BH–05(–3)
CDM–CPT–7(–7)
CDM–CPT–6(–28)
GT–1(6)
GT–2(–3)
LF–B3(–15)
CDM–CPT–1(–5)
LF–B6(–12)
CDM–SB–11(–5)
IS–BH–07 (–6)
LF–B5(<–22)
CDM–CPT–2(–8)
IS–BH–06(–15)
CT–4(–11)
LF–P21(2)
CDM–CPT–3
IS–BH–02(–7)
LF–B4(–16)
SA–BH–01(–13)
GT–5(–12)
CDM–CPT–4(–15)
SA–AH–20(–3)
SA–AH–19(–13)
SA–BW–01(–18)
SA–AH–18(<–13)
CDM–SB–12(–12)
CDM–CPT–5(–18)

10 FT
0 FT
–10 FT

LEGEND:

- EXCAVATION TO EL –11 FT
- EXCAVATION TO EL 10 FT
- EXCAVATION TO EL 0 FT
- HOT SPOT EXCAVATION
- UTILITY PIPE EXCAVATION
- SELECTED SOIL BORING – INSTALLED PRIOR TO REMEDY IMPLEMENTATION (INFERRED ELEVATION OF BASE OF LAYERS 1 AND 2)
- REMEDIATION TRENCH FEATURES
- EXISTING SLURRY WALL LEFT IN PLACE
- INFERRED ELEVATION OF BASE OF LAYERS 1 AND 2 (CONTOUR INTERVAL 10 FEET)

N

SITE PLAN

20 0 40

THIS MAP IS NOT INTENDED FOR USE IN DESIGN BUT FOR CONCEPTUAL PROJECT PLANNING PURPOSES. THE DATA ILLUSTRATED PROVIDE A REASONABLE INTERPRETATION OF THE BASE OF UNSUITABLE SHALLOW SOILS BASED ON DATA DEVELOPED BY CDM SMITH AND OTHER CONSULTANTS UNDER CONTRACT TO THE SHERWIN–WILLIAMS COMPANY. CDM SMITH RECOMMENDS THAT ADDITIONAL GEOTECHNICAL INVESTIGATIONS BE CONDUCTED FOLLOWING REFINEMENT OF THE CONCEPTUAL DESIGN.

NOTES:
1. LOCATIONS FOR FEATURES SURVEYED BY ENVIROCON, INC DURING 2011/2012 REMEDY IMPLEMENTATION, EXCEPT SLURRY WALL, GROUNDWATER WELLS, AND SOIL BORINGS.
2. EXISTING SLURRY WALL LEFT IN PLACE LOCATIONS BASED ON MARCH 8, 2002 ENTRIX REMEDIAL INVESTIGATION REPORT FOR SHERWIN–WILLIAMS SITE AND SURVEYED OBSERVATIONS OF SLURRY WALL DURING 2011/2012 REMEDY IMPLEMENTATION BY ENVIROCON, INC.; ACTUAL CONSTRUCTION MAY VARY.
3. GROUNDWATER WELL LOCATIONS SURVEYED BY MUIR CONSULTING, INC.
4. ELEVATIONS REFERENCE NORTH AMERICAN VERTICAL DATUM OF 1988 (NAVD88).
5. BACKFILL AREAS COVERED WITH APPROXIMATELY 8 INCHES OF DRAIN GRAVEL COVER AT SURFACE.

REV. NO.	DATE	DRWN	CHKD	REMARKS

DESIGNED BY: X
DRAWN BY: X
SHEET CHK'D BY: X
CROSS CHK'D BY: X
APPROVED BY:
DATE: NOVEMBER 2012

CDM Smith
100 Pringle Avenue, Suite 300
Walnut Creek, CA 94596
Tel: (925) 933-2900

VERIFY SCALE
THIS BAR IS ONE INCH LONG AT FULL SCALE

SHERWIN-WILLIAMS COMPANY

EMERYVILLE, CALIFORNIA

FIGURE 2
ISOPACH MAP – BASE OF LAYER 1 AND 2

PROJECT NO. 13452–81494
FILE NAME: GEOTECH MEMO FIG 2

Attachment A – Boring Logs

PROJECT: Sherwin-Williams Site
LOCATION: Emeryville, CA

MONITORING WELL NO: **CDM-101**

STARTED: 3/8/12 COMPLETED: 3/8/12
DRILLING COMPANY: Gregg Drilling and Testing Co.
DRILLING EQUIPMENT: D-55
DRILLING METHOD: Hollow Stem Auger, 8 In. Dia. Borehole
SAMPLING METHOD: Split Spoon
SURFACE COMPLETION: Steel Flush-mount

NORTHING: 2130911.96 Feet EASTING: 6044859.63 Feet
G.S. ELEVATION: 19.3 Feet M.P. ELEV: 18.97
WATER: 17 Feet TOTAL DEPTH: 21.0 Feet
LOGGED BY: S. Mysel
HORIZONTAL DATUM: NAD83, COORD. SYS.: California State Plane Zone I
VERTICAL DATUM:

DEPTH (feet)	GRAPHIC LOG	USCS	DESCRIPTION (Sampler Length: 1.5 Feet)	Blow Counts	LITHOLOGIC SAMPLE	RECOV. (feet)	PID (ppm)	ELEV. (ft)	ANALYTICAL SAMPLE	SAMPLE ID
			0-2': ASPHALT and MEDIUM GRAVEL cover, angular, dry.							
		SM	2'-3.5': Dark brown SILTY SAND, some clay, medium dense, well sorted, moist.	3 8 16		1.5				
		SM	3.5'-5': Dark brown SILTY SAND, some clay, medium dense, well sorted, moist.	8 9 6		1.5		15		
5		SM	5'-6.5': Dark brown SILTY SAND, some clay, medium dense, well sorted, moist.	6 9 12		1.5				
		SM	6.5'-8': Dark brown SILTY SAND, some clay, dense, well sorted, moist.	6 12 17		1.5				
		SM	8'-9.5': Dark brown SILTY SAND, some clay, dense, well sorted, moist.	7 12 15		1.5		10		
10		SM	9.5'-11': Dark brown SILTY SAND, some gravel, some clay, medium dense, well sorted, moist.	5 6 11		1.5				
		SM	11'-12.5': Dark brown SILTY SAND, some clay, loose, well sorted, moist.	5 7 2		1.5				
		SM	12.5'-14': Dark brown SILTY SAND, some clay, medium dense, well sorted, moist.	5 9 8		1		5		
15		SM	14'-15.5: Dark brown SILTY SAND, some clay, medium dense, well sorted, moist.	7 7 8		1.5				
		SP SM	15.5'-17': Dark brown SILTY SAND, some clay, very loose, well sorted, moist.	1 2 2		1.5		0		
		SP ML SP	17'-17.5': Dark brown FINE to MEDIUM SAND, angular, medium dense, well sorted, wet.	6 9 7		1				
20		ML SP	17.5'-18.5': Dark brown SILTY SAND, some clay, medium dense, well sorted, wet.	4 5 6						
			18.5'-19.75': Dark brown SILTY SAND, some gravel, some clay, medium dense, well sorted, moist.	2 4				-5		
25			19.75'-20': Dark brown FINE to MEDIUM SAND, angular, medium dense, well sorted, wet.							
			20'-20.25': Gray SILT, some clay, medium stiff, medium plasticity, wet.					-10		
30			20.25'-20.5': Gray COARSE SAND and FINE GRAVEL, angular, loose, well sorted, wet.							
			20.5'-20.75': Gray SILT, some clay, soft, medium plasticity, wet.					-15		
			20.75'-21': Gray COARSE SAND and FINE GRAVEL, angular, very loose, well sorted, wet.							
35			END OF BORING AT 21 FEET BGS.					-20		

CDM Smith Inc.
100 Pringle Avenue, Suite 300
Walnut Creek, CA 94596
Telephone: 925-933-2900
Fax: 925-933-4174

Monitoring Well LOG

PROJECT NO.

WHITE CHEMICAL HSA BORING LOG SHERWIN-WILLIAMS.GPJ STANDARD_ENVIRONMENTAL_PROJECT(2).GDT 7/24/12 REV.

PROJECT: Sherwin-Williams Site
LOCATION: Emeryville, CA

MONITORING WELL NO: **CDM-103**

STARTED: 3/7/12 COMPLETED: 3/8/12
DRILLING COMPANY: Gregg Drilling and Testing Co.
DRILLING EQUIPMENT: D-55
DRILLING METHOD: Hollow Stem Auger, 8 In. Dia. Borehole
SAMPLING METHOD: Split Spoon
SURFACE COMPLETION: Steel Stickup

NORTHING: 2130873.47 Feet EASTING: 6044933.36 Feet
G.S. ELEVATION: 17.79 Feet M.P. ELEV: 20.56
WATER: 10 Feet TOTAL DEPTH: 20.0 Feet
LOGGED BY: S. Mysel
HORIZONTAL DATUM: NAD83, COORD. SYS.: California State Plane Zone I
VERTICAL DATUM:

DEPTH (feet)	USCS	DESCRIPTION (Sampler Length: 1.5 Feet)	Blow Counts	RECOV. (feet)	PID (ppm)	ELEV. (ft)
0	GP	0-1': Gray MEDIUM GRAVEL, loose, well sorted, dry.	20 10 10	1.5		15
	SM	1'-2.5': Dark brown SILTY SAND, trace clay, medium dense, well sorted, dry.	6 9 13	1.25		
	GP	2.5'-3': Gray MEDIUM GRAVEL, medium dense, well sorted, dry.	5 10 9	1.5		
5	SM	3'-4': Dark brown SILTY SAND, trace clay, medium dense, well sorted, dry.	7 13 14	1.25		10
	SM	4'-5.5': Dark brown SILTY SAND, trace clay, medium dense, well sorted, dry.	6 11 14	1.5		
	SM	5.5'-7': Dark brown SILTY SAND, trace clay, dense, well sorted, moist.	7 13 10	1		5
10	SM	7'-8.5': Dark brown SILTY SAND, some gravel, trace clay, dense, well sorted, moist.	6 9 9	1.5		
	SM	8.5'-10': Dark brown SILTY SAND, trace clay, few medium gravel, dense, well sorted, moist.	5 9 12	1.25		0
	SM	10'-11.5': Dark brown SILTY SAND, trace clay, few medium gravel, dense, well sorted, wet.	5 10 12	1.25		
15	SM	11.5'-13': Dark brown SILTY SAND, trace clay, few medium gravel, dense, well sorted, wet.	4 4 3	1.5		-5
	SM	13'-14.5: Dark brown SILTY SAND, trace clay, few medium gravel, dense, well sorted, wet.	NA NA NA	1		
	SM	14.5'-16': Dark brown SILTY SAND, trace clay, few medium gravel, loose, well sorted, wet.	NA NA 8			-10
20		16'-17.5': Dark brown SILTY SAND, trace clay, few medium gravel, loose, well sorted, wet.	8 11			
		17.5'-19': Dark brown SILTY SAND, trace clay, few medium gravel, loose, well sorted, wet.				-15
		19'-20': Dark brown SILTY SAND, trace clay, few medium gravel, loose, well sorted, wet.				
25		END OF BORING AT 20 FEET BGS.				-20
30						
35						

LITHOLOGIC SAMPLE | ANALYTICAL SAMPLE | SAMPLE ID

CDM Smith Inc.
100 Pringle Avenue, Suite 300
Walnut Creek, CA 94596
Telephone: 925-933-2900
Fax: 925-933-4174

Monitoring Well LOG

PROJECT NO.

WHITE CHEMICAL HSA BORING LOG SHERWIN-WILLIAMS.GPJ STANDARD_ENVIRONMENTAL_PROJECT(2).GDT 7/24/12 REV.

PROJECT: Sherwin-Williams Site
LOCATION: Emeryville, CA

MONITORING WELL NO: **CDM-104**

STARTED: 3/9/12 COMPLETED: 3/9/12
DRILLING COMPANY: Gregg Drilling and Testing Co.
DRILLING EQUIPMENT: D-55
DRILLING METHOD: Hollow Stem Auger, 8 In. Dia. Borehole
SAMPLING METHOD: Split Spoon
SURFACE COMPLETION: Steel Stickup

NORTHING: 2130887.13 Feet EASTING: 6044790.61 Feet
G.S. ELEVATION: 15.81 Feet M.P. ELEV: 18.6
WATER: 6.25 Feet TOTAL DEPTH: 18.0 Feet
LOGGED BY: S. Mysel
HORIZONTAL DATUM: NAD83, COORD. SYS.: California State Plane Zone I
VERTICAL DATUM:

DEPTH (feet)	GRAPHIC LOG	USCS	DESCRIPTION (Sampler Length: 1.5 Feet)	Blow Counts	LITHOLOGIC SAMPLE	RECOV. (feet)	PID (ppm)	ELEV. (ft)	ANALYTICAL SAMPLE	SAMPLE ID
		GP	0-2': Gray MEDIUM GRAVEL, loose, well sorted, dry.					15		
		SM	2'-3.5': Brown SILTY FINE SAND, medium dense, well sorted, moist.	7 8 8		1.5				
		SM	3.5'-5': Brown SILTY FINE SAND, medium dense, well sorted, moist.	6 10 9		1.5				
5		SM	5'-6.25': Brown SILTY FINE SAND, medium dense, well sorted, moist.	4 5 7		1.5		10		
		SP	6.25'-6.5': Brown FINE to MEDIUM SAND, angular, medium dense, well sorted, wet.	6 9 8		1.5				
		SP	6.5'-8': Brown FINE to MEDIUM SAND, trace silt, angular, medium dense, well sorted, wet.	5 9 12		1.5		5		
10		SP	8'-9.5': Brown FINE to MEDIUM SAND, angular, medium dense, well sorted, wet.	5 9 8		1.25				
		SP	9.5'-11': Brown FINE to MEDIUM SAND, angular, medium dense, well sorted, wet.	3 7 8		1.5				
		SP	11'-12.5': Brown FINE to MEDIUM SAND, angular, medium dense, well sorted, wet.	5 8 6		1.5		0		
15		SP	12.5'-14: Brown FINE to MEDIUM SAND, angular, medium dense, well sorted, wet.	8 14 10		1.5				
		SP	14'-15.5': Brown FINE to MEDIUM SAND, trace silt, angular, medium dense, well sorted, wet.	3 4 3				-5		
20			15.5'-17': Brown FINE to MEDIUM SAND, angular, loose, well sorted, wet.	6 2						
			17'-18': Brown FINE to MEDIUM SAND, angular, loose, well sorted, wet.					-10		
25			END OF BORING AT 18 FEET BGS.							
30								-15		
35								-20		

CDM Smith Inc.
100 Pringle Avenue, Suite 300
Walnut Creek, CA 94596
Telephone: 925-933-2900
Fax: 925-933-4174

Monitoring Well LOG

PROJECT NO.

WHITE CHEMICAL HSA BORING LOG SHERWIN-WILLIAMS.GPJ STANDARD_ENVIRONMENTAL_PROJECT(2).GDT 7/24/12 REV.

PROJECT: Sherwin-Williams Site
LOCATION: Emeryville, CA

MONITORING WELL NO: **CDM-110**

STARTED: 3/12/12 COMPLETED: 3/12/12
DRILLING COMPANY: Gregg Drilling and Testing Co.
DRILLING EQUIPMENT: D-55
DRILLING METHOD: Hollow Stem Auger, 8 In. Dia. Borehole
SAMPLING METHOD: Split Spoon
SURFACE COMPLETION: Steel Flush-mount

NORTHING: 2130581.99 Feet EASTING: 6044812.80 Feet
G.S. ELEVATION: 16 Feet M.P. ELEV: 15.62
WATER: 5.5 Feet TOTAL DEPTH: 18.0 Feet
LOGGED BY: S. Mysel
HORIZONTAL DATUM: NAD83, COORD. SYS.: California State Plane Zone I
VERTICAL DATUM:

DEPTH (feet)	GRAPHIC LOG	USCS	DESCRIPTION (Sampler Length: 1.5 Feet)	Blow Counts	LITHOLOGIC SAMPLE	RECOV. (feet)	PID (ppm)	ELEV. (ft)	ANALYTICAL SAMPLE	SAMPLE ID
			0-1': CONCRETE.					15		
		GP	1'-4': Gray MEDIUM GRAVEL and brown FILL.							
5		CL	4'-5.5': Black CLAY with some coarse sand, fine gravel, high plasticity, medium stiff, moist, petroleum-like odor.	1 3 2		1.5				
		CL		1 3 1		1.5		10		
		CL	5.5'-7': Black CLAY with some medium to coarse sand, fine gravel, high plasticity, soft, wet, petroleum-like odor.	2 2 3		1.5				
		CL								
		SW	7'-7.5': Black CLAY with some silt, fine gravel, high plasticity, medium stiff, wet, petroleum-like odor.	2 2 2		0.5				
10		SP				1.5		5		
		ML	7.5'-8.5': Black CLAY with some silt, high plasticity, medium stiff, wet, petroleum-like odor.	2 4 2		1.5				
		SP								
		ML								
			8.5'-10': Gray MEDIUM to COARSE SAND and FINE to MEDIUM GRAVEL, angular, very loose, poorly sorted, wet, slight petroleum-like odor.	1 2 2		0				
15		SP		0 1 2				0		
		CL								
		CL	10'-11': Gray FINE to MEDIUM SAND with fine gravel, angular, loose, well sorted, wet.	1 1 1						
		ML								
			11'-11.5': Gray SILT, soft, wet.							
20			11.5'-12.5': Gray FINE to MEDIUM SAND with fine gravel, angular, very loose, well sorted, wet.					-5		
			12.5'-13': Gray SILT and CLAY, soft, wet.							
			13'-14.5': NO RECOVERY.							
25			14.5'-15': Gray FINE to MEDIUM SAND with fine gravel, angular, very loose, well sorted, wet.					-10		
			15'-16': Black CLAY, high plasticity, soft, wet.							
			16'-17': Black CLAY, high plasticity, soft, wet.							
			17'-17.5': Gray SILT, soft, wet.							
30			NO SAMPLE TAKEN.					-15		
			END OF BORING AT 18 FEET BGS.							
35								-20		

CDM Smith Inc.
100 Pringle Avenue, Suite 300
Walnut Creek, CA 94596
Telephone: 925-933-2900
Fax: 925-933-4174

Monitoring Well LOG

PROJECT NO.

WHITE CHEMICAL HSA BORING LOG SHERWIN-WILLIAMS.GPJ STANDARD_ENVIRONMENTAL_PROJECT(2).GDT 7/24/12 REV.

PROJECT: Sherwin-Williams Site
LOCATION: Emeryville, CA

MONITORING WELL NO: **CDM-111**

STARTED: 3/9/12 COMPLETED: 3/9/12
DRILLING COMPANY: Gregg Drilling and Testing Co.
DRILLING EQUIPMENT: D-55
DRILLING METHOD: Hollow Stem Auger, 8 In. Dia. Borehole
SAMPLING METHOD: Split Spoon
SURFACE COMPLETION: Steel Flush-mount

NORTHING: 2130733.76 Feet EASTING: 6044709.23 Feet
G.S. ELEVATION: 14.81 Feet M.P. ELEV: 18.14
WATER: 6.5 Feet TOTAL DEPTH: 17.0 Feet
LOGGED BY: S. Mysel
HORIZONTAL DATUM: NAD83, COORD. SYS.: California State Plane Zone I
VERTICAL DATUM:

DEPTH (feet)	USCS	DESCRIPTION (Sampler Length: 1.5 Feet)	Blow Counts	RECOV. (feet)	PID (ppm)	ELEV. (ft)
		0-5': MEDIUM GRAVEL, CONCRETE, FILL.				
5	SM	5'-6.5': Brown FINE SAND and SILT, some medium gravel, concrete pieces, angular, loose, poorly sorted.	8 5 3	0.5		10
	SW					
	CL	6.5'-7': Gray COARSE SAND and FINE to MEDIUM GRAVEL, angular, loose, poorly sorted, wet.	5 3 2	1.5		
	SW					
	CL	7'-8': Gray CLAY and SILT, medium stiff, medium plasticity, wet.	2 2 1	0.75		
10	SW					5
	CL	8'-8.5': Gray COARSE SAND and FINE to MEDIUM GRAVEL, angular, very loose, poorly sorted, wet.	0 0 2	1.5		
	SC					
	SC	8.5'-8.75': Gray CLAY, soft, medium plasticity, wet.	1 2 2	1.5		
	SW					
	CL	8.75'-9.5': NO RECOVERY.	0 2 1	1.5		0
15	SC					
	SC	9.5'-10: Gray COARSE SAND and FINE to MEDIUM GRAVEL, angular, very loose, poorly sorted, wet.	0 2 2	1.5		
	CL					
		10'-11': Gray CLAY, soft, medium plasticity, wet.	1 2 2			-5
20		11'-11.5': Brown CLAY with FINE SAND and SILT, soft, medium plasticity, wet, petroleum-like odor.				
		11.5'-12.5': Brown CLAY with FINE SAND, SILT and FINE GRAVEL, soft, medium plasticity, wet, petroleum-like odor.				
25		12.5'-13.5: Gray COARSE SAND and FINE to MEDIUM GRAVEL, angular, very loose, poorly sorted, wet.				-10
		13.5'-14': Gray CLAY and SILT, soft, medium plasticity, wet.				
30		14'-15.5': Brown CLAY with FINE SAND, SILT and FINE GRAVEL, soft, medium plasticity, wet, petroleum-like odor.				-15
		15.5'-16': Brown CLAY with FINE SAND, SILT and FINE GRAVEL, soft, medium plasticity, wet, petroleum-like odor.				
35		16'-17': Gray CLAY, soft, medium plasticity, wet.				-20
		END OF BORING AT 17 FEET BGS.				

LITHOLOGIC SAMPLE | ANALYTICAL SAMPLE | SAMPLE ID

CDM Smith Inc.
100 Pringle Avenue, Suite 300
Walnut Creek, CA 94596
Telephone: 925-933-2900
Fax: 925-933-4174

Monitoring Well LOG

PROJECT NO.

WHITE CHEMICAL HSA BORING LOG SHERWIN-WILLIAMS.GPJ STANDARD_ENVIRONMENTAL_PROJECT(2).GDT 7/24/12 REV.

PROJECT: Sherwin-Williams Site
LOCATION: Emeryville, CA

MONITORING WELL NO: **CDM-113**

STARTED: 3/8/12 COMPLETED: 3/8/12
DRILLING COMPANY: Gregg Drilling and Testing Co.
DRILLING EQUIPMENT: D-55
DRILLING METHOD: Hollow Stem Auger, 8 In. Dia. Borehole
SAMPLING METHOD: Split Spoon
SURFACE COMPLETION: Steel Flush-mount

NORTHING: 2130690.09 Feet EASTING: 6044669.57 Feet
G.S. ELEVATION: 15.96 Feet M.P. ELEV: 15.47
WATER: 5.5 Feet TOTAL DEPTH: 18.0 Feet
LOGGED BY: S. Mysel
HORIZONTAL DATUM: NAD83, COORD. SYS.: California State Plane Zone I
VERTICAL DATUM:

DEPTH (feet)	GRAPHIC LOG	USCS	DESCRIPTION (Sampler Length: 1.5 Feet)	Blow Counts	LITHOLOGIC SAMPLE	RECOV. (feet)	PID (ppm)	ELEV. (ft)	ANALYTICAL SAMPLE	SAMPLE ID
			0-0.7': CONCRETE.					15		
		GP	0.7'-3.5': MEDIUM to COARSE GRAVEL FILL.							
		GP	3.5'-4.5': MEDIUM to COARSE GRAVEL FILL.	10 13 33		1				
5		SP SP CL	4.5'-5': Grayish brown FINE to MEDIUM SAND, some silt and fine to medium gravel, angular, dense, well sorted, dry.	5 6 4		1.5		10		
		CL	5'-5.5': Grayish brown FINE to MEDIUM SAND, some silt and fine to medium gravel, angular, loose, well sorted, dry.	2 2 3		1.5				
		CL	5.5'-6.5': Dark brown CLAY, high plasticity, stiff, wet.	0 1 1		1				
10		GP CL	6.5'-8': Dark brown CLAY with trace silt, fine sand, and fine gravel, high plasticity, stiff, wet, petroleum-like odor.	1 1 2		1.5		5		
		CL CL	8'-9.5': Dark brown CLAY with trace silt, fine sand, and fine gravel, high plasticity, medium hard, wet, slight petroleum-like odor.	1 1 1		1.25				
15		CL CL CL	9.5'-11': Dark brown CLAY, medium plasticity, stiff, wet.	2 1 0		1.5		0		
			11'-11.25': MEDIUM GRAVEL, angular, very loose, well sorted, wet.	0 2 2		1				
20			11.25'-12.25': Dark brown CLAY, high plasticity, soft, wet.	1 1 1				-5		
			12.25'-12.5': NO RECOVERY.	1 2						
			12.5'-13.25': Gray CLAY with trace silt, and fine gravel, high plasticity, very soft, wet.							
25			13.25'-14': Gray CLAY with trace silt, high plasticity, very soft, wet.					-10		
			14'-15.5': Gray CLAY with trace silt, high plasticity, soft, wet.							
			15.5'-16': Gray CLAY with trace silt, and fine gravel, medium plasticity, soft, wet.							
30			16'-17': Gray CLAY, medium plasticity, soft, wet.					-15		
			17'-18': Gray CLAY, high plasticity, soft, wet.							
			END OF BORING AT 18 FEET BGS.							
35								-20		

WHITE CHEMICAL HSA BORING LOG SHERWIN-WILLIAMS.GPJ STANDARD_ENVIRONMENTAL_PROJECT(2).GDT 7/24/12 REV.

CDM Smith Inc.
100 Pringle Avenue, Suite 300
Walnut Creek, CA 94596
Telephone: 925-933-2900
Fax: 925-933-4174

Monitoring Well LOG

PROJECT NO.

PROJECT: Sherwin-Williams Site
LOCATION: Emeryville, CA

MONITORING WELL NO: **CDM-114**

STARTED: 3/12/12 COMPLETED: 3/12/12
DRILLING COMPANY: Gregg Drilling and Testing Co.
DRILLING EQUIPMENT: D-55
DRILLING METHOD: Hollow Stem Auger, 8 In. Dia. Borehole
SAMPLING METHOD: Split Spoon
SURFACE COMPLETION: Steel Flush-mount

NORTHING: 2130623.78 Feet EASTING: 6044967.96 Feet
G.S. ELEVATION: 15.49 Feet M.P. ELEV: 14.72
WATER: 8.5 Feet TOTAL DEPTH: 17.5 Feet
LOGGED BY: S. Mysel
HORIZONTAL DATUM: NAD83, COORD. SYS.: California State Plane Zone I
VERTICAL DATUM:

DEPTH (feet)	GRAPHIC LOG	USCS	DESCRIPTION (Sampler Length: 1.5 Feet)	Blow Counts	LITHOLOGIC SAMPLE	RECOV. (feet)	PID (ppm)	ELEV. (ft)	ANALYTICAL SAMPLE	SAMPLE ID
		GP	0-4': AB GRAVEL COVER.					15		
5		SM	4'-5.5': Brown SILTY FINE SAND, trace medium gravel and clay, angular, medium dense, well sorted, moist.	2 5 9		1.5		10		
		SM	5.5'-7': Brown SILTY FINE SAND, trace medium gravel and clay, angular, medium dense, well sorted, moist.	3 6 6		1.5				
		SW	7'-7.25': CONCRETE.	10 10 8		0.25				
10		ML SW	7.25'-8.5': NO RECOVERY.	5 3 1		0.75		5		
		CL	8.5'-9.25': Brown FINE to MEDIUM SAND, some silt, very loose, wet, petroleum-like odor.	2 1 1		1.5				
		CL	9.25'-10': NO RECOVERY.	1 2 1		1.5				
15		CL	10'-10.25': Gray SILT with FINE SAND and CLAY, medium plasticity, soft, wet, petroleum-like odor.	1 1 1		1.5		0		
		SC	10.25'-11.5': MEDIUM to COARSE SAND and FINE to MEDIUM GRAVEL, angular, very loose, wet, petroleum-like odor.	1 2 1		1.5				
20			11.5'-13': Brown CLAY, high plasticity, soft, wet, petroleum-like odor.	3 3 2				-5		
			13'-14.5': Gray CLAY, high plasticity, soft, wet, slight petroleum-like odor.							
			14.5'-16': Gray CLAY with FINE GRAVEL, angular, high plasticity, soft, wet, slight petroleum-like odor.							
25			16'-17.5': Gray SILTY CLAY, medium plasticity, medium stiff, wet.					-10		
			END OF BORING AT 17.5 FEET BGS.							
30								-15		
35								-20		

CDM Smith Inc.
100 Pringle Avenue, Suite 300
Walnut Creek, CA 94596
Telephone: 925-933-2900
Fax: 925-933-4174

Monitoring Well LOG

PROJECT NO.

WHITE CHEMICAL HSA BORING LOG SHERWIN-WILLIAMS.GPJ STANDARD_ENVIRONMENTAL_PROJECT(2).GDT 7/24/12 REV.

Attachment B – Laboratory Test Reports

Particle Size Distribution Report

	% COBBLES	% GRAVEL	% SAND	% SILT	% CLAY	USCS	AASHTO	PL	LL
○		14.6	53.5	23.7	8.2				

SIEVE inches size	PERCENT FINER ○		
1"	100.0		
3/4"	95.6		
3/8"	90.7		
GRAIN SIZE			
D_{60}	0.259		
D_{30}	0.0683		
D_{10}	0.0043		
COEFFICIENTS			
C_c	4.23		
C_u	60.97		

SIEVE number size	PERCENT FINER ○		
#4	85.4		
#10	81.6		
#30	76.8		
#40	72.4		
#50	63.7		
#100	47.5		
#200	31.9		
#270	25.5		

SOIL DESCRIPTION

○ Dark Olive Gray Silty SAND

REMARKS:

○

○ Source: CDM-101-18-19.5-20120320

Elev./Depth: 18-19.5'

COOPER TESTING LABORATORY

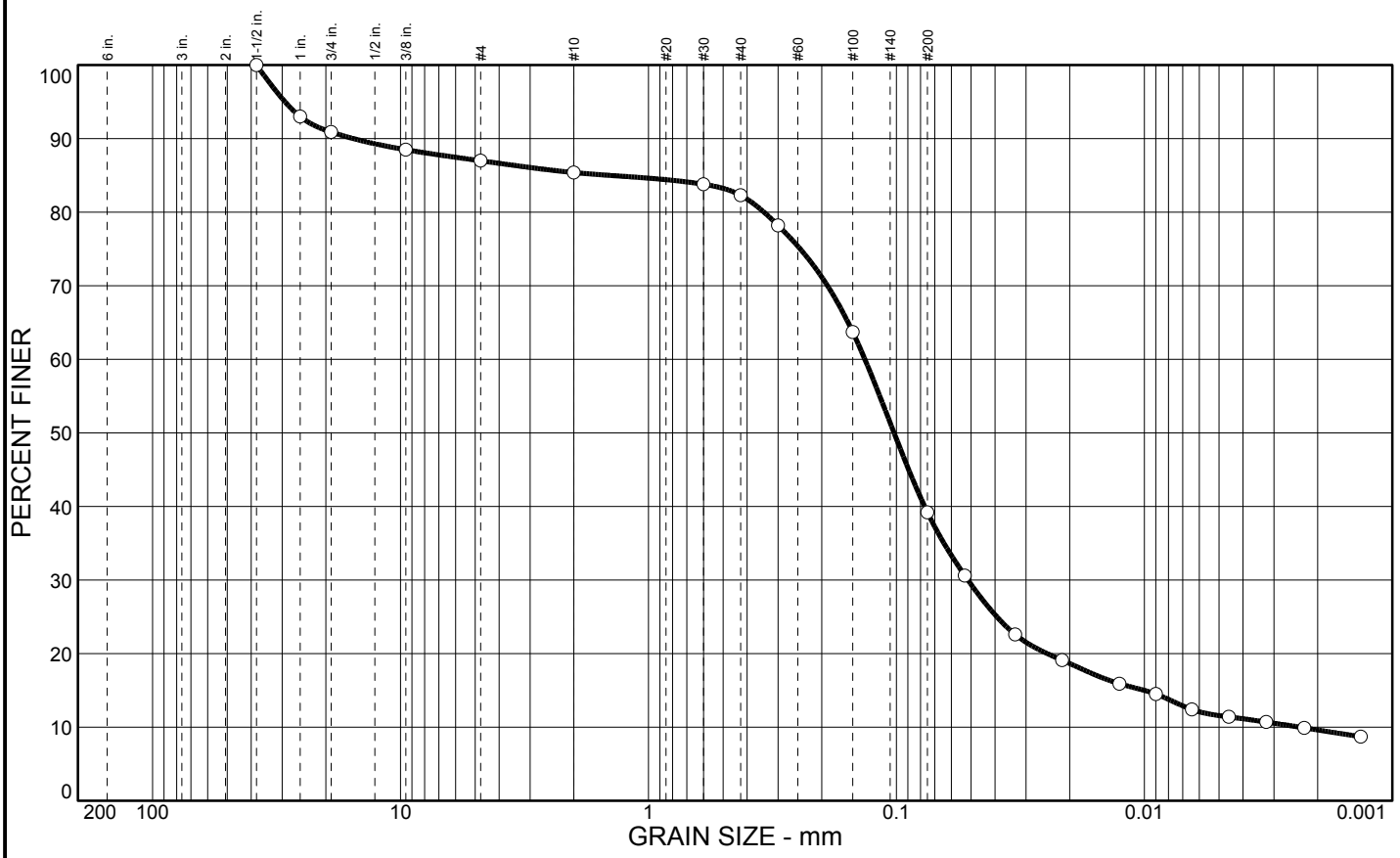
Client: CDM Smith

Project: Sherwin-Williams, Emeryville - 13452

Project No.: 580-018

Figure

Particle Size Distribution Report



	% COBBLES	% GRAVEL	% SAND	% SILT	% CLAY	USCS	AASHTO	PL	LL
○		13.0	47.8	29.6	9.6	SM		23.8	27.8

SIEVE inches size	PERCENT FINER ○		
1.5"	100.0		
1"	93.0		
3/4"	90.9		
3/8"	88.5		

GRAIN SIZE			
D_{60}	0.134		
D_{30}	0.0515		
D_{10}	0.0024		

COEFFICIENTS			
C_c	8.37		
C_u	56.75		

SIEVE number size	PERCENT FINER ○		
#4	87.0		
#10	85.4		
#30	83.8		
#40	82.3		
#50	78.2		
#100	63.7		
#200	39.2		
#270	30.6		

SOIL DESCRIPTION

○ Dark Olive Gray Silty SAND

REMARKS:

○

○ Source: CDM-101-3.5-5-20120320 Elev./Depth: 3.5-5'

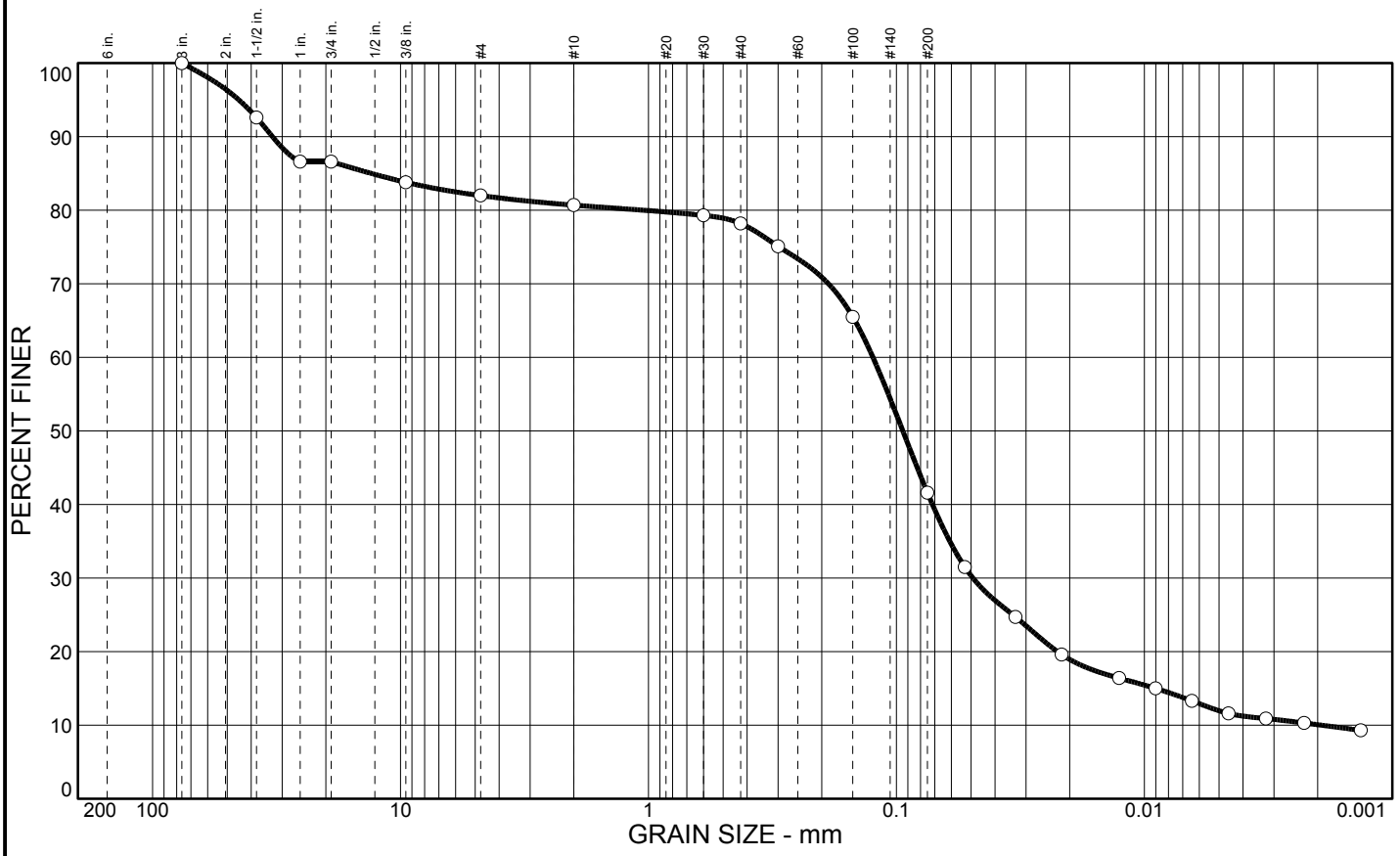
COOPER TESTING LABORATORY

Client: CDM Smith

Project: Sherwin-Williams, Emeryville - 13452

Project No.: 580-018 Figure

Particle Size Distribution Report



	% COBBLES	% GRAVEL	% SAND	% SILT	% CLAY	USCS	AASHTO	PL	LL
○	0.0	18.0	40.4	31.5	10.1	SC-SM		22.4	27.5

SIEVE inches size	PERCENT FINER ○		
3"	100.0		
1.5"	92.6		
1"	86.6		
3/4"	86.6		
3/8"	83.8		
	GRAIN SIZE		
D_{60}	0.124		
D_{30}	0.0492		
D_{10}	0.0019		
	COEFFICIENTS		
C_c	10.06		
C_u	64.49		

SIEVE number size	PERCENT FINER ○		
#4	82.0		
#10	80.7		
#30	79.3		
#40	78.2		
#50	75.1		
#100	65.5		
#200	41.6		
#270	31.5		

SOIL DESCRIPTION

○ Dark Olive Gray Silty, Clayey SAND w/ Gravel

REMARKS:

○

○ Source: CDM-101-9.5-11-20120320 Elev./Depth: 9.5-11'

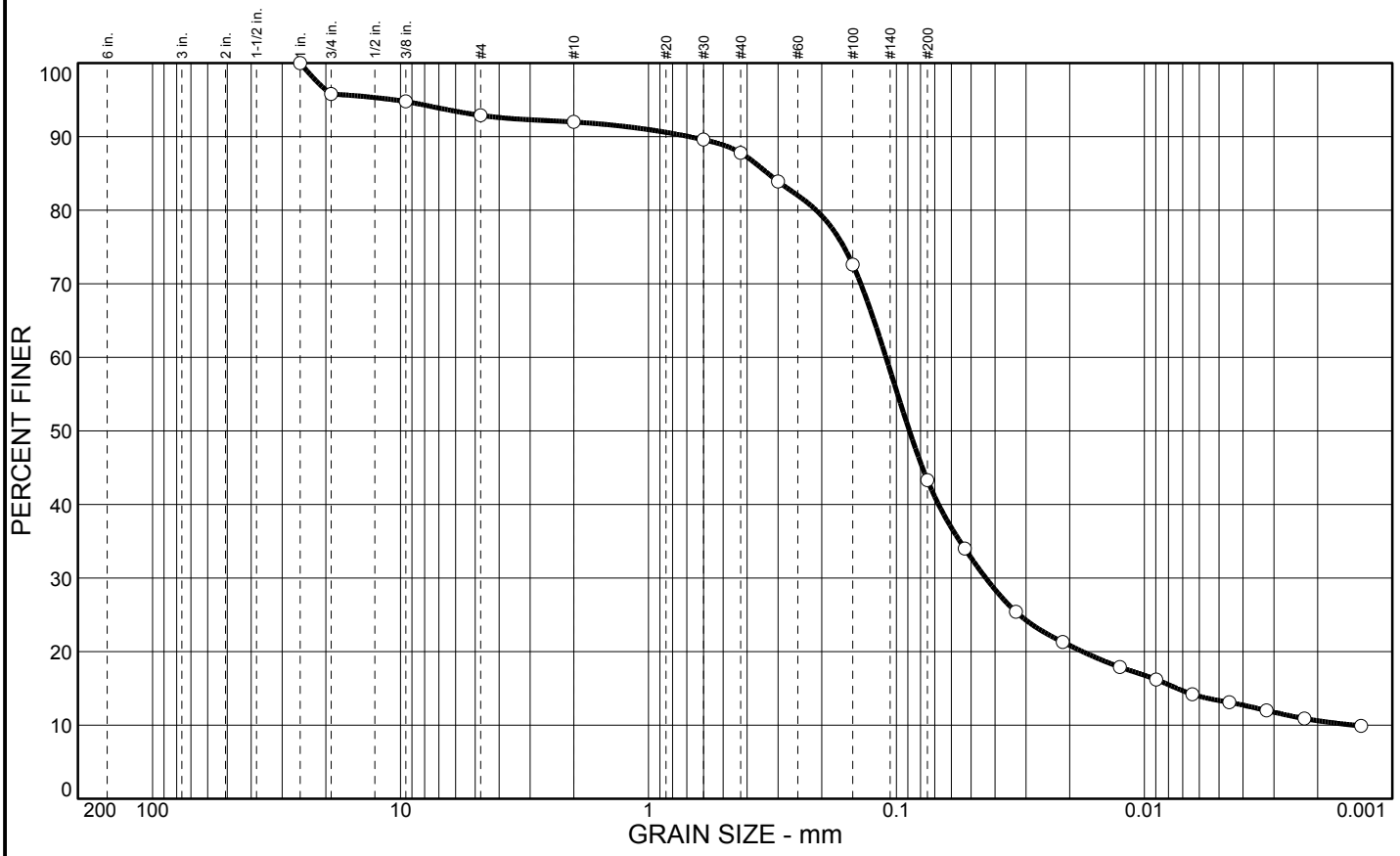
COOPER TESTING LABORATORY

Client: CDM Smith

Project: Sherwin-Williams, Emeryville - 13452

Project No.: 580-018 Figure

Particle Size Distribution Report



	% COBBLES	% GRAVEL	% SAND	% SILT	% CLAY	USCS	AASHTO	PL	LL
○		7.1	49.6	32.7	10.6				

SIEVE inches size	PERCENT FINER ○		
1"	100.0		
3/4"	95.8		
3/8"	94.8		
GRAIN SIZE			
D_{60}	0.110		
D_{30}	0.0436		
D_{10}	0.0014		
COEFFICIENTS			
C_c	12.11		
C_u	77.42		

SIEVE number size	PERCENT FINER ○		
#4	92.9		
#10	92.0		
#30	89.6		
#40	87.8		
#50	83.9		
#100	72.6		
#200	43.3		
#270	34.0		

SOIL DESCRIPTION

○ Dark Olive Gray Silty SAND

REMARKS:

○

○ Source: CDM-103-19-20-20120320 Elev./Depth: 19-20'

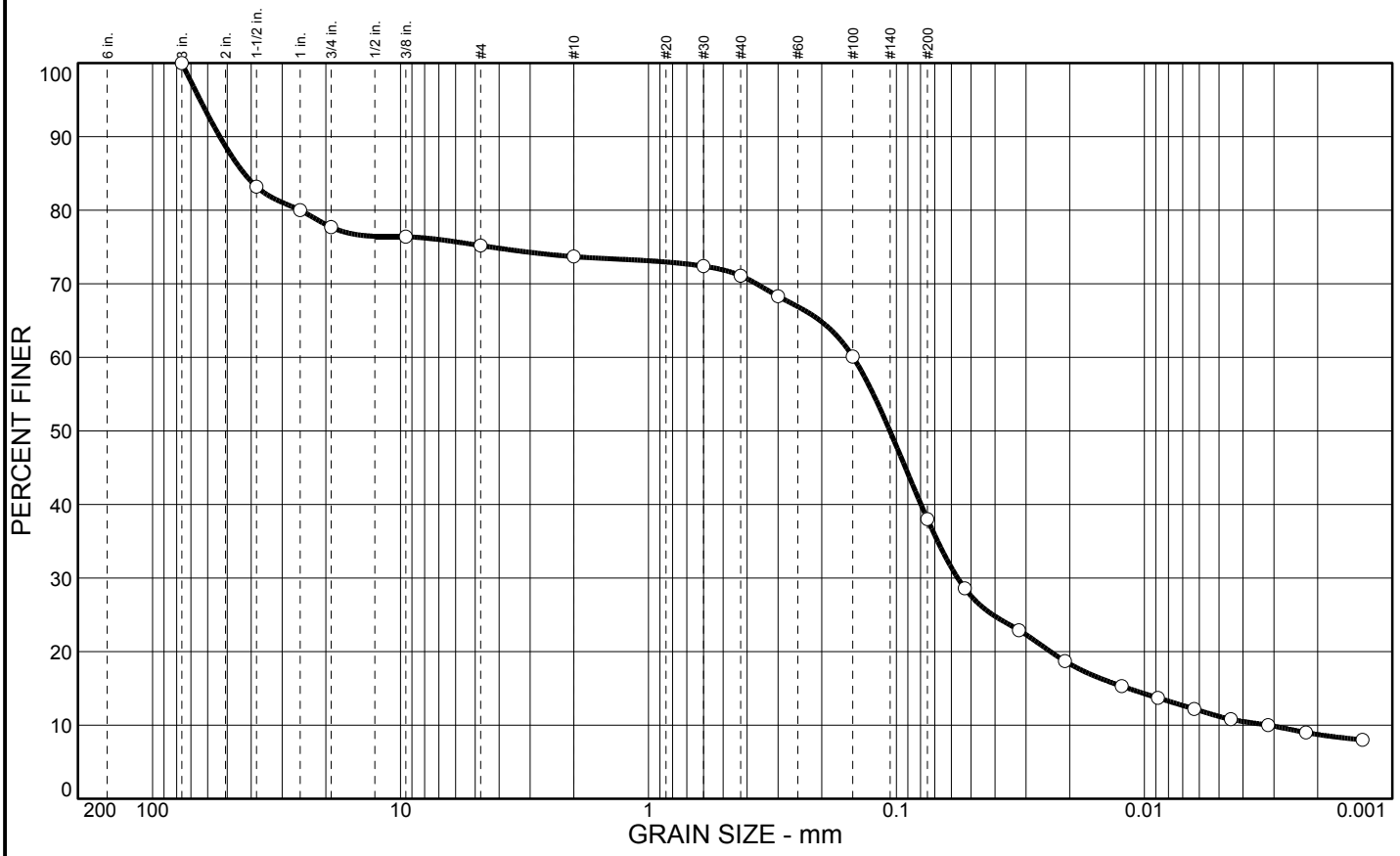
COOPER TESTING LABORATORY

Client: CDM Smith

Project: Sherwin-Williams, Emeryville - 13452

Project No.: 580-018 Figure

Particle Size Distribution Report



	% COBBLES	% GRAVEL	% SAND	% SILT	% CLAY	USCS	AASHTO	PL	LL
○	0.0	24.8	37.2	29.3	8.7	SC-SM		22.2	27.7

SIEVE inches size	PERCENT FINER ○		
3"	100.0		
1.5"	83.2		
1"	80.0		
3/4"	77.7		
3/8"	76.4		
	GRAIN SIZE		
D_{60}	0.149		
D_{30}	0.0566		
D_{10}	0.0032		
	COEFFICIENTS		
C_c	6.77		
C_u	47.13		

SIEVE number size	PERCENT FINER ○		
#4	75.2		
#10	73.7		
#30	72.4		
#40	71.1		
#50	68.3		
#100	60.1		
#200	38.0		
#270	28.6		

SOIL DESCRIPTION

○ Dark Olive Gray Silty, Clayey SAND w/ Gravel

REMARKS:

○

○ Source: CDM-103-7-8.5-20120320

Elev./Depth: 7-8.5'

COOPER TESTING LABORATORY

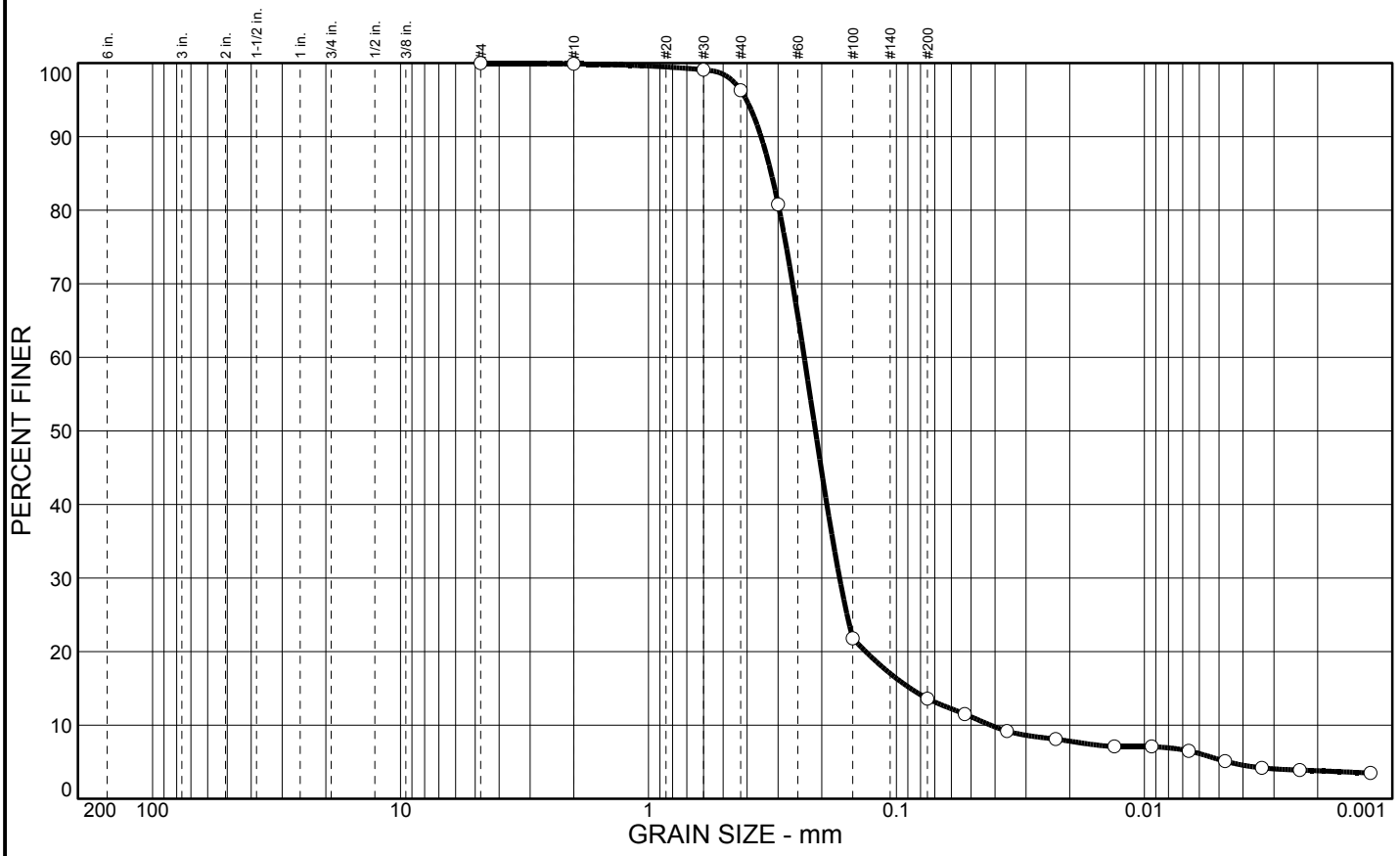
Client: CDM Smith

Project: Sherwin-Williams, Emeryville - 13452

Project No.: 580-018

Figure

Particle Size Distribution Report



	% COBBLES	% GRAVEL	% SAND	% SILT	% CLAY	USCS	AASHTO	PL	LL
○			86.4	9.8	3.8				

SIEVE inches size	PERCENT FINER ○		
	GRAIN SIZE		
D_{60}	0.235		
D_{30}	0.170		
D_{10}	0.0417		
	COEFFICIENTS		
C_c	2.93		
C_u	5.65		

SIEVE number size	PERCENT FINER ○		
#4	100.0		
#10	99.9		
#30	99.1		
#40	96.3		
#50	80.8		
#100	21.8		
#200	13.6		
#270	11.5		

SOIL DESCRIPTION

○ Olive Silty SAND

REMARKS:

○

○ Source: CDM-104-14-15.5-20120320

Elev./Depth: 14-15.5'

COOPER TESTING LABORATORY

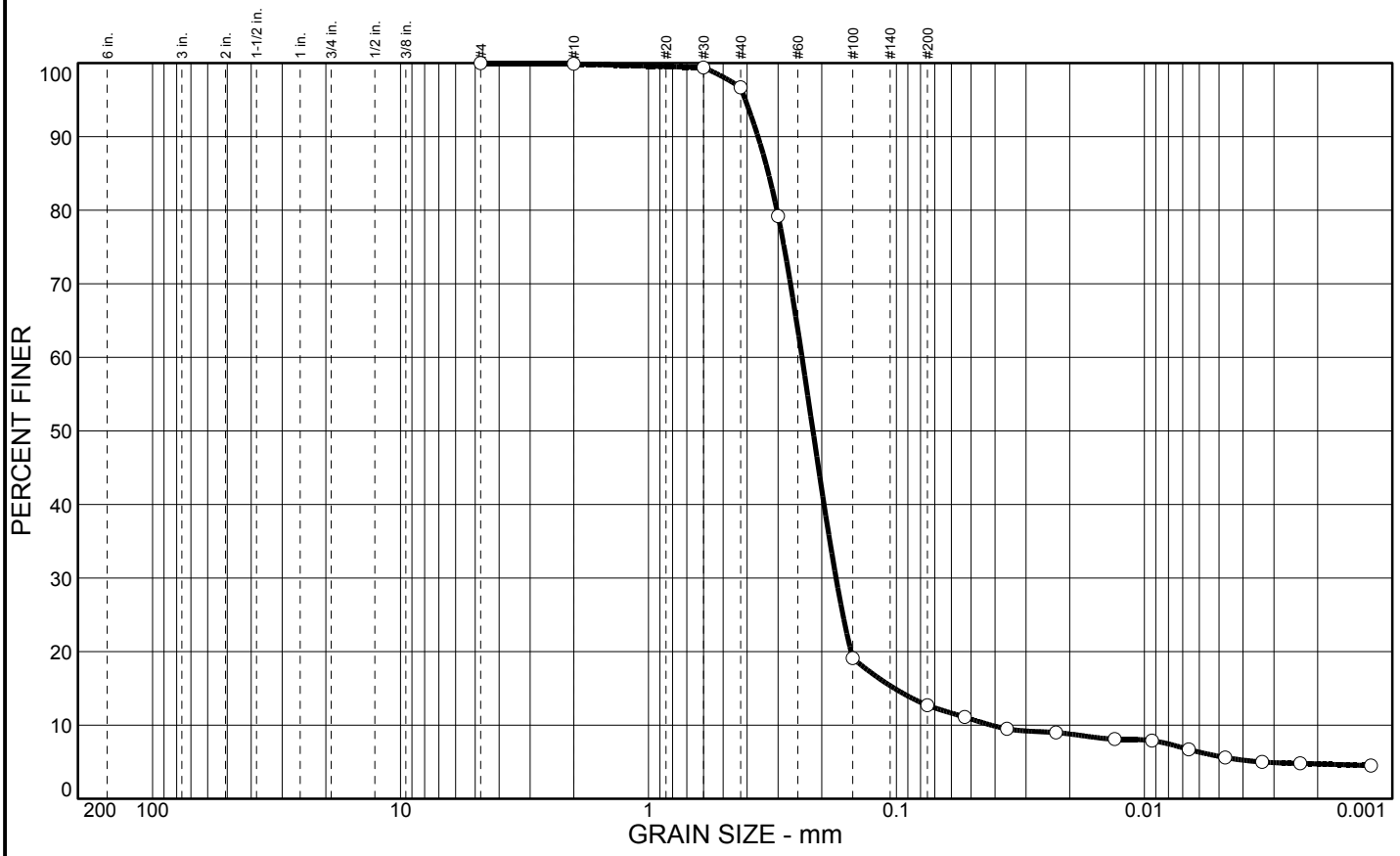
Client: CDM Smith

Project: Sherwin-Williams, Emeryville - 13452

Project No.: 580-018

Figure

Particle Size Distribution Report



	% COBBLES	% GRAVEL	% SAND	% SILT	% CLAY	USCS	AASHTO	PL	LL
○			87.3	8.0	4.7				

SIEVE inches size	PERCENT FINER ○		
	GRAIN SIZE		
D_{60}	0.240		
D_{30}	0.175		
D_{10}	0.0415		
	COEFFICIENTS		
C_c	3.08		
C_u	5.79		

SIEVE number size	PERCENT FINER ○
#4	100.0
#10	99.9
#30	99.4
#40	96.7
#50	79.2
#100	19.1
#200	12.7
#270	11.1

SOIL DESCRIPTION

○ Olive Silty SAND

REMARKS:

○

○ Source: CDM-104-6.5-8-20120320 Elev./Depth: 6.5-8'

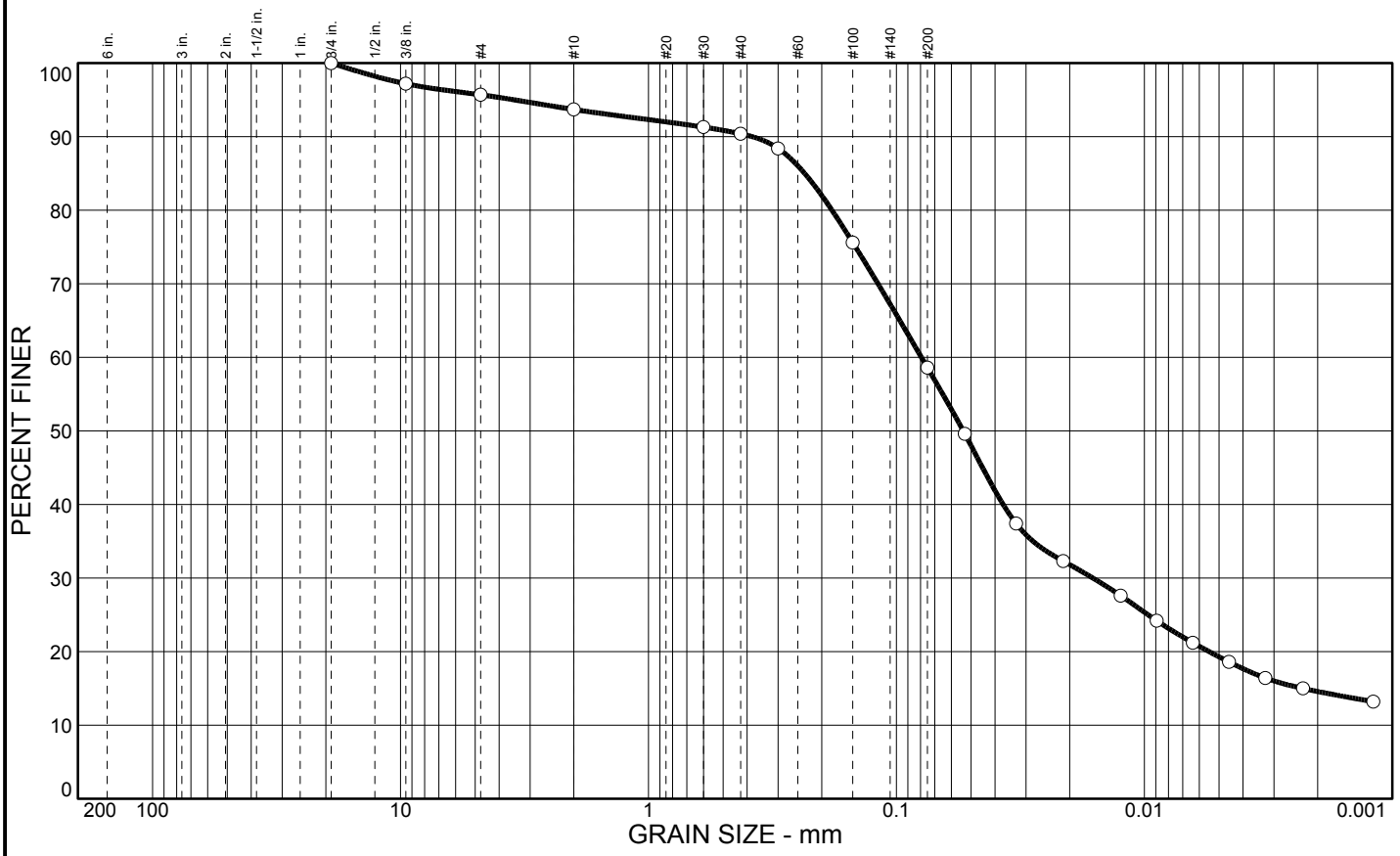
COOPER TESTING LABORATORY

Client: CDM Smith

Project: Sherwin-Williams, Emeryville - 13452

Project No.: 580-018 Figure

Particle Size Distribution Report



	% COBBLES	% GRAVEL	% SAND	% SILT	% CLAY	USCS	AASHTO	PL	LL
○		4.3	37.1	44.0	14.6				

SIEVE inches size	PERCENT FINER ○		
3/4"	100.0		
3/8"	97.2		
GRAIN SIZE			
D_{60}	0.0793		
D_{30}	0.0161		
D_{10}			
COEFFICIENTS			
C_c			
C_u			

SIEVE number size	PERCENT FINER ○		
#4	95.7		
#10	93.7		
#30	91.3		
#40	90.4		
#50	88.4		
#100	75.6		
#200	58.6		
#270	49.6		

SOIL DESCRIPTION

○ Greenish Gray Sandy CLAY

REMARKS:

○

○ Source: CDM-110-11.5-13-20120320 Elev./Depth: 11.5-13'

COOPER TESTING LABORATORY

Client: CDM Smith

Project: Sherwin-Williams, Emeryville - 13452

Project No.: 580-018 Figure

Particle Size Distribution Report

	% COBBLES	% GRAVEL	% SAND	% SILT	% CLAY	USCS	AASHTO	PL	LL
○		2.3	33.3	47.2	17.2				

SIEVE inches size	PERCENT FINER ○		
3/4"	100.0		
3/8"	98.9		
GRAIN SIZE			
D_{60}	0.0620		
D_{30}	0.0091		
D_{10}			
COEFFICIENTS			
C_c			
C_u			

SIEVE number size	PERCENT FINER ○		
#4	97.7		
#10	93.7		
#30	87.4		
#40	85.8		
#50	83.5		
#100	76.3		
#200	64.4		
#270	56.4		

SOIL DESCRIPTION

○ Very Dark Greenish Gray Sandy CLAY

REMARKS:

○

○ Source: CDM-111-12.5-14-20120320

Elev./Depth: 12.5-14'

COOPER TESTING LABORATORY

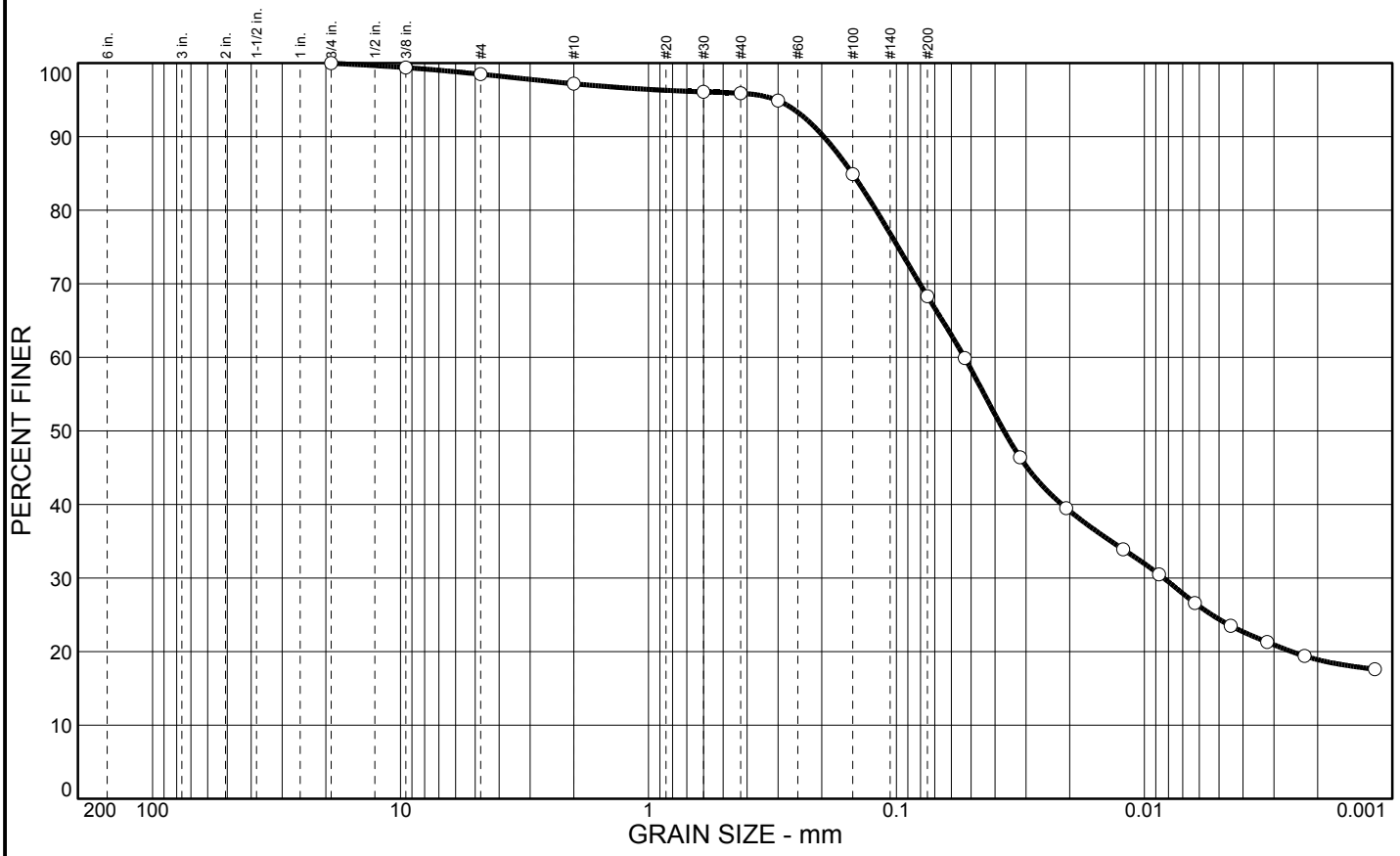
Client: CDM Smith

Project: Sherwin-Williams, Emeryville - 13452

Project No.: 580-018

Figure

Particle Size Distribution Report



	% COBBLES	% GRAVEL	% SAND	% SILT	% CLAY	USCS	AASHTO	PL	LL
○		1.5	30.2	49.4	18.9				

SIEVE inches size	PERCENT FINER ○		
3/4"	100.0		
3/8"	99.4		
GRAIN SIZE			
D_{60}	0.0532		
D_{30}	0.0084		
D_{10}			
COEFFICIENTS			
C_c			
C_u			

SIEVE number size	PERCENT FINER ○		
#4	98.5		
#10	97.2		
#30	96.1		
#40	95.9		
#50	94.9		
#100	84.9		
#200	68.3		
#270	59.9		

SOIL DESCRIPTION

○ Bluish Gray Sandy CLAY

REMARKS:

○

○ Source: CDM-111-6.5-8-20120320 Elev./Depth: 6.5-8'

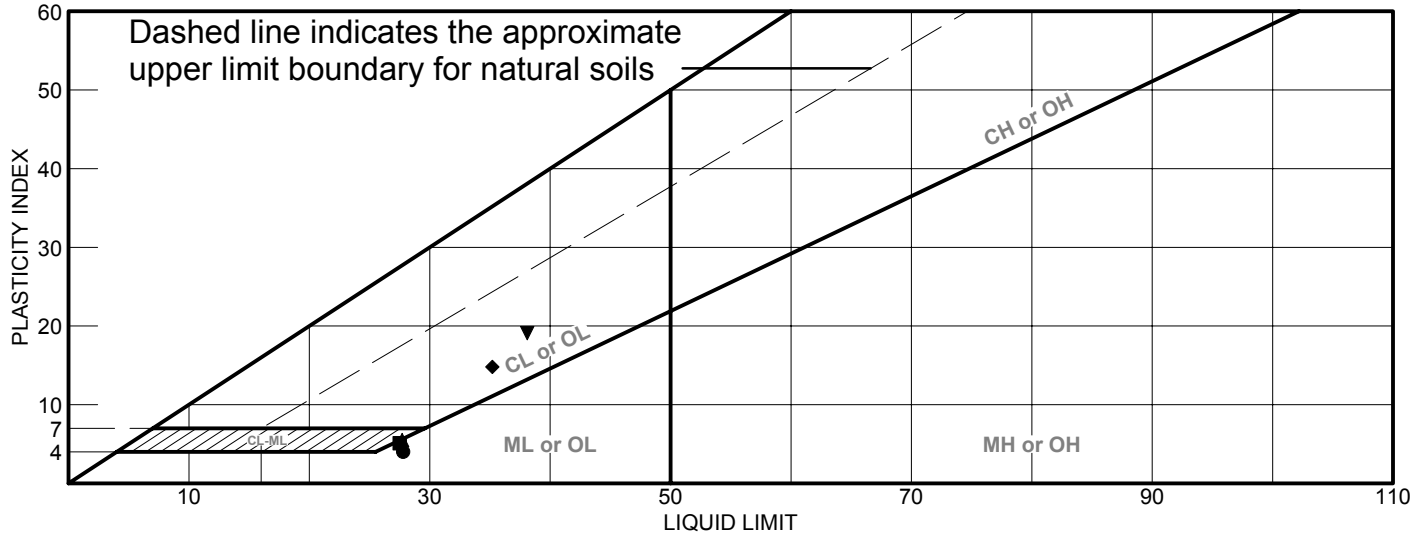
COOPER TESTING LABORATORY

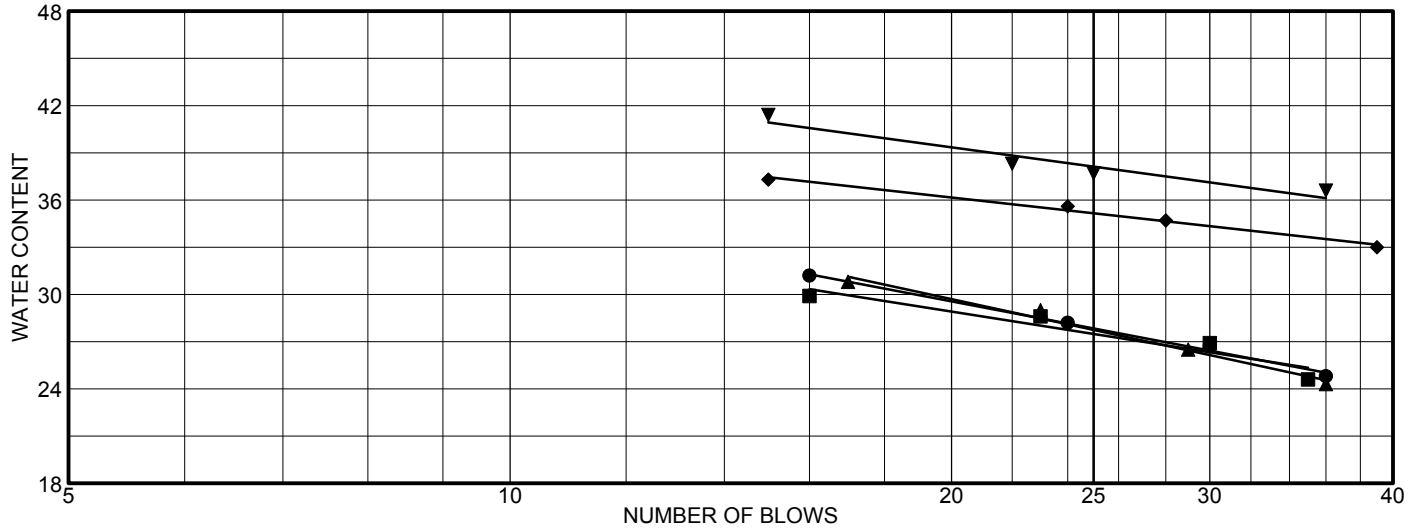
Client: CDM Smith

Project: Sherwin-Williams, Emeryville - 13452

Project No.: 580-018 Figure

LIQUID AND PLASTIC LIMITS TEST REPORT





	MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	USCS
●	Dark Olive Gray Silty SAND	27.8	23.8	4.0	82.3	39.2	SM
■	Dark Olive Gray Silty, Clayey SAND w/ Gravel	27.5	22.4	5.1	78.2	41.6	SC-SM
▲	Dark Olive Gray Silty, Clayey SAND w/ Gravel	27.7	22.2	5.5	71.1	38.0	SC-SM
◆	Dark Greenish Gray Sandy Lean CLAY	35.2	20.4	14.8			
▼	Very Dark Greenish Gray Sandy Lean CLAY	38.1	19.0	19.1			

Project No. 580-018 **Client:** CDM Smith

Project: Sherwin-Williams, Emeryville - 13452

● **Source:** CDM-101-3.5-5-20120320 **Elev./Depth:** 3.5-5'
■ **Source:** CDM-101-9.5-11-20120320 **Elev./Depth:** 9.5-11'
▲ **Source:** CDM-103-7-8.5-20120320 **Elev./Depth:** 7-8.5'
◆ **Source:** CDM-111-16-17-20120320 **Elev./Depth:** 16-17'
▼ **Source:** CDM-113-9.5-11-20120320 **Elev./Depth:** 9.5-11'

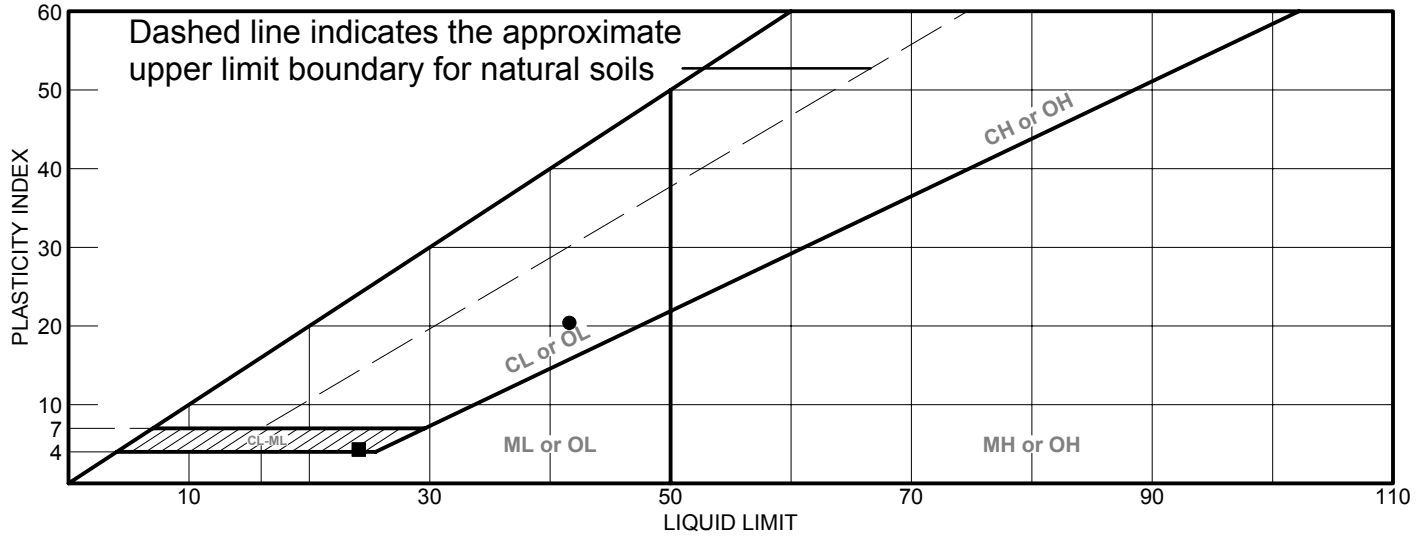
Remarks:
●
■
▲
◆
▼

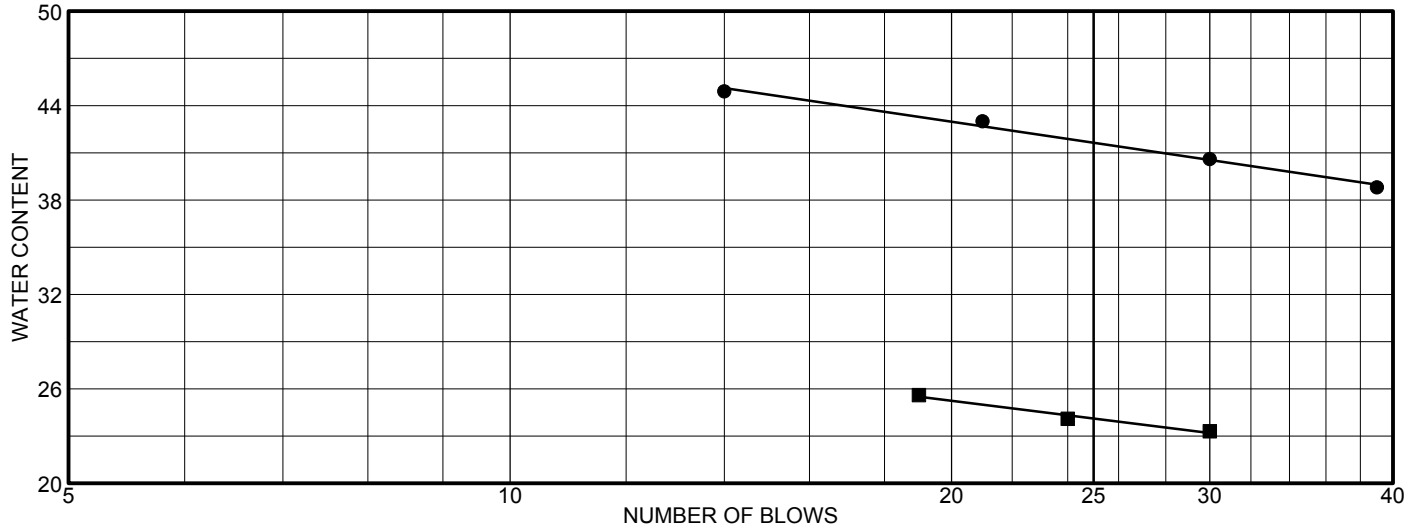
LIQUID AND PLASTIC LIMITS TEST REPORT

COOPER TESTING LABORATORY

Figure

LIQUID AND PLASTIC LIMITS TEST REPORT





	MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	USCS
●	Very Dark Greenish Gray Sandy Lean CLAY	41.6	21.2	20.4			
■	Very Dark Greenish Gray Silty, Clayey SAND	24.1	19.8	4.3			

Project No. 580-018 **Client:** CDM Smith

Project: Sherwin-Williams, Emeryville - 13452

● **Source:** CDM-113-15.5-17-20120320 **Elev./Depth:** 15.5-17'

■ **Source:** PZ-102-16-17.5-20120320 **Elev./Depth:** 16-17.5'

Remarks:

●

■

LIQUID AND PLASTIC LIMITS TEST REPORT

COOPER TESTING LABORATORY

Figure

Moisture-Density-Porosity Report
Cooper Testing Labs, Inc. (ASTM D 2937)

CTL Job No:	580-018a	**Project No.**	13452	**By:**	RU
Client:	CDM Smith	**Date:**	04/13/12		
Project Name:	Sherwin-Williams, Emeryville	**Remarks:**			

Boring:	CDM-101-2-3.5	CDM-101-3.5-5	CDM-101-5-6.5	CDM-101-6.5-8	CDM-101-8-9.5	CDM-101-9.5-11	CDM-101-11-12.5	CDM-12.5-14
Sample:	20120320	20120320	20120320	20120320	20120320	20120320	20120320	20120320
Depth, ft:	2-3.5	3.5-5	5-6.5	6.5-8	8-9.5	9.5-11	11-12.5	12.5-14
Visual Description:	Dark Olive Gray Silty SAND (slightly plastic)	Dark Olive Gray Silty SAND	Very Dark Greenish Gray Silty SAND (slightly plastic)	Very Dark Greenish Gray Clayey SAND w/ Gravel	Dark Olive Clayey SAND	Dark Olive Gray Silty, Clayey SAND w/ Gravel	Dark Olive Clayey SAND w/ Gravel	Dark Olive Gray Clayey SAND
Actual G_s								
Assumed G_s								
Moisture, %	16.3	13.5	11.1	14.1	13.5	13.3	13.8	20.9
Wet Unit wt, pcf								
Dry Unit wt, pcf								
Dry Bulk Dens.pb, (g/cc)								
Saturation, %								
Total Porosity, %								
Volumetric Water Cont,Θw								
Volumetric Air Cont., Θa								
Void Ratio								
Series	1	2	3	4	5	6	7	8

Note: All reported parameters are from the as-received sample condition unless otherwise noted. If an assumed specific gravity (Gs) was used then the saturation, porosities, and void ratio should be considered approximate.

Moisture-Density-Porosity Report
Cooper Testing Labs, Inc. (ASTM D 2937)

CTL Job No:	580-018b	**Project No.**	13452	**By:**	RU
Client:	CDM Smith	**Date:**	04/13/12		
Project Name:	Sherwin-Williams, Emeryville	**Remarks:**			

Boring:	CDM-101-14-15.5	CDM-101-15.5-17	CDM-103-1-2.5	CDM-103-2.5-4	CDM-103-4-5.5	CDM-103-5.5-7	CDM-103-7-8.5	CDM-103-8.5-10
Sample:	20120320	20120320	20120320	20120320	20120320	20120320	20120320	20120320
Depth, ft:	14-15.5	15.5-17	1-2.5	3-4	4-5.5	5.5-7	7-8.5	8.5-10
Visual Description:	Dark Olive Gray Clayey SAND	Dark Olive Clayey SAND w/ Gravel	Dark Greenish Gray Clayey SAND w/ Gravel	Dark Olive Clayey SAND	Very Dark Olive Gray Sandy CLAY	Dark Olive Silty SAND w/ Gravel (slightly plastic)	Dark Olive Gray Silty, Clayey SAND w/ Gravel	Dark Olive Gray Clayey SAND w/ Gravel
Actual G_s								
Assumed G_s								
Moisture, %	16.0	12.6	13.2	14.7	16.4	13.7	13.7	13.6
Wet Unit wt, pcf								
Dry Unit wt, pcf								
Dry Bulk Dens.pb, (g/cc)								
Saturation, %								
Total Porosity, %								
Volumetric Water Cont,Θw								
Volumetric Air Cont., Θa								
Void Ratio								
Series	1	2	3	4	5	6	7	8

Note: All reported parameters are from the as-received sample condition unless otherwise noted. If an assumed specific gravity (Gs) was used then the saturation, porosities, and void ratio should be considered approximate.

Moisture-Density-Porosity Report
Cooper Testing Labs, Inc. (ASTM D 2937)

CTL Job No:	580-018c	**Project No.**	13452	**By:**	RU
Client:	CDM Smith	**Date:**	04/13/12		
Project Name:	Sherwin-Williams, Emeryville	**Remarks:**			

Boring:	CDM-104-2-3.5	CDM-104-3.5-5						
Sample:	20120320	20120320						
Depth, ft:	2-3.5	3.5-5						
Visual Description:	Dark Olive Clayey SAND	Dark Olive Clayey SAND w/ Gravel						
Actual G_s								
Assumed G_s								
Moisture, %	16.1	17.2						
Wet Unit wt, pcf								
Dry Unit wt, pcf								
Dry Bulk Dens.ρb, (g/cc)								
Saturation, %								
Total Porosity, %								
Volumetric Water Cont,Θw								
Volumetric Air Cont., Θa								
Void Ratio								
Series	1	2	3	4	5	6	7	8

Note: All reported parameters are from the as-received sample condition unless otherwise noted. If an assumed specific gravity (Gs) was used then the saturation, porosities, and void ratio should be considered approximate.

Appendix:

Summary of Geotechnical Results and
Conceptual Geotechnical Engineering Recommendations for
The Sherwin-Williams Company Emeryville, CA Manufacturing Facility

The Sherwin-Williams Company

Summary of Geotechnical Results and Conceptual Geotechnical Engineering Recommendations for The Sherwin-Williams Company Emeryville, CA Manufacturing Facility

June 10, 2005

Technical Memorandum

Technical Memorandum
Results of Preliminary Geotechnical Investigation and Conceptual Geotechnical Engineering Recommendations

This technical memorandum (TM) presents the results of our preliminary geotechnical investigation and provides conceptual geotechnical engineering recommendations for design and construction of the proposed future development at the 8-acre Sherwin-William's facility in Emeryville, CA. The purpose of this TM is to provide Sherwin-Williams with preliminary geotechnical engineering recommendations to facilitate conceptual site development planning with SRM Associates (SRM). The information contained in this TM is considered preliminary, as the primary objective of the investigation was to characterize the overall site geotechnical conditions for planning level evaluations. The recommendations provided herein are based on review of available site data, the results of CDM's preliminary geotechnical investigation, discussions with SRM and Sherwin-Williams representatives, and review of the Parcelization Map, dated May 17, 2004, prepared by ROMA Design Group in association with BKF Engineering.

Purpose and Scope

The purpose of this study was to conduct a preliminary geotechnical investigation to characterize the site subsurface conditions and provide preliminary design recommendations that would be used by SRM to evaluate conceptual design options and perform supporting economic analyses.

Specifically, our scope of work included the following tasks:

- Conduct a preliminary subsurface exploration program consisting of 2 test borings and 6 cone penetration tests (CPTs) at the site;
- Conduct laboratory tests on selected soil samples to assist with classification of soils encountered and determine engineering properties;
- Develop conceptual geotechnical engineering recommendations for foundation design and construction associated with future development as defined herein;
- Present data collected as part of the investigation.
- Prepare this technical memorandum presenting the site characterisitics and CDM's preliminary geotechnical recommendations based on ROMA's Parcelization Map (2004).

Proposed Future Development

The proposed future development plan has not been finalized but based on review of the Parcelization Map, the site will be redeveloped to include a mix of residential and commercial land use with a central open space and links to future greenway or bike trail extensions, refer to Figure 1, Conceptual Site Map. The 8-acre site is subdivided into five parcels using a variety of structure types and height relationships. In general, the development plan includes multi-story structures with podium style parking on the lower levels with provisions for two high rise tower elements ranging in height from 120 feet to 200 feet. A generalized description of the size and intended land use for each of the five parcels is provided below.

- Parcel A: approximately 0.62 acres, mixed residential and commercial use, existing building to remain with structure height up to 50 feet.

- Parcel B: approximately 1.44 acres, mixed residential and commercial use, multi-story structure up to 65 feet in height with podium style parking on lower level, demo existing structures.

- Parcel C: approximately 1.37 acres, mixed residential and commercial use, multi-story structure up to 65 feet in height with podium style parking on lower level, demo existing structures.

- Parcel D: approximately 0.95 acres, mixed residential and commercial use, multi-story structure up to 120 feet in height with podium style parking on lower 3 to 5 levels.

- Parcel E: approximately 1.46 acres, mixed residential and commercial use, multi-story structure up to 65 feet in height including a tower element up to 200 feet high with podium style parking on the lower 3 to 5 levels. The northern portion of this parcel may include a multi-level parking structure up to 65 feet high.

To conduct our analysis and develop our recommendations, CDM made the following design assumptions regarding the proposed development.

- **Multi-level parking structure:** Multi-level parking structures are planned for Parcels B, C, D, and E. For purposes of this study, we have assumed the parking structures will have no below grade parking and up to 6 levels of above grade parking;

- **Mixed-use commercial/residential units:** As currently planned, the site consists of mixed use commercial and residential units with no below grade space and range in height from low rise (up to 2 stories), mid-rise (up to 5 stories), and high rise (over 5 stories). The current development plan indicates that parking will be located beneath the first and upper ground levels beneath each building; and

- **Central parking and asphalt-paved streets**: For purposes of this study, we have assumed that little to no site regrading will be required.

As an overall site consideration, this evaluation is based on the condition that final site grading will be minimal and that the first floor of all structures will be essentially at grade or embedded no more than 5 feet below the existing grade.

At this time, the existing buildings (Buildings No. 1 and 31) along Horton Street are to remain and will be incorporated into the development. The remainder of the existing structures will likely be demolished as part of the new development.

Note that the redevelopment plans for the site are conceptual in nature and other building types may ultimately be considered. Figure 1, Conceptual Site Development Plan, illustrates the proposed conceptual site development plan with proposed building structure heights (ROMA, 2004), and discussions with SRM.

Existing Site Conditions

The project site (Site) is located at 1450 Sherwin Ave in Emeryville, CA. The parcel encompasses about 8 acres and is located in an historically industrial neighborhood approximately ¾-mile east of the San Francisco Bay and along Temescal Creek. The site is bounded on the west by Union Pacific Railroad tracks, on the north by Chiron Corporation property, on the east by Horton Avenue and on the south by Sherwin Avenue. The site is an active paint manufacturing facility and is currently occupied by several 1 to 3-story administration and manufacturing structures with multiple aboveground tanks used to manufacture paint products. It is our understanding that all the existing structures at the site are supported on relatively shallow spread footings and that numerous structures have been removed from the site (areas underlying Parcels B and D). However, the foundations for these demolished structures were not removed during demolition and are covered by fill and pavement.

Currently, a significant portion of the site is enclosed by a soil-bentonite and cement-bentonite slurry wall. This impermeable wall is approximately 3 feet thick and extends to an approximate depth of 22 feet depth. Beneath Parcel D, an environmental cap was constructed to encapsulate metals-impacted soils and to reduce potential exposure pathways, surface water infiltration and subsequent contaminant migration. The approximate location of the slurry wall and environmental cap are shown on Figure 2, Boring Location Map. The area of the cap is paved with asphalt and is about 2 to 4 feet higher than the surrounding site grades. The remainder of the site grades range from about El. 10 to El. 20 feet.

A groundwater extraction and treatment system consisting of 13 extraction wells is in operation at the site.

Geotechnical Exploration Program

CDM's geotechnical exploration consisted of drilling two mud rotary borings and six Cone Penetrometer (CPT) soundings up to depths of 100 feet at selected locations across the site. The mud rotary borings and CPT soundings were performed by Gregg Drilling and In-Situ of Martinez, California, on January 28 and 29, 2003. The purpose of the investigation was to characterize the subsurface conditions and determine engineering properties of soils to support development of remedial alternatives and conceptual design planning.

Soil Borings

Two test borings, CDMSB-11 and CDMSB-12, were drilled as part of this investigation. Test boring CDMSB-11 was drilled near the northeastern corner of the property that extends along Horton Street. Test boring CDMSB-12 was drilled near the southwestern corner of the property along Sherwin Avenue. The test borings were located in the field by chaining from existing site features and were monitored in the field by a CDM representative.

Sample collection alternated between a California Modified Split-Spoon Sampler and a Standard Penetration Test (SPT) in general accordance with American Society of Testing Method (ASTM) D1586. Soil samples in the test borings were typically collected at 5-foot intervals over the depth of the boring. Relatively undisturbed samples were collected using a California Modified Split-Spoon Sampler lined with 1-inch brass rings. Generally, the lower 6 rings of the sample were sealed in plastic bags and placed in rigid tubes with resealable end caps for transport to the laboratory. The SPT sampler was unlined and the retained sample material was placed in sealed plastic bags for transport to the laboratory. The drill rig utilized a 140 lb hydraulically driven auto-hammer to drive the sampler 18-inches. The blow count for each six-inch driven interval was recorded and the penetration resistance (N) was determined by adding the second and third 6-inch penetration resistance blow counts.

Water levels in the test borings were estimated from the condition of the samples obtained and by the observed water levels within the borehole at the time of drilling, if any. Both test borings were drilled to a depth of 101.5 feet below ground surface (bgs). At the completion of drilling, each boring was backfilled using Portland cement that was pumped through a 1-inch tremmie pipe to 100 feet bgs. Excess bentonite drilling mud and soil cuttings were collected and placed in 55-gallon drums for characterization and disposal.

In addition to the test borings conducted for this study, CDM reviewed three additional test borings, B11 through B13, which were drilled by others near the project area. The information contained on these logs was incorporated into our evaluation. These borings are located on the adjacent Chiron property, which is to the northeast of the Sherwin-Williams site adjacent to Parcels D and E.

A summary of the subsurface conditions encountered in the explorations is included in Table 1, Summary of Subsurface Explorations. Locations of the test borings

(CDMSB-11 and CDMSB-12 and B11 to B13) and the CPT soundings described in the following section are shown on Figure 2, Site Map. Copies of CDM boring logs, as well as boring logs B11 to B13 prepared by others are included in Appendix A.

Cone Penetrometer Soundings

A total of seven CPTs were planned for this investigation, however, near surface refusal on two attempts, attributed to possible buried foundation footing at location CPT-3, resulted in abandonment of this location. Therefore, a total of six CPTs (CPT-1, CPT-2, and CPT-4 through CPT-7) were conducted to provide information regarding subsurface conditions at the site. A copy of these CPT test data including the interpretation report is included in Appendix B.

Geotechnical Laboratory Testing

Laboratory tests were performed on selected split spoon samples and Shelby tube samples obtained from the test borings CDMSB-11 and CDMSB-12. The following analyses were conducted to characterize material index and strength properties:

- Grain size analyses using ASTM D422,
- Atterberg Limits using ASTM D4318,
- Moisture Content and Dry Unit Weight using ASTM D2216 and D2937, respectively,
- Direct shear tests performed in accordance with ASTM D3080, and
- Consolidation tests using ASTM D2435.

Results of the laboratory tests are summarized in Table 2, and a copy of the laboratory report is included as Appendix C.

Site Geology

The Sherwin-Williams site is located immediately to the east of the former margin of San Francisco Bay and is underlain by a variety of natural and culturally-modified soils.

Soil and Groundwater Conditions

The subsurface conditions encountered in test borings CDMSB-11 and CDMSB-12, B11 to B13, and the CPTs consist of a variety of different soils that CDM defined as follows:

- Layer 1: Silty/clayey gravel with sand
- Layer 2: Black sandy clay
- Layer 3: Clayey sand/ Silty sand
- Layer 4: Sandy clay
- Layer 5: Sand/ Gravelly sand/ Silty Gravel

Layer 1: Soils designated as fill (Layer 1 – silty clayey gravel with sand) were encountered in every test boring and CPT as the topmost Layer. The thickness of this Layer is estimated to be between 4 feet and 22 feet at borings and CPT locations. Layer 1 includes clay, silts, sand and gravel and may contain organic material and debris consisting of glass, concrete or brick fragments. USCS-classification of Layer 1 includes GP, GC, SM, ML, and CL. The SPT and California Modified Split Spoon Sampler N-values measured in the test borings as well as the CPTs indicate a wide range of density and consistency; loose to medium dense in granular soils and medium stiff to very stiff in fine grained soils, respectively.

The presence of debris, including glass and brick fragments, along with interlayed gravel observed in some borings suggests that certain areas are overlain by artificial fill materials. The thickness of artificial fill at these locations is estimated to be on the order of about 7 feet thick. Artificial fill is expected beneath/adjacent to existing and/or abandoned building foundations.

Layer 2: Layer 2 soils consist of mostly fine-grained soils containing organic compounds (Layer 2 – Black sandy clay). Layer 2 is generally described as soft, dark grayish to black, clay with medium to high plasticity with organic odors and varying amounts of silt and sand. The SPT and California Modified Split Spoon Sampler N-values measured in the test borings as well as the CPTs indicate that this stratum is soft. USCS-classification of Layer 2 includes CL and CH. Layer 2 ranges in thickness from 10 to 33 feet at the test boring locations. The bottom of Layer 2 extends to depths ranging from 19 to 43 feet below existing site grades in explorations where this layer was encountered. It appears that the thickness of Layer 2 is variable throughout the site and may be controlled be deposition/erosion along Temescal Creek.

Layer 3: Soils assigned to Layer 3 (Clayey sand/ Silty sand), generally directly underlie Layer 2, however, in some places Layer 3 directly underlies Layer 1. Layer 3 and layer 4 are inter-layered. Layer 3 is generally described as clayey sand, clayey sand with gravel with interbeds of clayey gravel. USCS-classification of Layer 3 includes SC and GC. Layer 3 ranges in thicknesses from 3 feet to greater than 16 feet at the test boring locations. The SPT and California Modified Split Spoon Sampler N-values measured in the test borings as well as the CPTs indicate that this layer is medium dense to dense.

Layer 4: Layer 4 (Sandy clay) generally consists of clay with varying contents of sand, silt and/or gravel with trace organic compounds. The plasticity of this layer is predominantly described as medium to high. USCS-classification of Layer 4 includes CH and CL. Layer 3 and layer 4 are inter-layered. Layer 4 ranges in thickness from 3 to greater than 53 feet thick at the test boring locations. The SPT and California Modified Split Spoon Sampler N-values measured in the test borings as well as the CPTs indicate that this layer is medium stiff to very stiff.

Layer 5: Layer 5 (Sand/ Gravelly sand/ Silty Gravel) generally consists of sand, gravelly sand, and silty gravel. USCS-classification of Layer 5 includes SP, SW and GM. Layer thicknesses range from 5 to 13 feet thick at the test boring locations. The

SPT and California Modified Split Spoon Sampler N-values measured in the test borings as well as the CPTs indicate that this layer is medium dense to very dense.

Groundwater beneath the site varies from depths of 10 to 14 feet below existing ground surface. The extraction well network was operating during this work.

A summary of the subsurface conditions is presented in Table 1. Figure 3, Isopach Map – Base of Layers 1 or 2, illustrates the approximate base or bottom of shallow unsuitable soils. Using this figure, it is possible to estimate the thickness of unsuitable soils (base of Layers 1 and 2) by adding the ground surface elevation (black) contour line to the contour value depicted by the base of Layer 1 or 2 (red) contour line. The sum of these values represents the interpreted thickness of the underlying unsuitable soils.

Assessment of Geologic Hazards

The geologic hazards at the site are attributed to the regional seismicity. Specifically, the seismic hazards include fault surface rupture, liquefaction of saturated granular soils, and ground shaking. The hazard potential associated the seismic potential for the Site is presented below.

Surface Fault Rupture

Based on review of current publications available from the California Geological Survey (CGS), Alquist-Priolo Earthquake Fault Zone map (CGS, 2003) there are no known or identified active or potentially active faults intersecting or trending into the Site (Jennings, 1992; WGCEP, 1996). The nearest known active fault is the Hayward fault, situated approximately 3 miles northeast of the site. Other active regional faults such as the San Andreas, Calaveras, Rodgers Creek – Healdsburg, Concord-Green Valley, San Gregorio, and Greenville faults are located at least 15 miles from the site. Refer to Appendix D for the EQFAULT (EQFAULT, 2000) preliminary listing of active regional faults with estimated moment magnitudes and peak site accelerations values, based on Abrahamson & Silva (1997). Based on review of published information, the potential for fault surface rupture is considered low.

Liquefaction

Liquefaction is a soil behavior phenomenon in which loose saturated granular soils lose their inherent shear strength due to increased pore water pressures as a result of cyclic loading, such as ground shaking during a strong earthquake. While a detailed liquefaction analysis was not conducted for this site, the liquefaction potential for the site ranges from "very high" to "moderate" (CGS, 2003). This determination is generally consistent with site investigation results. However, the continuity of potentially liquefiable zones at the Site was not evaluated as part of this study.

Potential consequences of liquefaction include bearing capacity failure, flotation of lightweight embedded or buried structures, landsliding (lateral spreads and flow slides), and differential settlement. Among these deformation mechanisms, large permanent ground deformations resulting from liquefaction-induced settlement is

considered to be the most significant potential mode of liquefaction-induced ground failure at the Site.

Planned Future Site Remediation

Portions of the site are underlain by impacted soil and groundwater and a variety of remedial approaches are being evaluated. An area approximately 200 feet by 200 feet and located to the north of the existing Building No. 31 and within the area of the raised cap will be remediated (Parcel D). The existing retaining wall surrounding the raised cap will also be removed. Remediation may include removal or in-situ/ex-situ treatment of the contaminated soils to a maximum depth of about 20 feet and replacement as needed with compacted structural fill.

Alternatively, soil-mixing consisting of in-situ mixing of cement-ferrous sulfate slurry with the existing soils to a maximum depth of about 20 feet may be conducted. Soil-mixing, if used, will likely result in a zone of remediated soil with compressive strengths in the range of 100 to 1,000 pound per square inch (psi), depending on final mix design.

It should be noted that future structures supported on shallow foundations that bear on this zone of stabilized soil and extend on to zones of soil not previously treated will require special attention with respect to differential settlement since the mixed soils will be significantly less compressible than the existing, untreated soils present at the site.

Conceptual Geotechnical Design Recommendations

Conceptual geotechnical engineering evaluations have been made as they relate to the proposed future development of the Sherwin-William's Facility in Emeryville, CA. In general, these evaluations have been based on the minimum requirements of the Unified Building Code (UBC) 1997. In addition, recommended design criteria are based on performance tolerances, such as allowable settlement, as understood to relate to similar structures.

Low and Mid Rise Buildings – Conceptual Foundation Design

The proposed low-rise and some of the mid-rise buildings can be supported on spread footings or on mat foundations bearing on suitable foundation bearing soils. Suitable foundation layers consist of Layers 3, 4, or 5 or on structural fill placed after the excavation of unsuitable soils. Unsuitable soils include all of existing Layers 1 and 2 and any loose or disturbed soils present at the subgrade level. As presently understood, no below grade space is anticipated for the proposed buildings, therefore, normal foundation level for the structures will not likely extend into the suitable bearing materials and over excavation and removal of unsuitable soils will be required. Over excavated areas should be backfilled with compacted fill.

Foundations should be designed for maximum net allowable bearing pressures of no more than 5,000 pounds per square foot (psf) for both dead and live loads bearing directly on the existing naturally deposited clayey sand/silty sand, sandy clay, or silty

gravel/gravel and silt stratum soils or on compacted fill placed after the removal of all unsuitable soils. An ultimate bearing pressure for the suitable bearing Layer at the site should be assumed to be no more than 10,000 psf.

All foundations should bear at least 3 feet below any adjacent lowest ground surface. Settlement of these structure, under the anticipated loads and designed as recommended above, is expected to be less than 2 inches with no more than 1 inch of differential settlement across the width of the structure.

Due to the depth of suitable bearing bearings soils, in some areas it may not be economical to support some low and mid-rise structures on shallow spread footings or mat foundations. In these areas it may be more economical to support these structures on deep foundations as described below for high-rise structures.

High Rise Buildings – Conceptual Foundation Design

The proposed high-rise buildings or mid-rise buildings with heavy loads should be supported on deep foundations bearing in the underlying Layer 3, 4 and/or 5 stratums. End driven piles or deep-drilled shafts can be used.

Driven piles consisting of precast prestressed concrete piles are likely to be the most economical pile type. Pile capacities of 100 and 125 tons for 12 and 14-inch square piles, respectively, can be achieved. Piles will develop capacity in both skin friction and end bearing. Piles should be driven to a minimum tip elevation and/or final driving resistance as required to reach the design capacity. Pile lengths should be expected to be about 80 to 100 feet and a load test will be required. Little spoil should be produced during installation of driven piles, thus disposal costs for contaminated soils should be limited. Care should be used when piles are driven in close proximity to adjacent structures or sensitive utilities as excess vibrations may cause damage.

Deep-drilled shafts, bearing in the underlying Layers 3, 4, and 5, can also be used. Drilled shafts will develop capacity in both skin friction and end bearing. Drilled shaft capacities of up to approximately 200 tons can be achieved. Shaft diameters should be expected to range from 2 to 4 feet. Shaft lengths of 80 to 100 feet would be required as shorter shaft lengths will result in less capacity. For conceptual design purposes a 60 foot long, 2-foot diameter shaft should be expected to result in a design capacity of about 80 tons and a 100 foot long, 3-foot diameter shaft should expected to result in a design capacity of 200 tons. Shafts may encounter layers of granular soils (sand and/or gravel) and steel casing or drilling mud may be required to maintain the shaft opening during construction. A significant amount of spoil will result from the drilled shaft construction. Spoils from the upper contaminated layers will require proper disposal. Drilled shafts may be installed adjacent to existing structures. Provided proper construction techniques are used, damage to adjacent structures and/or utilities can be minimized.

Alternatively, it may be feasible and more economic able to support some high-rise structures on an intermediate pile-raft foundation system. Intermediate length piles and a raft, i.e., mat, foundation system can be designed as a composite system to carry

foundation loads. This approach allows for the use of shorter piles since some of the foundation load is carried by the mat/raft. It is unlikely that structures with very high column loads can be supported on a pile raft foundation system, however, structures with 6 to 10 stories may be appropriate.

Lowest Level Floor Slab

The lowest level floor slab may be designed as slabs-on-grade bearing on a minimum of 18-inches of compacted, non-expansive fill. Any existing fill, disturbed, or otherwise unsuitable soils present below the slab level should be removed and replaced with compacted, non-expansive fill. A moisture-proof membrane should be installed below the slab and a 2-inch layer of sand placed between the membrane and the underside of the slab to protect the membrane from damage during construction.

Seismic Design Considerations

For purposes of determining design earthquake forces in accordance with the 1997 Uniform Building Code (UBC), the site may be considered as a "Zone 4" soil site as determined by Figure 16-2 of the UBC 1997. Therefore, in accordance with Table 16-I of the UBC, a Seismic Zone Factor equal to 0.4 should be used. Based on the type of soil encountered in our borings and our recommendations, the site may be considered S_D-Stiff, per Table 16-J of UBC 1997. The site is approximately 3 miles from the Hayward Fault, which is a Type A fault per Table 16-U of UBC 1997. Per Table 16-S and 16-T of the UBC, the near source acceleration (N_a) and velocity (N_v) with respect to the subject site is 1.2 and 1.6, respectively. Per Tables 16-Q and 16-R, the site seismic coefficient of acceleration (C_a) and velocity (C_v) is 0.44 N_a and 0.64 N_v, respectively.

Construction Considerations

Deep Foundation Construction

Installation of deep foundations should be conducted to address the following issues:

- **Potential for contaminant migration during installation of deep foundations through contaminated soils:** Use of precast prestressed piles (e.g., displacement piles) should not require the installation of a casing in areas of shallow impacted soils or groundwater as the piles will displace the surrounding soft plastic ductile soils during driving thus preventing pathways for migration. Flow path development at the pile/soil interface is unlikely because of the resultant relatively high soil/pile interface shear stresses that are induced during driving. In addition, the surface of the piles tend to be relatively smooth and tend not to smear the soil along the pile surface during driving, which in turn reduces "drag down" of soil contamination. Furthermore, the potential for down drag of shallow contaminated soils during installation should be insignificant as the planned remedial action to stabilize these materials in-place will be completed prior to pile installation.

  Displacement piles have been installed at numerous locations throughout the San Francisco Bay Area, through areas of documented soil impacts. Representative

major-construction projects that installed displacement piles through impacted soil include the San Francisco Bay Area Rapid Transit SFO extension and the nearby Shellmound/Bay Street development. These local projects with similar site and soil/groundwater contaminant conditions support this choice of using displacement piles.

In the event that drilled piles are used, then the use of double-cased pile should be evaluated. However, CDM recommends using displacement piles such as prestressed precast concrete piles to prevent the need for casing or other special construction methods. As previously stated, displacement piles also provides the most cost beneficial foundation support for structures requiring deep foundation systems.

- **Driving piles through stabilized soils:** It is our experience that driving piles directly though stabilized soils without pre-drilling can result in damage to the piles, particularly concrete piles. Pre-drilling through stabilized soils using a small caisson drill rig may be required prior to pile driving.

Excavation Support

Removal of contaminated soil located to the north of the existing Building No. 31 and within the area of the raised cap will require an excavation support system due to the proximity of the excavation to adjacent structures and the property limits. As stated previously, excavation and/or in-situ treatment depths of up to 20 feet may be required. Excavation support systems consisting of continuous steel sheeting, soldier piles and lagging, seacant pile walls, or soil-mix walls are considered suitable excavation support systems. In addition, bracing and/or tiebacks may be required. The following is a brief summary of some of the key issues associated with each support system:

- **Continuous Sheeting:** The use of continuous steel sheeting will likely require pre-excavation along the wall alignment to remove obstructions. A vibratory hammer will be used to install the sheeting. Vibrations from a vibratory hammer are not expected to cause damage to adjacent structures but may be a temporary nuisance to adjacent residences/businesses. A steel sheet piling wall will be relatively water tight and thus, reduce site dewatering requirements.

- **Soldier Piles:** Soldier piles can be drilled, or installed into pre-drilled holes. Driven soldier piles can be installed with a vibratory hammer; however, installation using an impact hammer is more common. Provided proper construction methods are used vibrations from an impact hammer are not expected to cause damage to adjacent structures but will likely be a temporary nuisance to adjacent residences/businesses. Soldier piles installed in pre-drilled holes are not expected to result in significant vibrations. The lower portion of the drilled hole should be filled with concrete and the portion of the drilled hole above the lowest excavation level may be backfilled with soil. Some pre-excavation should be expected to remove underground obstructions prior to soldier pile installation. Timber lagging

is typically installed between the soldier piles, however, steel plates may be also be used. A soldier pile and lagging wall system is not considered to be a watertight wall system. Soldier piles that are driven in-place may be extracted once the site has been backfilled. Soldier piles concreted into pre-drilled holes will need to be cut-off and abandoned in place.

- **Seacant Pile Wall:** Seacant pile walls consist of concrete filled, overlapping drilled shafts. A steel section is installed in every other drilled shaft in order to provide sufficient strength to the wall system. Construction of a seacant pile wall system is not expected to result in significant vibrations. Pre-excavation should be expected to remove obstruction located along the wall alignment. A seacant pile wall system is considered to be a watertight wall system. In addition, the top of the wall will need to be cut-off and abandoned in place once the site is backfilled.

- **Soil-Mix Wall:** Soil-mix walls consist of overlapping soil-cement mix columns with a steel section is installed in each or every other column in order to provide sufficient strength to the wall system. Construction of a soil-mix wall system is not expected to result in significant vibrations. Pre-excavation should be expected to remove obstruction located along the wall alignment. A soil-mix wall system is considered to be a watertight wall system. In addition, the top of the wall will need to be cut-off and abandoned in place once the site is backfilled.

- **Bracing/Tiebacks:** Internal bracing and/or tiebacks should be expected to be required for excavation depths over about 15 feet. The actual depth that the excavation can extend without installing bracing will depend on the wall system used. It is not clear at this time if installation of tiebacks below city streets and railroad tracks will be permitted. In addition, installation of tiebacks may be hindered by unknown buried site obstructions. The presence of internal bracing inside the excavation will likely hamper excavation efforts whereas tiebacks allow for a wide-open excavation area.

Compacted Fill

All imported structural fills and backfills shall be predominantly granular, less than 3 inches in any dimensions, free of organic and inorganic debris and other deleterious materials, with less than 35 percent passing the No. 200 sieve. All fill and backfill materials should be observed and tested by the geotechnical engineer prior to their use in order to evaluate the suitability.

Granular structural fill should be placed in layers no thicker than 8 inches, as placed, and compacted with a self-propelled vibratory roller. Each layer of fill should be compacted to at least 95 percent of the maximum dry density as determined by ASTM-D1557. Lift thicknesses should be reduced to 4 inches in confined areas accessible only to hand guided compaction equipment.

Structural fill placed below foundations should extend at least 3 feet beyond the edge of foundations, then outward and downward at a slope of 1 horizontal to 1 vertical (1H:1V).

Closure

The recommendations contained herein are considered suitable for conceptual design level development evaluations associated with the proposed future development of the Sherwin-William's facility in Emeryville, CA as understood at this time and described herein. These recommendations have been prepared in accordance with generally accepted engineering practices. No other warranty, expressed or implied, is made. In the event that changes in the design or location of the structures occur, the conclusions and recommendations contained herein should not be considered valid unless verified in writing by CDM.

References

Abrahamson, N.H. and W.J, Silva, 1997. *Empirical Response Spectral Attenuation Relations for Shallow Crustal Earthquakes, Seismology Research Letter*. Volume 68, No.1.

California Geological Survey, 2003. *Seismic Hazard Zone Report for the West Oakland 7.5 Minute, Alameda County, Report 081 CA 2003.*

EQFAULT User's Manual. April 2000.

Jenning C.W., 1992. *Preliminary Fault Activity Map of California. California Division of Mines and Geology Open-File Report 92-3, Scale 1:750:000.*

ROMA Design Group, 2004. , Parcelization Map. ROMA Design Group in association with BKF Engineering for SRM Associates. May 17, 2004.

Uniform Building Code, 1997. *International Conference of Building Officials*. 1997.

WGCEP, Working Group on Northern California Earthquake Probabilities. 1996 *Database of Potential Sources for Earthquakes Larger Than Magnitude 6 in Northern California*, U.S. Geological Survey, Open File Report 96-705.

Attachments:

Figure 1 -	Site Location Map
Figure 2 -	Site Map
Figure 3 -	Isopach Map – Base of Layers 1 or 2
Table 1 –	Summary of Subsurface Explorations
Table 2 -	Summary of Geotechnical Laboratory Results
Appendix A -	Boring Logs
Appendix B -	Cone Penetrometer Test Results
Appendix C -	Geotechnical Laboratory Test Results
Appendix D -	EQFAULT Summary

Tables

Sherwin-Williams
1450 Sherwin Avenue
Emeryville, California

Table 1
SUMMARY OF SUBSURFACE EXPLORATIONS

Test Boring Number	Approximate Ground Surface EL [1]	Total Drilling Depth (ft)	Layer Thickness (ft)					Approximate Depth to Groundwater (ft) [2]
			Layer 1	Layer 2	Layer 3	Layer 4	Layer 5	
CDMSB-11		101.5	16	11	5 / 10	20 / 20 / >6.5	5 / 5	10
CDMSB-12		101.5	6	21	4 / 5 / >15.5	11/15/2011	13	10
B11		98	7	NE	7 / 2.5 / 4	3 / 8 / 3.5 / 26 / >34	3	NR
B12		81.5	10.5	NE	9	10.5 / >51.5	NE	13
B13		81	4	NE	4 / 11 / >7	8/21/2014	12	14
CPT-1 [3]		100.1	15	12	4 / 7	27 / 26 / >10	3	NR
CPT-2 [3]		100.1	22	10	8 / >24	11 / 19	6	NR
CPT-4 [3]		100.1	20	14	5 / 15	10 / 13 / >15	8	NR
CPT-5 [3]		100.1	5	27	1 / 2 / 9	12 / 21 / >8	4	NR
CPT-6 [3]		100.1	10	33	2 / 6	21 / >28	NE	NR
CPT-7 [3]		100.1	5	14	4 / 5 / 10 / >8	23 / 10 / 6 / 15	NE	NR

Notes:
1. Elevations based on Mean Sea Level (MSL) and are reported in feet.
2. Depth to groundwater is reported at the time of drilling.
3. CPT is an indirect means of investigation. Classification of Layer might be different.

Abbreviations:

NE	Not Encountered
NR	Not Recorded
>	Indicates Layer not fully penetrated
/	Indicates Layer is discontinuous. See test boring logs (Appendix A) for additional information.

Sherwin-Williams
1450 Sherwin Avenue
Emeryville, California

Table 2
SUMMARY OF LABORATORY TEST RESULTS

Test Boring Number	Sample Depth (ft)	Layer No.	Grain Size Analysis [1]			Atterberg Limits [2]			USCS Classification [3]
			Gravel %	Sand %	Fines %	LL (%)	PL (%)	PI (%)	
SB-12	15	2				31	15	16	CL
SB-11	18.5	2				34	15	19	
SB-11	21	2	26.8	52.3	20.9				SM
SB-11	25	2							
SB-12	25	2				46	13	33	
SB-11	27	5				30	14	16	
SB-11	30	5	27.7	61.2	11.1				SP-SM
SB-12	30	5				49	22	27	CL
SB-11	35	4							
SB-12	35	5	43.5	47.0	9.5				SW-SM
SB-11	40	4				36	16	20	
SB-12	40	4							
SB-11	45	4				33	15	18	
SB-12	45	4				33	15	18	
SB-11	55	5							
SB-12	60	4				70	16	54	
SB-11	65	4				39	20	19	CL
SB-12	65	4				47	16	31	
SB-12	70	3							

Notes:

1 Grain size analysis tests were conducted in accordance with ASTM D422.
2 Atterberg Limit tests were performed in accordance with ASTM D4318.
3 USCS classifications were performed in accordance with ASTM D2488.

Abbreviations:

LL Liquid Limit
PL Plastic Limit
PI Plasticity Index
CL Clay
SM Silty Sand
SP Poorly Graded Sand
SW Well Graded Sand

Sherwin-Williams
1450 Sherwin Avenue
Emeryville, California

Table 2
SUMMARY OF LABORATORY TEST RESULTS (continued)

Test Boring Number	Sample Depth (ft)	Layer No.	Moisture Content (%)	Dry Unit Weight (pcf)	Total Unit Weight (pcf)	Consolidation Test [1]			Direct Shear Test [2]	
						PP (ksf)	CC (-)	CR (-)	Phi (deg)	C (psf)
SB-12	15	2							27.7	388
SB-11	18.5	2							23.5	303
SB-11	21	2								
SB-11	25	2	25.0	97.6	122.0					
SB-12	25	2				0.69	0.145	0.020		
SB-11	27	5							30.3	204
SB-11	30	5								
SB-12	30	5							26.0	859
SB-11	35	4	24.2	102.6	127.4	2.0	0.086	0.017		
SB-12	35	5								
SB-11	40	4								
SB-12	40	4	18.5	111.0	131.5	5.0	0.100	0.021		
SB-11	45	4	18.0	113.3	133.7				29.8	298
SB-12	45	4								
SB-11	55	5	16.2	118.9	138.2					
SB-12	60	4	25.8	99.8	125.5					
SB-11	65	4				4.5	0.089	0.021		
SB-12	65	4								
SB-12	70	3	17.5	114.3	134.3					

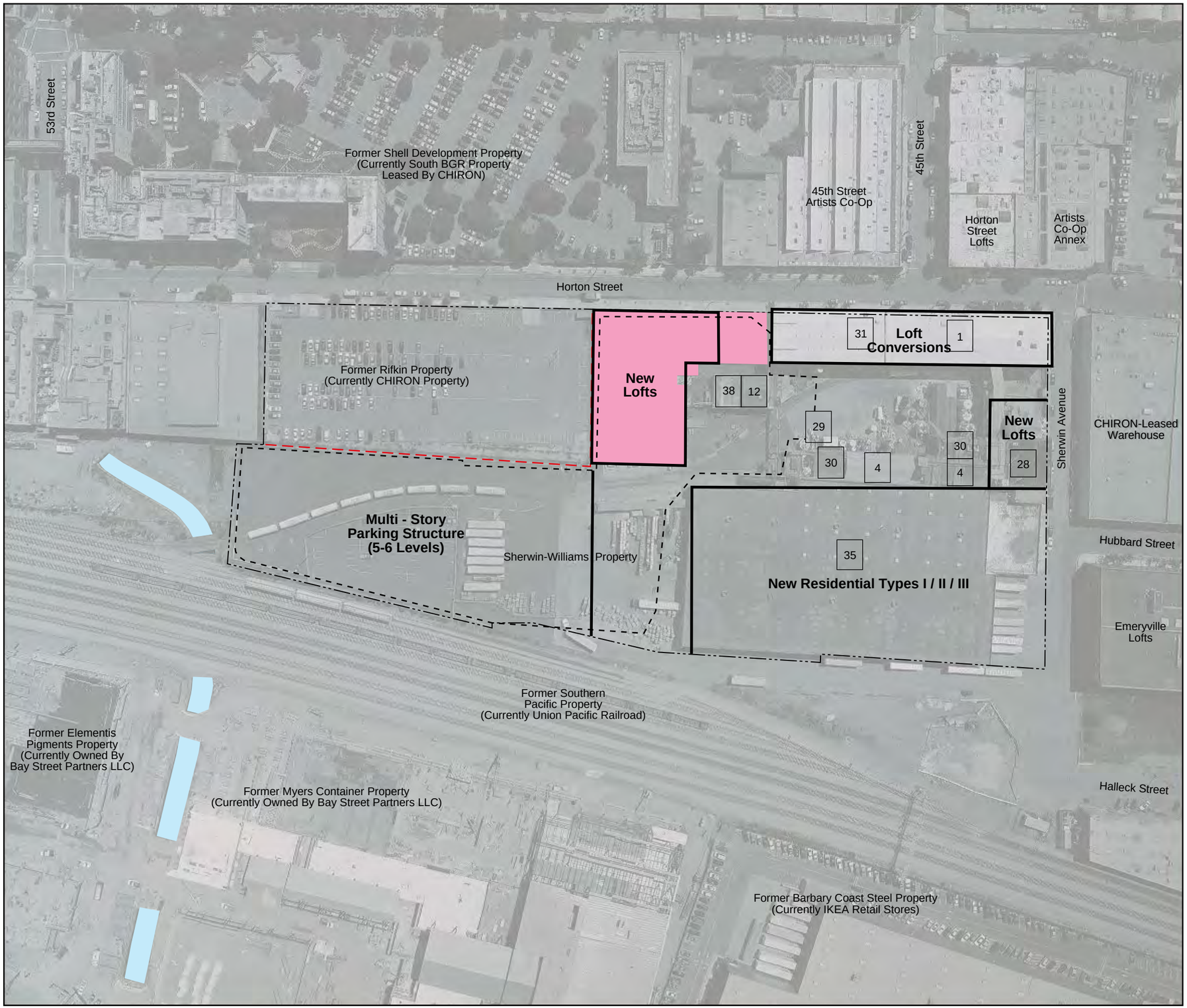
Notes:

1 Consolidation tests were performed in accordance with ASTM D2435
2 Direct shear tests were performed in accordance with ASTM D3080
3 Using CC = cc/(1+e0) with approximation cc = 0.007*(LL-10%)
4 Using approximation CR = 0.2*CC

Abbreviations:

PP Maximum past pressure.
CC Compression Ratio, (C_c/1+e_o)
CR Recompression Ratio, (C_r/1+eo)
Phi Friction Angle.
C Cohesion.

Figures



NORTH

0 100 200

FEET

Legend

- Site Boundary
- Approximate Location of Slurry Wall
- Boundary Between S-W and Former Rifkin Property
- 1 Building Number
- Raised Cap
- Temescal Creek

Figure 1
Conceptual Site Development Plan
Sherwin-Williams Company
Emeryville, California

CDM

N E S W

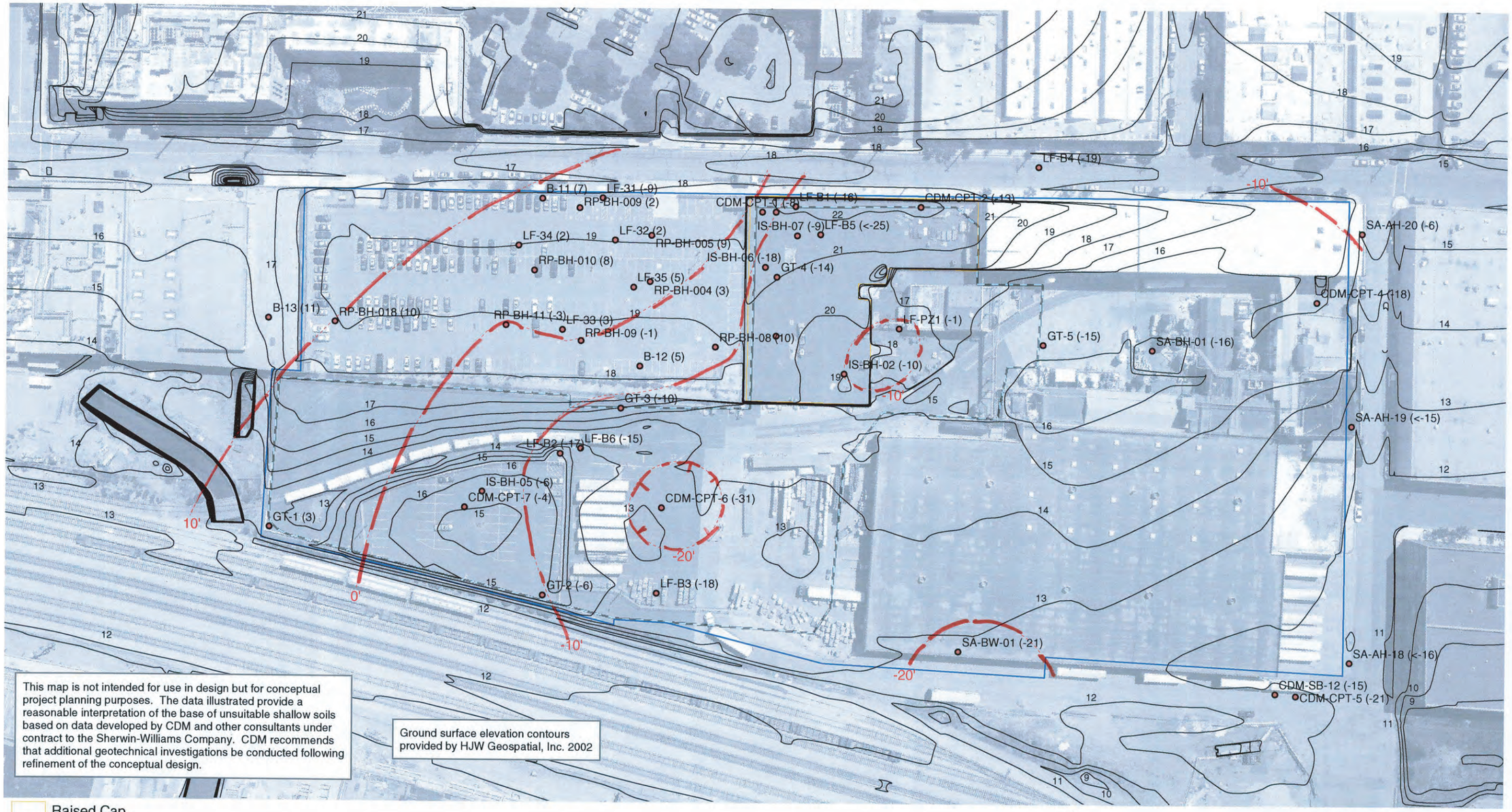
0 25 50 100 150 200 Feet

NAD83 California Stateplane III

Legend

- Extraction Well
- Approx Location Soil Boring By Others
- Approx Location Cone Penetromer Sounding (CDM, 2003)
- Approx Location Mud Rotary Boring (CDM, 2003)
- Temescal Creek
- Raised Cap
- Railroad Track
- Slurry Wall
- Boundary Between S-W and Former Rifkin Property

Figure 2
Boring Location Map
Sherwin-Williams Company
Emeryville, California



Raised Cap
Property Boundary
Slurry Wall
Inferred Elevation of Layers 1 and 2 (Contour Interval 10 Feet)
Ground Surface Elevation Contours (Ft. msl)
GT-1 (2.5)
Selected Soil Borings (Inferred Elev. of the Base of Layer 1 or Layer 2)

100 50 0 100 Feet
NAD83 California Stateplane III

N E S W

Figure 3
Isopach Map - Base of Layers 1 or 2
Sherwin-Williams Company
Emeryville, California

C:\arcgis\Projects\32581_Emeryville\contour_020504.mxd

Appendix A
Boring Logs

Boring Log CDMSB-11

Other Tests	Sample No.	Moisture Content (%)	Dry Density	PID (ppm)	Penetration Resistance (blows / 6 in.)	Depth (feet)	Sample	USCS	Symbol	DESCRIPTION	Elev. (feet)
	SB11-BULK							ML		Asphalt - 2 inches. SANDY SILT WITH GRAVEL, dark brown (10YR3/3), moist, 70% fine grained sand and silt, 25% gravel to 20 cm, and 5% dark gray-brown clay.	
	SB11-5			0.0	6 9 12			ML		SILT, dark brown (10YR3/3), moist, medium stiff, non-plastic, trace gravel to 0.5 cm, minor decayed vegetation.	
				0.0	3 6 6	10				SILTY SAND, dark yellowish-brown (10YR4/4), wet, medium dense, fine grained, 60% sand, 40% silt, some gravel, trace biotite, some gravel slough.	
	SB11-11			0.0	2 5 12			SM			
	SB11-15			0.0	3 3 3			GC		CLAYEY GRAVEL, very dark gray (10YR3/1), wet, 0.5 to 1 cm well rounded clasts.	
	SB11-18.5			0.0	400 lb			CH		CLAY, dark grayish-brown (10YR4/3), wet, mottled with orange-brown, medium to high plasticity.	
	SB11-21			0.0	5 8 8	20		SP		POORLY GRADED SAND WITH GRAVEL, very dark gray (10YR3/1), wet, medium dense, medium to coarse grained sand, 20% fine gravel to 0.5 cm, subangular to angular grains.	
	SB11-25			0.0	2 4 6			CL		CLAY, black (10YR2/1), wet, soft, medium to high plasticity, some gravel slough.	
	SB11-27			0.0	1500 lb			CL SP		GRAVELLY CLAY, dark yellowish-brown (10YR4/4), wet, gravel up to 1 cm. POORLY GRADED SAND WITH GRAVEL, very dark grayish-brown (10YR3/2), wet, medium dense, medium to coarse grained sand, trace gravel, some clay.	
	SB11-30			0.0	6 10 9	30		SW		WELL GRADED SAND, very dark grayish-brown (10YR3/2), wet, medium dense, coarse to medium grained, trace gravel.	
	SB11-35			0.0	4 7 11			CH		CLAY, grayish-brown (2.5YR5/2), moist, medium stiff, low to medium plasticity, medium toughness, stratified layers of brown (7.5YR4/4) oxidized clay, trace black organics, 3 inches of clayey gravel slough at 36.5 feet bgs.	
	SB11-40			0.0	2 3 6	40		CH		As above, medium stiff, no organics, no slough.	
	SB11-45			0.0	13 18 18			CL		GRAVELLY CLAY, gray (2.5Y5/1), moist, stiff, low plasticity, 15% well rounded gravel (chert and siltstone clasts) to 0.5 cm, abundant dark brown oxidation around edges of gravel clasts.	
	SB11-50			0.0	4 5 7	50		CH		CLAY, light olive-brown (2.5Y5/6), moist, medium stiff, medium plasticity, medium toughness, low dilatency.	
	SB11-55			0.0	14 39 38			SP SW		POORLY GRADED SAND, light yellowish-brown (2.5YR6/3), wet, fine to medium grained. WELL GRADED SAND WITH GRAVEL, dark yellowish-brown (10YR4/6), wet, very dense, medium to	

Location: Sherwin-Williams Emeryville
Surface Elevation:
Logged By: H. Young

Drill Rig: D-21
Equipment/Hammer: Mud Rotary/140 lb
Date Completed: 1-28-03

CDM

Sherwin-Williams
Sherwin-Williams Geotechnical Investigation
Emeryville, California

Boring Log CDMSB-11
Project No:

Figure:
1 of 2

BORING LOG SWGEOT.GPJ CDM_BLLV.GDT 4/23/03 REV. 5

Boring Log CDMSB-11

Other Tests	Sample No.	Moisture Content (%)	Dry Density	PID (ppm)	Penetration Resistance (blows / 6 in.)	Depth (feet)	Sample	USCS	Symbol	DESCRIPTION	Elev. (feet)
	SB11-60			0.0	7 11 12			GC		coarse grained, 20% fine gravel (subrounded) to 0.5 cm, subangular grains, quartz and red chert composition. CLAYEY GRAVEL, light yellowish-brown (2.5Y6/3), wet, medium dense, 50% subanular gravel to 4 mm, clay is highly plastic.	
	SB11-65			0.0	7 9 14			CH		CLAY, grayish-brown (2.5Y5/2), moist, medium stiff, medium plasticity, low to medium toughness, mottled with brown (7.5YR4/4) clay, dark brown rootlets to 3 mm.	
	SB11-70			0.0	6 9 11	70		CH		CLAY, as above, moist, stiff, medium plasticity, 5% fine gravel (well rounded, red, light gray, and gray clasts) to 1 cm, dark brown rootlets.	
	SB11-75			0.0	16 24 32			CH		CLAY, light olive brown (2.5Y5/4), moist, very stiff, medium plasticity and toughness, slow dilatency, abundant dark brown rootlets.	
	SB11-80			0.0	4 5 8	80		CL		CLAY, as above, mottled pale olive (5Y6/3) and light olive-brown (2.5Y5/4), moist, stiff, low to medium plasticity, trace fine grained sand, trace white shell fragments.	
	SB11-85			0.0	24 29 35			SC		CLAYEY SAND WITH GRAVEL, dark yellowish-brown (10YR4/6), wet, medium dense, 40% sand, 30% clay, 30% gravel, sand is coarse grained to 3 mm, poorly graded, gravel is well rounded, 0.5 to 3 cm, spherical to oblate clasts, black, light gray, gray, and red.	
	SB11-90			0.0	18 22 24	90		SC		As above, dense, less gravel (15%).	
	SB11-95			0.0	11 15 24			CH		CLAY, light olive-brown (2.5Y5/4), moist, stiff, medium to high plasticity, medium toughness, trace black well rounded gravel to 0.5 cm.	
	SB11-100			0.0	6 12 14	100		CH		As above, very stiff.	
										Total depth 101.5 feet bgs. Borehole abandoned with Portland cement (10-94 lb bags Type I/II cement and 60 gallons of potable water) pumped through a 1-inch tremmie pipe to 100 feet bgs. Bentonite drilling mud and soil cuttings containerized in 55-gallon drums for characterization and disposal.	
						110					

Location: Sherwin-Williams Emeryville
Surface Elevation:
Logged By: H. Young

Drill Rig: D-21
Equipment/Hammer: Mud Rotary/140 lb
Date Completed: 1-28-03

CDM

Sherwin-Williams
Sherwin-Williams Geotechnical Investigation
Emeryville, California

Boring Log CDMSB-11
Project No:

Figure:
2 of 2

BORING LOG SWGEOT.GPJ CDM_BLLV.GDT 4/23/03 REV. 5

Boring Log CDMSB-12

Other Tests	Sample No.	Moisture Content (%)	Dry Density	PID (ppm)	Penetration Resistance (blows / 6 in.)	Depth (feet)	Sample	USCS	Symbol	DESCRIPTION	Elev. (feet)
								GP		Asphalt/concrete-5-inches.	
										GRAVEL, dark yellowish-brown (10YR4/4), moist, loose, angular to subangular clasts to 5 cm, some asphalt.	
	SB12-2.5			0.0			G	CL		CLAY, black (10YR2/1), moist, medium to low plasticity, slight organic odor.	
	SB12-5			0.0	4 3 4			GP		GRAVEL, gray, moist, loose, angular to subangular clasts to 4 cm, 20% clay.	
										CLAY, very dark gray (10YR3/1), moist, soft, high plasticity, high toughness, trace gravel to 0.5 cm, odor like decayed vegetation.	
	SB12-10			0.0	1 1 1	10		CH			
	SB12-15			0.0	1 4 5			CH		CLAY, very dark grayish-brown (10YR3/2), moist, soft, high plasticity and toughness, trace decayed rootlets to 1 cm, strong odor like decayed vegetation.	
	SB12-20			0.0	2 4 6	20		CH		SILTY CLAY, dark gray (10YR4/1), moist, medium stiff, high plasticity, high toughness, mottled with orange-brown clay, trace gravel to 4 mm, well rounded, white and gray clasts.	
	SB12-25			0.0	300 lb			CH		CLAY, grayish-brown (2.5Y5/2), wet, firm, high plasticity, high toughness, trace fine sand.	
								SP		GRAVELLY SAND, dark grayish-brown (2.5Y4/2), wet, medium dense, fine to medium grained, 10% fine gravel to 0.5 cm, subangular to subrounded grains, gray, white, and red clasts.	
	SB12-30			0.0	12 15 17	30		CH		CLAY, grayish-brown (2.5Y5/2) mottled with light olive-brown (2.5Y5/6), moist, stiff, high plasticity, stratified, minor dark brown organics.	
								GM		SILTY GRAVEL, dark yellowish-brown (10YR4/4), wet, medium dense, medium grained sand to medium gravel, 20% silt, well rounded gravel clasts to 2 cm, gray and white clasts, some stratification of clasts, gravel contact at 32.5 feet bgs infered by drill rig chatter.	
	SB12-35			0.0	7 9 16			GM		As above, medium dense.	
	SB12-40			0.0	6 11 13	40		CH		CLAY, light olive-brown (2.5Y5/3), wet, stiff, high plasticity, high toughness, some mottling, 6 inches of gravel slough.	
	SB12-45			0.0	3 5 7			CH		SILTY CLAY, light olive-brown (2.5Y5/3) with stratified layers of yellowish-brown (10YR5/6) clay, moist, medium stiff, medium plasticity low to medium toughness.	
	SB12-50			0.0	6 8 11	50		CH		50 - 50.5 feet bgs: yellow-brown stratification of 2 mm fine grained sand layers.	
								SC		50.5 - 51 feet bgs: trace 3 mm white gravel and shell fragments.	
	SB12-55			0.0	3 4 4			CH		CLAYEY SAND, light olive-brown (2.5Y5/4), wet, loose, fine to coarse grained, trace fine gravel and shell fragments to 0.5 cm, angular to subrounded grains.	
										CLAY, light olive-gray (5Y6/2), moist, medium stiff, high plasticity, medium toughness.	
										55.5 feet bgs: 2-inch clayey sand layer, stratified.	

Location: Sherwin-Williams Emeryville
Surface Elevation:
Logged By: H. Young

Drill Rig: D-21
Equipment/Hammer: Mud Rotary/140 lb
Date Completed: 1-29-03

Sherwin-Williams
Sherwin-Williams Geotechnical Investigation
Emeryville, California

Boring Log CDMSB-12
Project No:

Figure:
1 of 2

CDM

BORING LOG SWGEOT.GPJ CDM_BLLV.GDT 4/23/03 REV. 5

Boring Log CDMSB-12

Other Tests	Sample No.	Moisture Content (%)	Dry Density	PID (ppm)	Penetration Resistance (blows / 6 in.)	Depth (feet)	Sample	USCS	Symbol	DESCRIPTION	Elev. (feet)
	SB12-60			0.0	7 10 12			CH		56 feet bgs: color changes to dark greenish gray (1 FOR GLEY4/1). CLAY, light olive-gray (5Y6/2), wet, medium stiff, high plasticity and toughness, 2% of sample comprises 1-2 mm, black (10YR2/1) round voids and organic fragments.	
	SB12-65			0.0	4 8 9			CH		At 60 - 60.5 feet bgs, trace coarse sand to 4 mm, well rounded, red and white. CLAY, pale olive (5Y6/3), wet, stiff, high plasticity, abundant black (10YR2/2) sand grains to 2 mm, trace gravel to 2 cm, light gray with dark brown and black iron oxide coating, well rounded, siltstone composition.	
	SB12-70			0.0	50 50/4"	70		GC		CLAYEY GRAVEL, yellowish-brown (10YR5/6), wet, very dense, 70% gravel, red and black clasts, 0.5 to 3 cm, well rounded, siltstone composition, high plasticity clay matrix.	
	SB12-75			0.0	8 12 12					SANDY CLAY WITH GRAVEL, moist, very stiff, medium plasticity, 15% fine grained sand, 5% fine gravel to 0.5 cm, gravel is white, light gray, and red chert, well rounded, trace white shell material to 3 mm, thin and soft.	
	NR				27 29 33	80		CH			
	SB12-85A SB12-85B			0.0	29 45 42			CH		CLAY, grayish-brown (2.5Y5/2), wet, firm, high plasticity, minor dark brownish-gray mottling, firm.	
								SC		CLAYEY SAND WITH GRAVEL, grayish-brown (10YR5/2), wet, medium dense, 60% sand, 30% clay/silt, 10% gravel, sand is fine to coarse grained, gravel up to 1 cm, subrounded clasts, black, red, and light gray.	
	SB12-90			0.0	6 8 14	90		ML		SILT, yellowish-brown (10YR5/4), wet, firm, low to medium plasticity, trace fine sand, trace rootlets, <2 mm.	
								SC		CLAYEY SAND, yellowish-brown (10YR5/4), wet, medium dense, fine to medium grained.	
	NR				16 19 24						
	SB12-96.5			0.0	16 27 29			CL		GRAVELLY CLAY, pale olive (5Y6/3), moist, low to medium plasticity, 15% gravel to 0.5 cm, well rounded, black iron oxide around edges.	
								SC		CLAYEY SAND WITH GRAVEL, yellowish brown (10YR5/4), wet, medium dense, 50% fine to coarse grained sand, 30% clay, 20% well rounded gravel to 1 cm, black and gray clasts, abundant black iron oxide around grains.	
	SB12-100			0.0	12 16 22	100		CL		GRAVELLY CLAY, yellowish-brown (10YR5/8), wet, very stiff, low plasticity, gravel to 0.5 cm, white shell fragments.	
										Total depth 101.5 feet bgs. Borehole abandoned with Portland cement (10-94 lb bags Type I/II cement and 60 gallons of potable water) pumped through a 1-inch tremmie pipe to 100 feet bgs. Bentonite drilling mud and soil cuttings containerized in 55-gallon drums for characterization and disposal.	
						110					

Location: Sherwin-Williams Emeryville
Surface Elevation:
Logged By: H. Young

Drill Rig: D-21
Equipment/Hammer: Mud Rotary/140 lb
Date Completed: 1-29-03

Sherwin-Williams
Sherwin-Williams Geotechnical Investigation
Emeryville, California

CDM

Boring Log CDMSB-12
Project No:

Figure:
2 of 2

BORING LOG SWGEOT.GPJ CDM_BLLV.GDT 4/23/03 REV. 5

Boring Logs – Chiron, Geomatrix (1994)

PROJECT: CHIRON CAMPUS EXPANSION PROJECT
Emeryville, California

Log of Boring No. B11

BORING LOCATION: 490799.5N, 1483583.7E

DATE STARTED: 9/29/94 | DATE FINISHED: 9/29/94

DRILLING METHOD: Hollow stem auger/rotary wash

HAMMER WEIGHT: 140 lbs | DROP: 30 inches

SAMPLER: See Explanation, Figure A-1

NOTES:
Logged by: E. Chase
Drilling Equipment: Mobile B-53
Drilling Contractor: RNL Enterprises

Surface Elevation: +14.2 feet

DEPTH (feet)	Sample No.	Sample	Blows/ Foot	MATERIAL DESCRIPTION	Moisture Content (%)	Dry Density (pcf)	Unconf. Comp. Str. (psf)
0				2 inches ASPHALT CONCRETE over 5.5 inches CONCRETE			
1-3	1		26	SILTY SAND (SM) Medium dense, dark yellowish brown, dry, fine to medium gravel, some clay [FILL] GMTX-11A PID = 0 ppm -#200 = 16%	---	---	---
4-6	2		22	SANDY CLAY (CL) Stiff, dark brown to black with red [FILL] GMTX-11B PID = 0 ppm	25	93	---
7-9				SANDY CLAY (CL) Stiff, brown			
10-12	3		13	CLAYEY GRAVEL with SAND (GC) Medium dense, dark olive brown, moist, fine to coarse sand Loose, olive green, hydrocarbon odor	---	---	---
13-19	4		2	SANDY CLAY with SILT (CL) Very soft, dark gray, wet	---	---	---
20	5	Shelby	25 - 200 psi		25	102	200
21-24				SILTY SAND (SM) Stiff, olive brown, fine to medium			
25-27	6		44	CLAYEY SAND with GRAVEL (SC) Dense, olive green, fine to coarse	---	---	---
28-30				SANDY CLAY (CL) Medium stiff to stiff, olive green, fine sand			

DRAFT

gt-1-88

Project No. 2803 | Geomatrix Consultants | Figure A-12

PROJECT: CHIRON CAMPUS EXPANSION PROJECT
Emeryville, California

Log of Boring No. B11 (cont'd.)

DEPTH (feet)	SAMPLES Sample No.	SAMPLES Sample	SAMPLES Blows/Foot	MATERIAL DESCRIPTION	LABORATORY TESTS Moisture Content (%)	LABORATORY TESTS Dry Density (pcf)	LABORATORY TESTS Unconf. Comp. Str. (psf)
31	7		41	SANDY CLAY (CL) (continued)	---	---	---
32				CLAYEY SAND with GRAVEL (SC) Dense, mottled yellowish brown, olive brown and light gray, fine to coarse sand, fine gravel			
34							
35	8		20	SANDY CLAY (CL) Stiff, mottled olive brown, gray, and yellowish brown, fine sand			
36				Fine to coarse sand, some gravel	29	95	3900
37							
38							
39							
40	9		19	SILTY CLAY with SAND (CL) Stiff to very stiff, mottled olive gray and rust brown, fine sand	20	105	---
42				SANDY CLAY (CH) Very stiff, light gray with black, fine sand			
44							
45				SANDY CLAY with GRAVEL (CL) Very stiff, mottled olive brown and yellowish brown, fine to coarse sand, fine gravel			
46							
47							
48							
49							
50	10		50				
51					16	118	3850
52				SANDY CLAY (CL) Stiff, dark yellowish brown, fine sand			
53							
54							
55							
56							
57							
58							
59							
60	11		60	CLAYEY SAND with GRAVEL (SC) Very dense, dark olive brown, fine to coarse sand, fine gravel	---	---	---
62							
63							
64							

DRAFT

gt-2-88

Emeryville, California

Log of Boring No. B11 (cont'd.)

DEPTH (feet)	SAMPLES Sample No.	SAMPLES Sample	SAMPLES Blows/Foot	MATERIAL DESCRIPTION	LABORATORY TESTS Moisture Content (%)	LABORATORY TESTS Dry Density (pcf)	LABORATORY TESTS Unconf. Comp. Str. (psf)
65				SILTY CLAY (CL) Very stiff, light olive, some fine sand			
66							
67							
68				Gravel and sand			
69							
70							
71	12		31		28	96	5300
72							
73							
74							
75				SANDY CLAY (CL) Very stiff, mottled olive brown and yellowish brown, fine to coarse sand			
76							
77							
78							
79							
80	13		20	Mottled light olive and olive brown, some gravel	17	115	---
81							
82							
83							
84							
85							
86							
87							
88							
89							
90							
91	14		44	Olive brown	---	---	---
92				Fine sand, no gravel			
93				SANDY CLAY with GRAVEL (CL) Very dense, olive brown			
94							
95				Bottom of boring at 98.0 feet. Boring drilled using hollow stem augers to 36 feet; approximately 20 gallons of groundwater pumped from hollow stem augers; boring advanced to bottom using rotary wash drilling. Boring backfilled with cement bentonite grout.			
96							
97	15		50/6"		---	---	---
98							

DRAFT

gt-2-88

PROJECT: CHIRON CAMPUS EXPANSION PROJECT
Emeryville, California

Log of Boring No. B12

BORING LOCATION: 490572.6N, 1483467.3E

DATE STARTED: 9/17/94 | DATE FINISHED: 9/17/94

DRILLING METHOD: Hollow stem auger/rotary wash

HAMMER WEIGHT: 140 lbs | DROP: 30 inches

SAMPLER: See Explanation, Figure A-1

NOTES:
Logged by: J. Abitz
Drilling Equipment: CME 550
Drilling Contractor: RNL Enterprises

DRAFT

DEPTH (feet)	SAMPLES Sample No.	SAMPLES Sample	SAMPLES Blows/Foot	MATERIAL DESCRIPTION	LABORATORY TESTS Moisture Content (%)	LABORATORY TESTS Dry Density (pcf)	LABORATORY TESTS Unconf. Comp. Str. (psf)
				Surface Elevation: +15.4 feet			
0				6 inch CONCRETE SLAB			
1	1		11	SANDY SILT (ML) Medium dense, black, moist GMTX-12A PID = 0	---	---	---
2							
3							
4	2		26	GMTX-12B PID = 0	17	98	2200
5							
6							
7							
8							
9							
10	3		19	SILT (ML) Medium dense,dark greenish gray, moist	25	99	---
11				ATD ▽			
12							
13							
14							
15	4		16	SANDY SILT (ML) Medium dense, dark yellowish brown	---	---	---
16							
17							
18				SILT (ML) Dark greenish gray			
19							
20	5		35	Gravel	18	118	---
21				SILTY SAND with GRAVEL (SC) Dense, dark yellowish brown			
22							
23				SILTY SAND (SM) Dense, dark greenish gray, fine sand			
24							
25	6		26	SANDY SILT to SILTY SAND (ML - SM) Medium dense, dark greenish gray	---	---	---
26							
27							
28							
29							
30							

gt-1-88

PROJECT: CHIRON CAMPUS EXPANSION PROJECT
Emeryville, California

Log of Boring No. B12 (cont'd.)

DEPTH (feet)	SAMPLES Sample No.	SAMPLES Sample	SAMPLES Blows/ Foot	MATERIAL DESCRIPTION	LABORATORY TESTS Moisture Content (%)	LABORATORY TESTS Dry Density (pcf)	LABORATORY TESTS Unconf. Comp. Str. (psf)
31	7		52	SANDY CLAY (CL) Very stiff to hard, dark greenish gray	20	110	4900
32							
33							
34							
35				With gravel, dark yellowish brown			
36							
37							
38							
39							
40	8		45		24	101	---
41				SILTY CLAY (CL) Hard, dark greenish gray			
42							
43							
44							
45							
46							
47							
48							
49							
50	9		63		24	103	4400
51							
52							
53							
54							
55				GRAVELLY CLAY with SAND (CL) Hard, dark yellowish brown			
56							
57							
58							
59							
60	10		50/5"		---	---	---
61							
62							
63							
64							

DRAFT

gt-2-88

PROJECT: CHIRON CAMPUS EXPANSION PROJECT
Emeryville, California

Log of Boring No. B12 (cont'd.)

DEPTH (feet)	SAMPLES Sample No.	SAMPLES Sample	SAMPLES Blows/ Foot	MATERIAL DESCRIPTION	LABORATORY TESTS Moisture Content (%)	LABORATORY TESTS Dry Density (pcf)	LABORATORY TESTS Unconf. Comp. Str. (psf)
65				GRAVELLY CLAY with SAND (CL) (continued)			
66							
67							
68							
69							
70							
71				SILTY CLAY (CL) Hard, light yellowish brown			
72							
73							
74							
75							
76							
77							
78							
79							
80	11		59		26	98	---
81							
82				Bottom of boring at 81.5 feet. Boring drilled using hollow stem augers to 25 feet; approximately 1 gallon of groundwater bailed from hollow stem augers; boring advanced to bottom using rotary wash drilling. Boring backfilled with cement bentonite grout.			
83							
84							
85							
86							
87							
88							
89							
90							
91							
92							
93							
94							
95							
96							
97							
98							

DRAFT

gt-2-88

PROJECT: CHIRON CAMPUS EXPANSION PROJECT
Emeryville, California

Log of Boring No. B13

BORING LOCATION: 490826.6N, 1483410.0E

DATE STARTED: 9/16/94 | DATE FINISHED: 9/16/94

DRILLING METHOD: Hollow stem auger/rotary wash

HAMMER WEIGHT: 140 lbs | DROP: 30 inches

SAMPLER: See Explanation, Figure A-1

NOTES:
Logged by: J. Abitz
Drilling Equipment: CME 550
Drilling Contractor: RNL Enterprises

Surface Elevation: +15.4 feet

DEPTH (feet)	Sample No.	Sample	Blows/ Foot	MATERIAL DESCRIPTION	Moisture Content (%)	Dry Density (pcf)	Unconf. Comp. Str. (psf)
0				12 inches CONCRETE SLAB			
1	1		28	CLAYEY SILT (ML) Medium dense, very dark brown, trace gravel GMTX-13A PID = 0	18	89	---
4	2		12	CLAYEY SAND (SC) Medium dense, olive brown, trace gravel, moist GMTX-13B PID = 0	---	---	---
8	3		7	CLAYEY SILT (ML - CL) Medium stiff, dark greenish gray ATD ▽	31	89	---
15	4	SHELBY	50-250 psi		---	---	---
16				GRAVELLY SILT (ML) Medium dense, black, grayish green, fine sand, trace calcareous deposits			
20	5	SHELBY	---		22	108	700
25	6		15		19	106	---
28				SANDY CLAY with GRAVEL (CL) Very stiff to hard, greenish gray with dark yellowish brown, fine sand			
30							

DRAFT

gt-1-88

PROJECT: CHIRON CAMPUS EXPANSION PROJECT
Emeryville, California

Log of Boring No. B13 (cont'd.)

DEPTH (feet)	SAMPLES Sample No.	SAMPLES Sample	SAMPLES Blows/Foot	MATERIAL DESCRIPTION	LABORATORY TESTS Moisture Content (%)	LABORATORY TESTS Dry Density (pcf)	LABORATORY TESTS Unconf. Comp. Str. (psf)
65–74				SANDY CLAY (CL) (continued)			
70–71	12		75		---	---	---
74–81				CLAYEY SAND with GRAVEL (SC) Very dense, dark yellowish brown			
80–81	13		50/4"		---	---	---
81				Bottom of boring at 81.0 feet. Boring drilled using hollow stem augers to 25 feet; approximately 15 gallons of groundwater bailed from hollow stem augers; boring advanced to bottom using rotary wash drilling. Boring backfilled with cement bentonite grout.			

DRAFT

gt-2-88

Appendix B
Cone Penetration Test Results

PRESENTATION OF CONE PENETRATION TEST DATA

SHERWIN WILLIAMS

1450 SHERWIN AVENUE
EMERYVILLE, CALIFORNIA

Prepared for:

CDM

Prepared by:

GREGG IN SITU, INC.
Martinez, California
03-027ma

Prepared on:

February 4, 2003

TABLE OF CONTENTS

1.0 INTRODUCTION

2.0 FIELD EQUIPMENT & PROCEDURES

3.0 CONE PENETRATION TEST DATA & INTERPRETATION

3.1 CPT PLOTS
3.2 INTERPRETED OUTPUT
3.3 PORE PRESSURE DISSIPATION PLOTS

APPENDIX

- Figure 1 Piezocone Figure
- Figure 2 PPDT Correlation Figure
- Figure 3 Soil Classification Chart
- References

ATTACHMENTS

- Interpretation Method
- Computer Diskette with ASCII Files

PRESENTATION OF CONE PENETRATION TEST DATA

1.0 INTRODUCTION

This report presents the results of a Cone Penetration Testing (CPT) program carried out at the Sherwin Williams site located in Emeryville, CA. The work was performed on January 29th, 2003. The scope of work was performed as directed by CDM personnel.

2.0 FIELD EQUIPMENT & PROCEDURES

The Cone Penetration Tests (CPT) were carried out by GREGG IN SITU, INC. of Martinez, CA using an integrated electronic cone system. The CPT soundings were performed in accordance with ASTM standards (D 5778-95). A 20 ton capacity cone was used for all of the soundings (figure 1). This cone has a tip area of 15 cm^2 and friction sleeve area of 225 cm^2. The cone is designed with an equal end area friction sleeve and a tip end area ratio of 0.85.

The cones used during the program recorded the following parameters at 5 cm depth intervals:

- Tip Resistance (qc)
- Sleeve Friction (fs)
- Dynamic Pore Pressure (U)

The above parameters were printed simultaneously on a printer and stored on a computer diskette for future analysis and reference.

The pore water pressure element was located directly behind the cone tip. The pore water pressure element was 5.0 mm thick and consisted of porous plastic. Each of the elements were saturated in silicon oil under vacuum pressure prior to penetration. Pore pressure dissipations were recorded at 5 second intervals when appropriate during pauses in the penetration.

A complete set of baseline readings was taken prior to each sounding to determine temperature shifts and any zero load offsets. Monitoring base line readings ensures that the cone electronics are operating properly.

The cones were pushed using GREGG IN SITU's CPT rig, having a down pressure capacity of approximately 20 tons. Six CPT soundings were performed. The penetration tests were carried to depths of approximately 100 feet below ground surface. Test locations and depths were determined in the field by CDM personnel.

3.0 CONE PENETRATION TEST DATA & INTERPRETATION

The cone penetration test data is presented in graphical form. Penetration depths are referenced to existing ground surface. This data includes CPT logs of measured soil parameters and a computer tabulation of interpreted soil types along with additional geotechnical parameters and pore pressure dissipation data.

The stratigraphic interpretation is based on relationships between cone bearing (qc), sleeve friction (fs), and penetration pore pressure (U). The friction ratio (Rf), which is sleeve friction divided by cone bearing, is a calculated parameter which is used to infer soil behavior type. Generally, cohesive soils (clays) have high friction ratios, low cone bearing and generate large excess pore water pressures. Cohesionless soils (sands) have lower friction ratios, high cone bearing and generate little in the way of excess pore water pressures.

Pore Pressure Dissipation Tests (PPDT's) were taken at various intervals in order to measure hydrostatic water pressures and approximate depth to groundwater table. In addition, the PPDT data can be used to estimate the horizontal permeability (k_h) of the soil. The correlation to permeability is based on the time required for 50 percent of the measured dynamic pore pressure to dissipate (t_{50}). The PPDT correlation figure (figure 2) is provided in the Appendix.

The interpretation of soils encountered on this project was carried out using recent correlations developed by Robertson et al, 1990. It should be noted that it is not always possible to clearly identify a soil type based on qc, fs and U. In these situations, experience and judgement and an assessment of the pore pressure dissipation data should be used to infer the soil behavior type. The soil classification chart (figure 3) used to interpret soil types based on qc and Rf is provided in the Appendix.

Interpreted output requires that depth of water be entered for calculation purposes, where depth to water is unknown an arbitrary depth in excess of 10 feet of the deepest sounding is entered as the groundwater depth.

GREGG IN SITU, INC.
February 4, 2003
03-027ma

CDM
Sherwin Williams
Emeryville, Ca.

We hope the information presented is sufficient for your purposes. We recommend that all data be carefully reviewed by qualified personnel to verify the data and make appropriate recommendations. If you have any questions, please do not hesitate to contact our office at (925) 313-5800.

Sincerely,
GREGG IN SITU, INC.

Mary Walden
Operations Manager

APPENDIX

ELECTRICAL PIEZOCONE

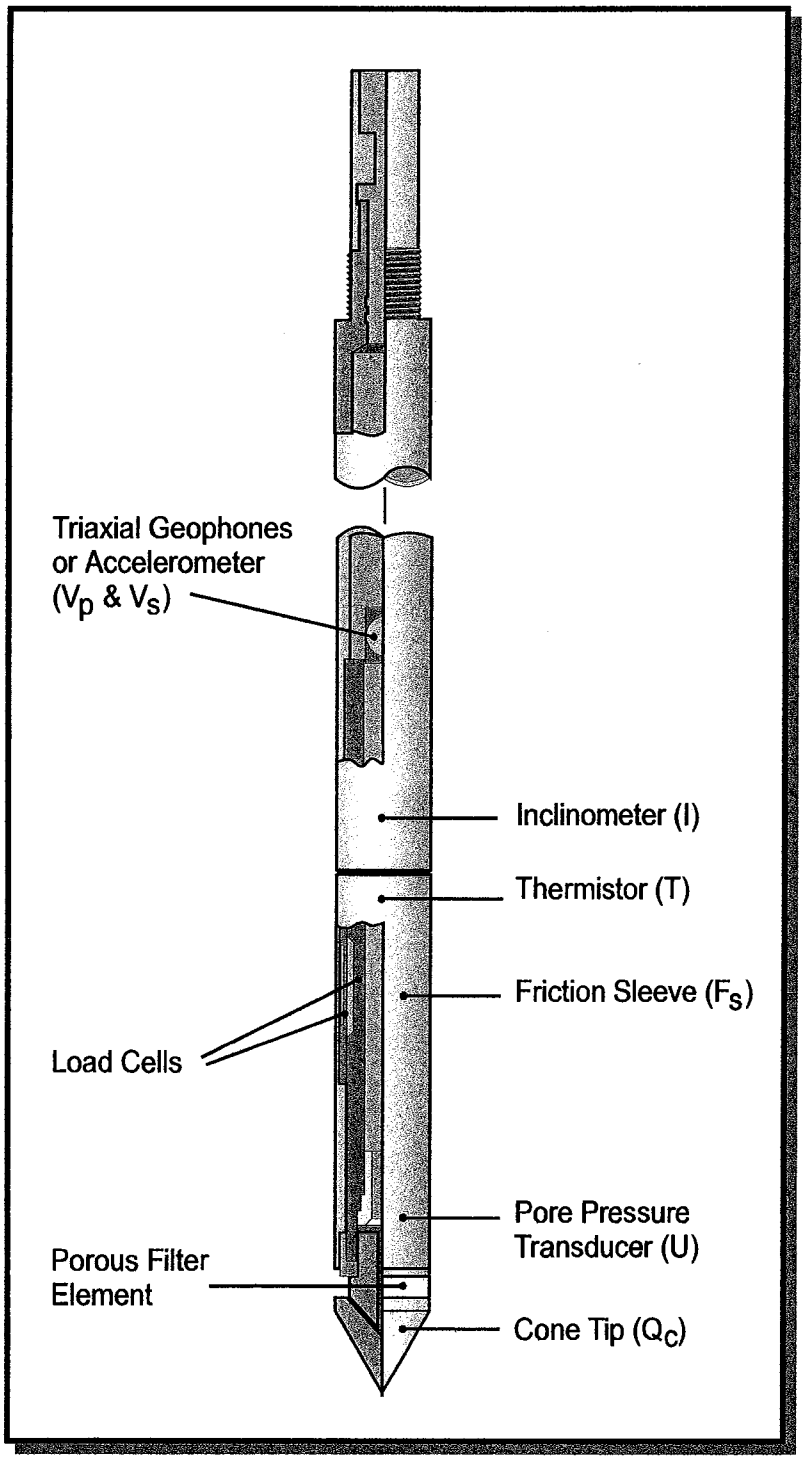
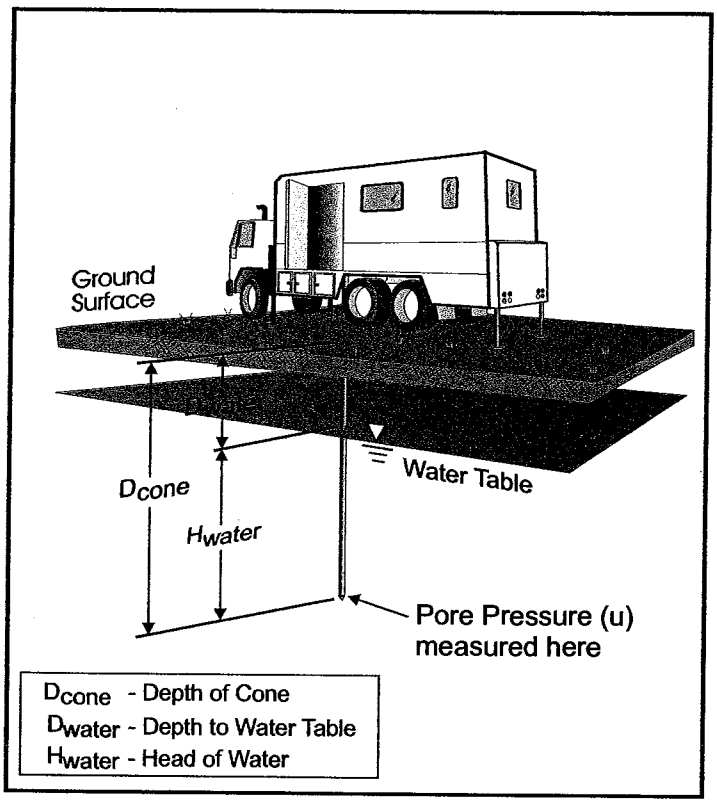
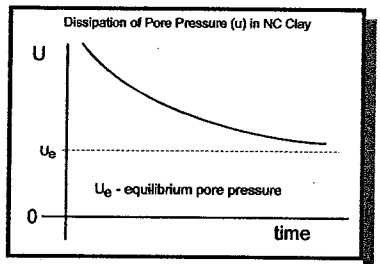
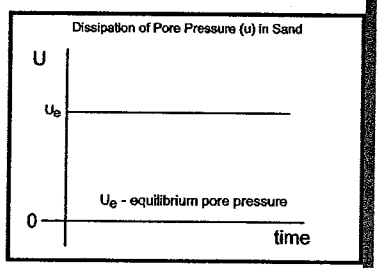


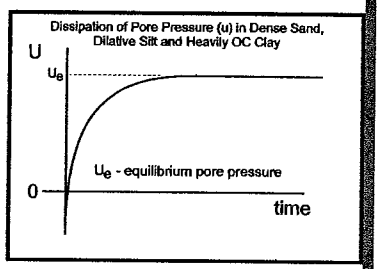
Figure 1

INTERPRETATION PORE PRESSUE DATA AND DISSIPATIONS









Water Table Calculation

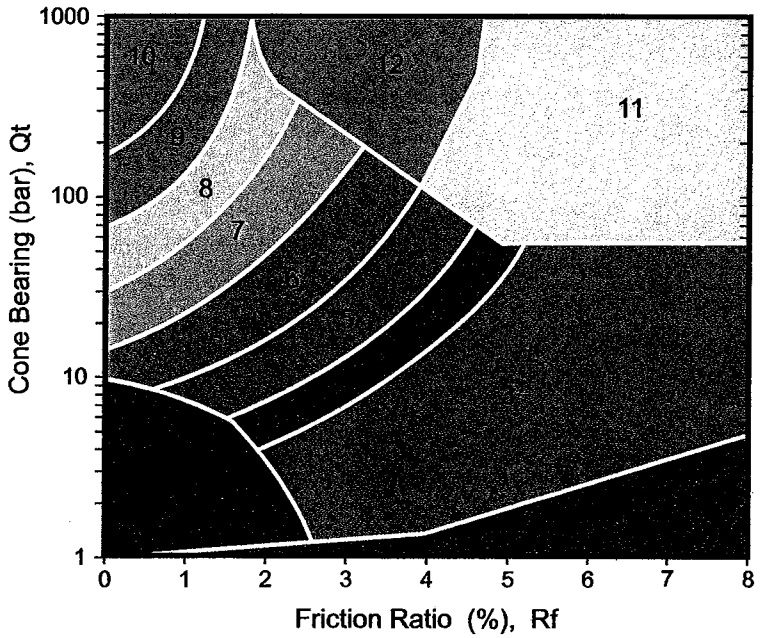
$$D_{water} = D_{cone} - H_{water}$$

where $H_{water} = U_e$ (depth units)

Useful Conversion Factors: 1psi = 0.704m = 2.31 feet (water)
1tsf = 0.958 bar = 13.9 psi
1m = 3.28 feet

Figure 2

SOIL BEHAVIOR TYPE



Zone	Q_t / N	Soil Behaviour Type
1	2	sensitive fine grained
2	1	organic material
3	1	clay
4	1.5	silty clay to clay
5	2	clayey silt to silty clay
6	2.5	sandy silt to clayey silt
7	3	silty sand to sandy silt
8	4	sand to silty sand
9	5	sand
10	6	gravelly sand to sand
11	1	very stiff fine grained *
12	2	sand to clayey sand *

* overconsolidated or cemented

Robertson (1990)

Figure 3

REFERENCES

Robertson, P.K. and Campanella, R.G. and Wightman, A., 1983 "SPT-CPT Correlations", Journal of the Geotechnical Division, ASCE, Vol. 109, No. GT11, Nov., pp. 1449-1460.

Robertson, P.K. and Wride C.E., 1998 "Evaluating Cyclic Liquefaction Potential Using The Cone Penetration Test", Journal of Geotechnical Division, Mar. 1998, pp. 442-459.

Robertson, P.K. and Campanella, R.G., Gillespie, D. and Greig, J., 1986, "Use of Piezometer Cone Data", Proceedings of In Situ 86, ASCE Specialty Conference, Blacksburg, Virginia.

Robertson, P.K. and Campanella, R.G., 1988, "Guidelines for Use, Interpretation and Application of the CPT and CPTU", UBC, Soil Mechanics Series No. 105, Civil Eng. Dept., Vancouver, B.C., V6T 1W5, Canada.

Robertson, P.K., Campanella, R.G., Gillespie, D. and Rice, A., 1986, "Seismic CPT to Measure In Situ Shear Wave Velocity", Journal of Geotechnical Engineering, ASCE, Vol. 112, No. 8, pp. 791-803.

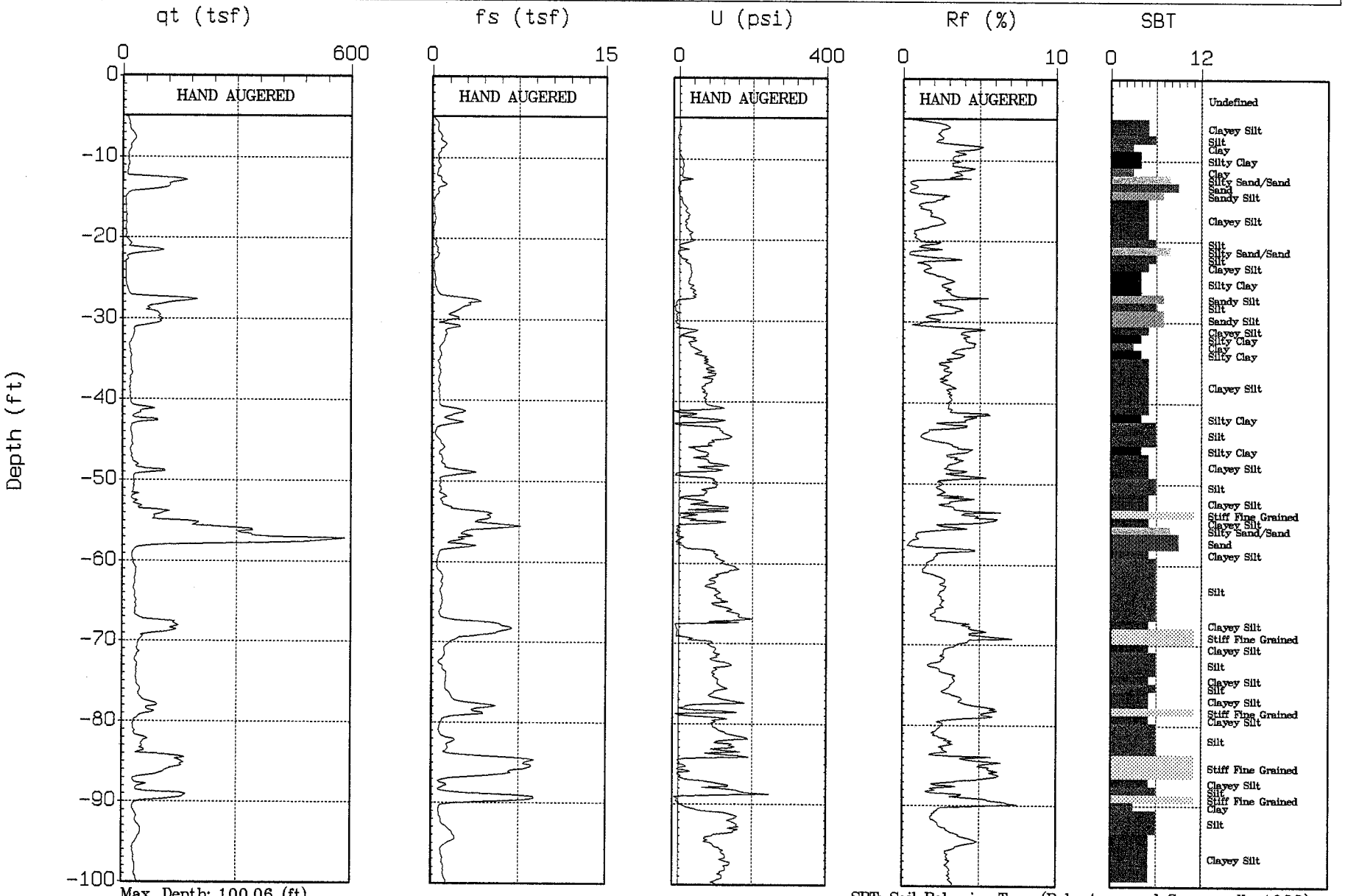
3.1 CPT PLOTS

GREGG

CDM

Site : SHERWIN WILLIAMS
Location : CPT-01

Engineer : H. YOUNG
Date : 01:29:03 11:54



Max. Depth: 100.06 (ft)

Depth Inc.: 0.164 (ft)

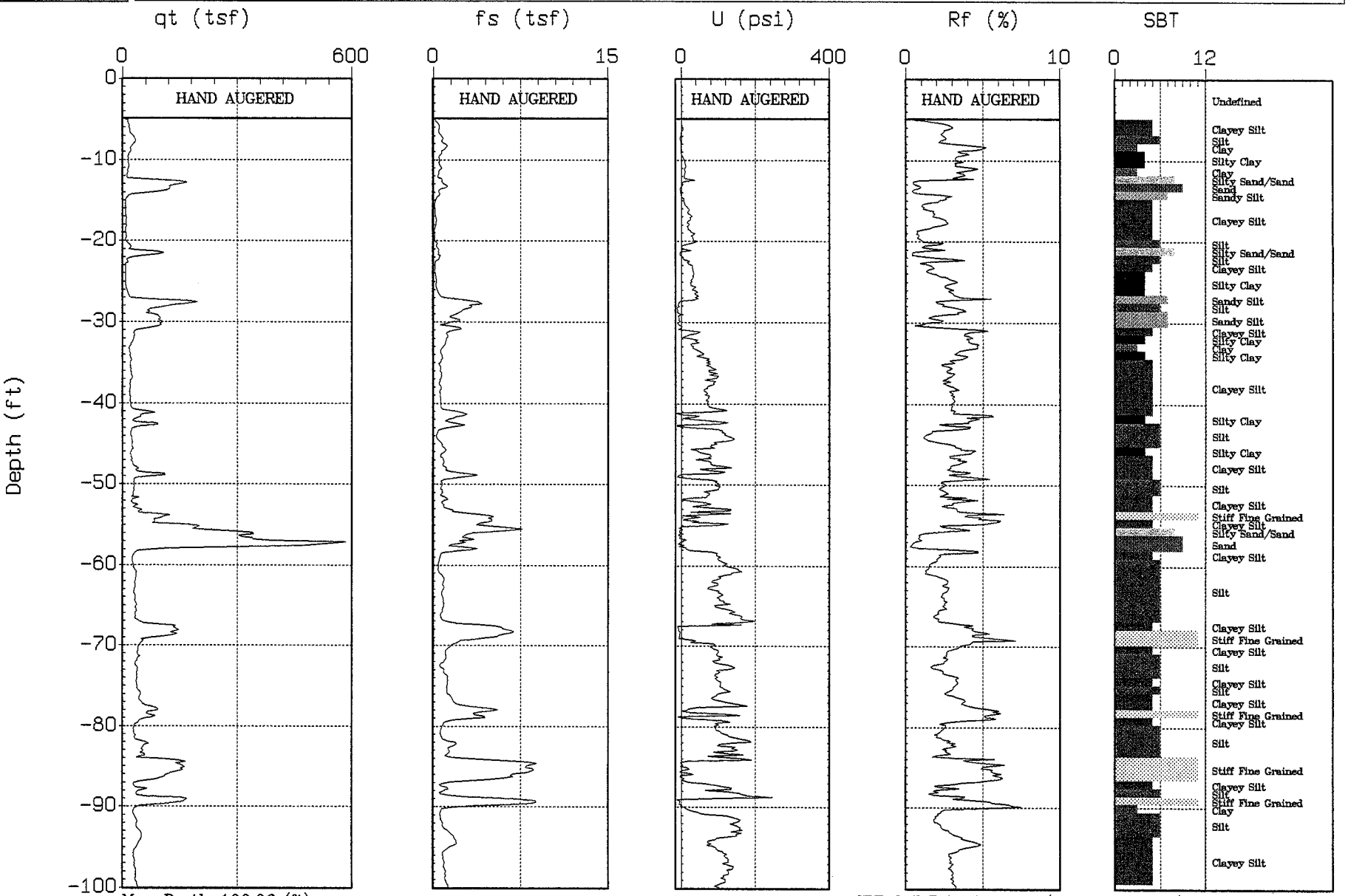
SBT: Soil Behavior Type (Robertson and Campanella 1988)

GREGG

CDM

Site : SHERWIN WILLIAMS
Location : CPT-01

Engineer : H. YOUNG
Date : 01:29:03 11:54



Max. Depth: 100.06 (ft)

Depth Inc.: 0.164 (ft)

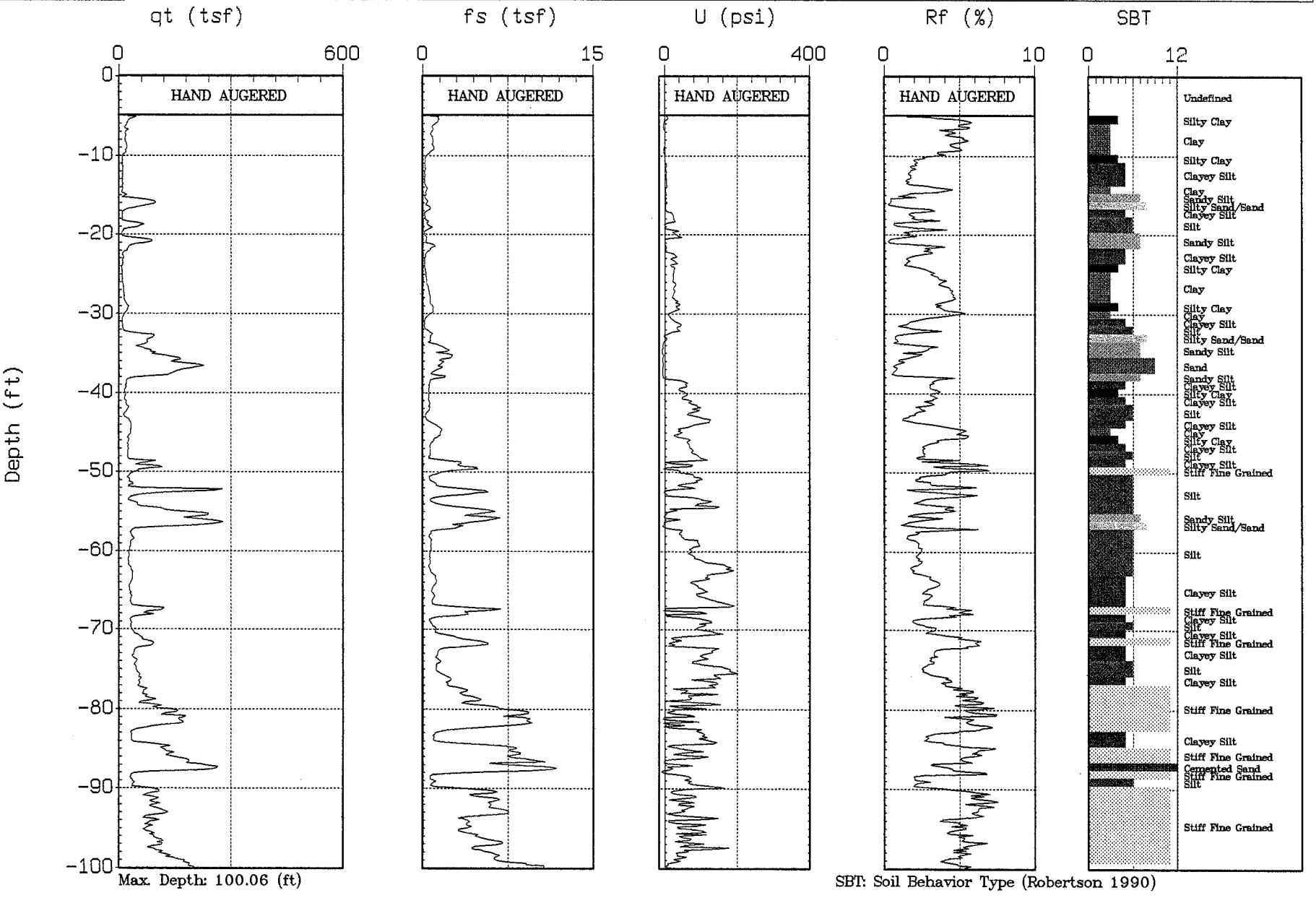
SBT: Soil Behavior Type (Robertson 1990)

GREGG

CDM

Site : SHERWIN WILLIAMS
Location : CPT-02

Engineer : H. YOUNG
Date : 01:29:03 09:33



Max. Depth: 100.06 (ft)

Depth Inc.: 0.164 (ft)

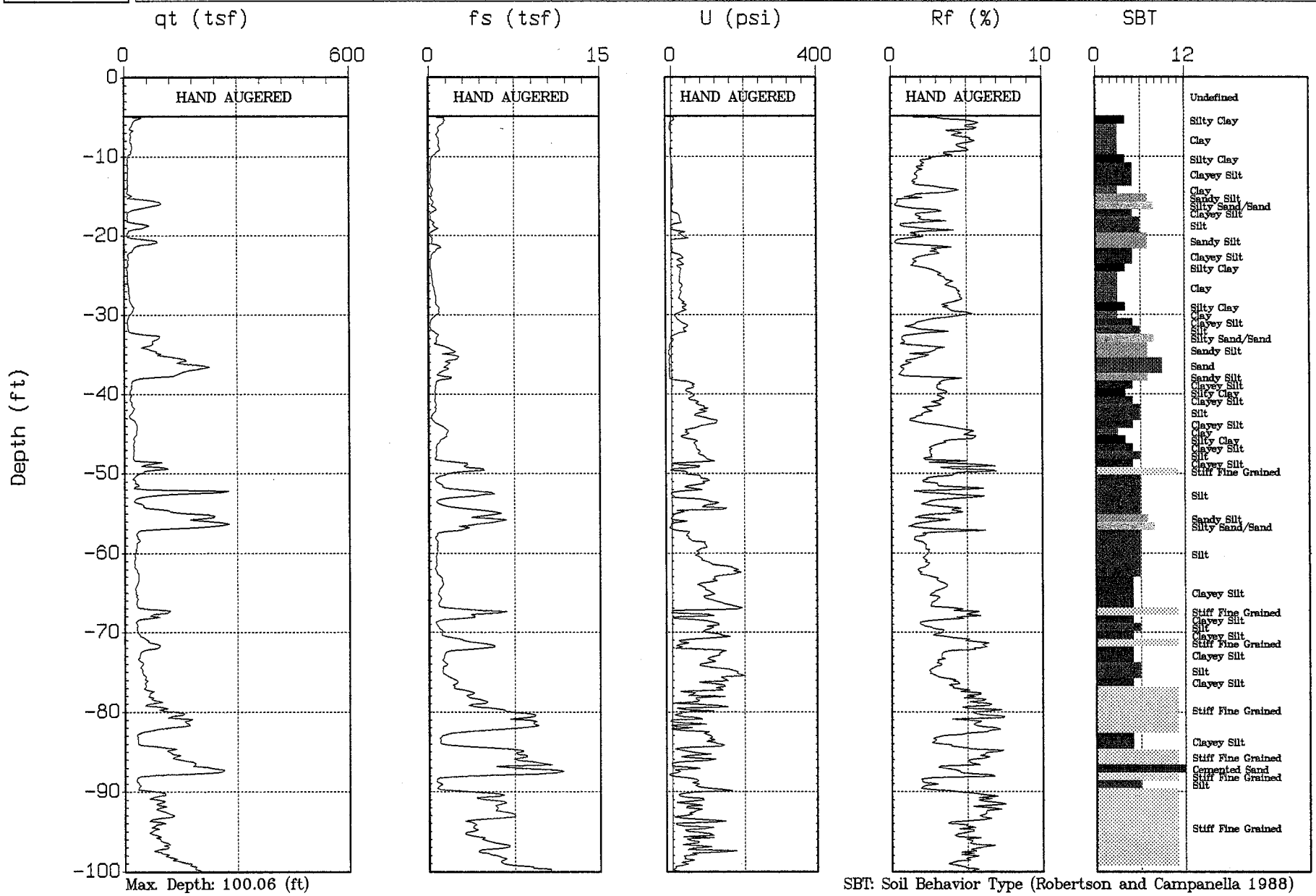
SBT: Soil Behavior Type (Robertson 1990)

GREGG

CDM

Site : SHERWIN WILLIAMS
Location : CPT-02

Engineer : H. YOUNG
Date : 01:29:03 09:33



Max. Depth: 100.06 (ft)

Depth Inc.: 0.164 (ft)

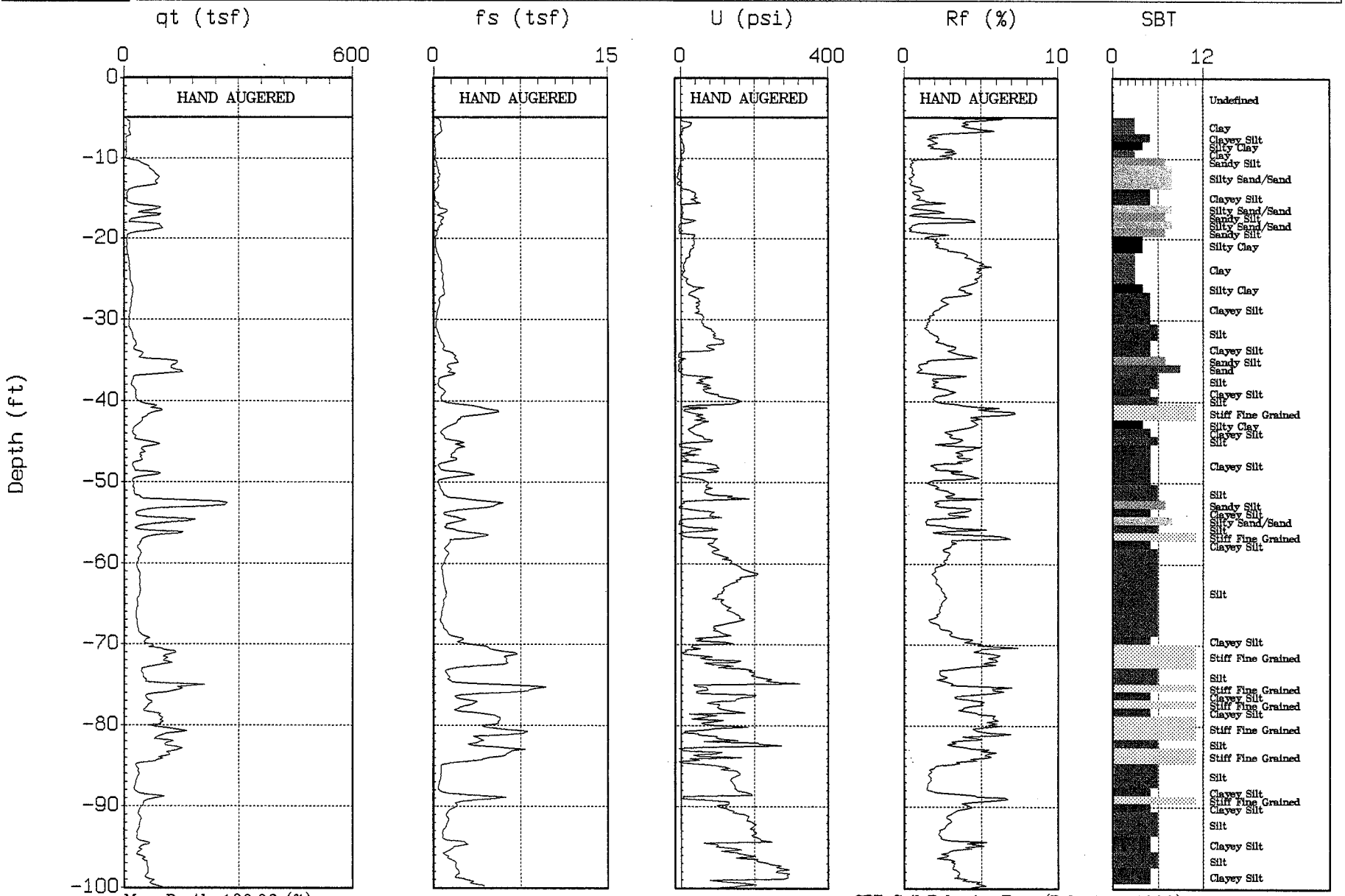
SBT: Soil Behavior Type (Robertson and Campanella 1988)

GREGG

CDM

Site : SHERWIN WILLIAMS
Location : CPT-04

Engineer : H. YOUNG
Date : 01:28:03 08:29



Max. Depth: 100.06 (ft)

Depth Inc.: 0.164 (ft)

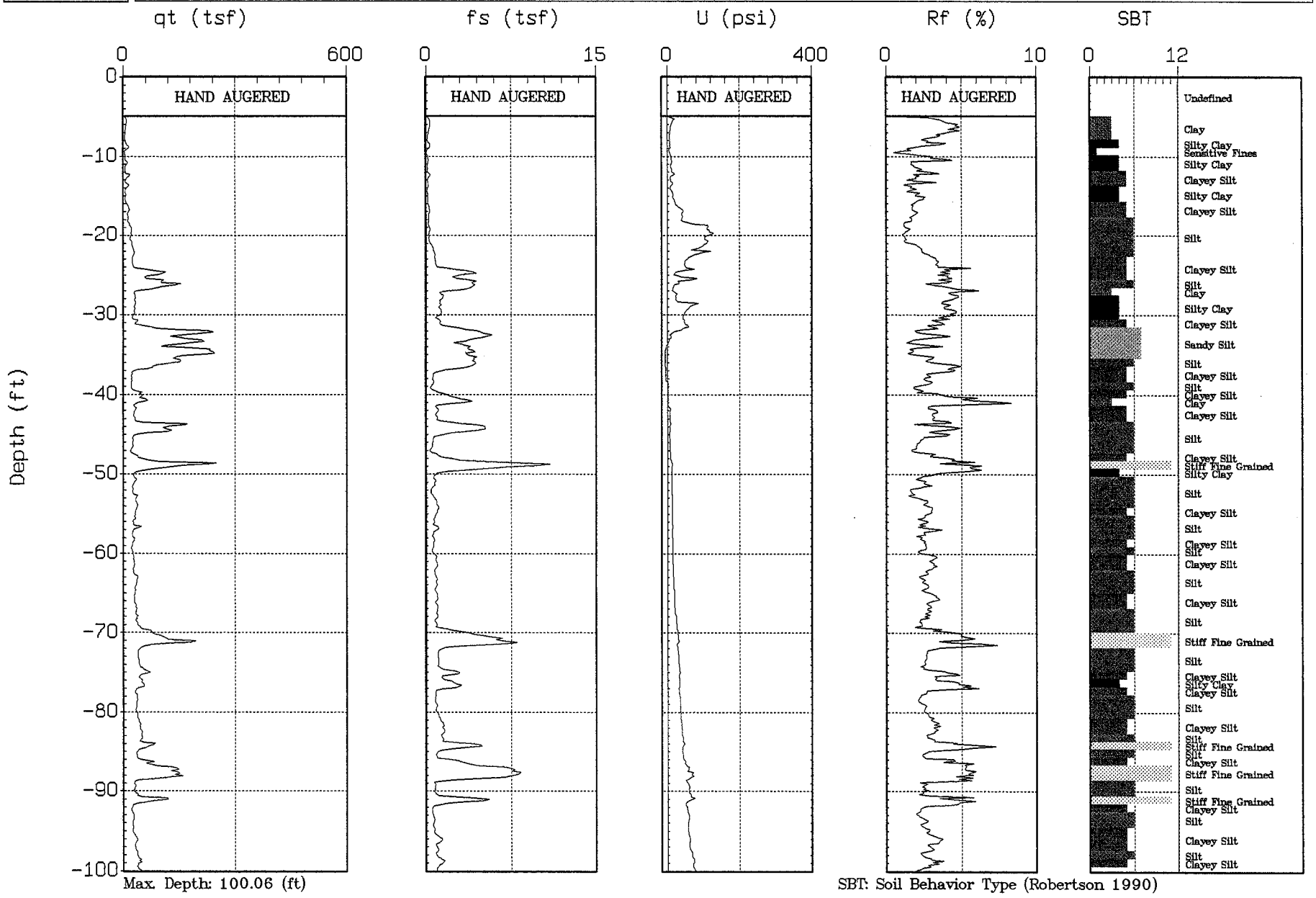
SBT: Soil Behavior Type (Robertson 1990)

GREGG

CDM

Site : SHERWIN WILLIAMS
Location : CPT-05

Engineer : H. YOUNG
Date : 01:28:03 10:52



Max. Depth: 100.06 (ft)

Depth Inc.: 0.164 (ft)

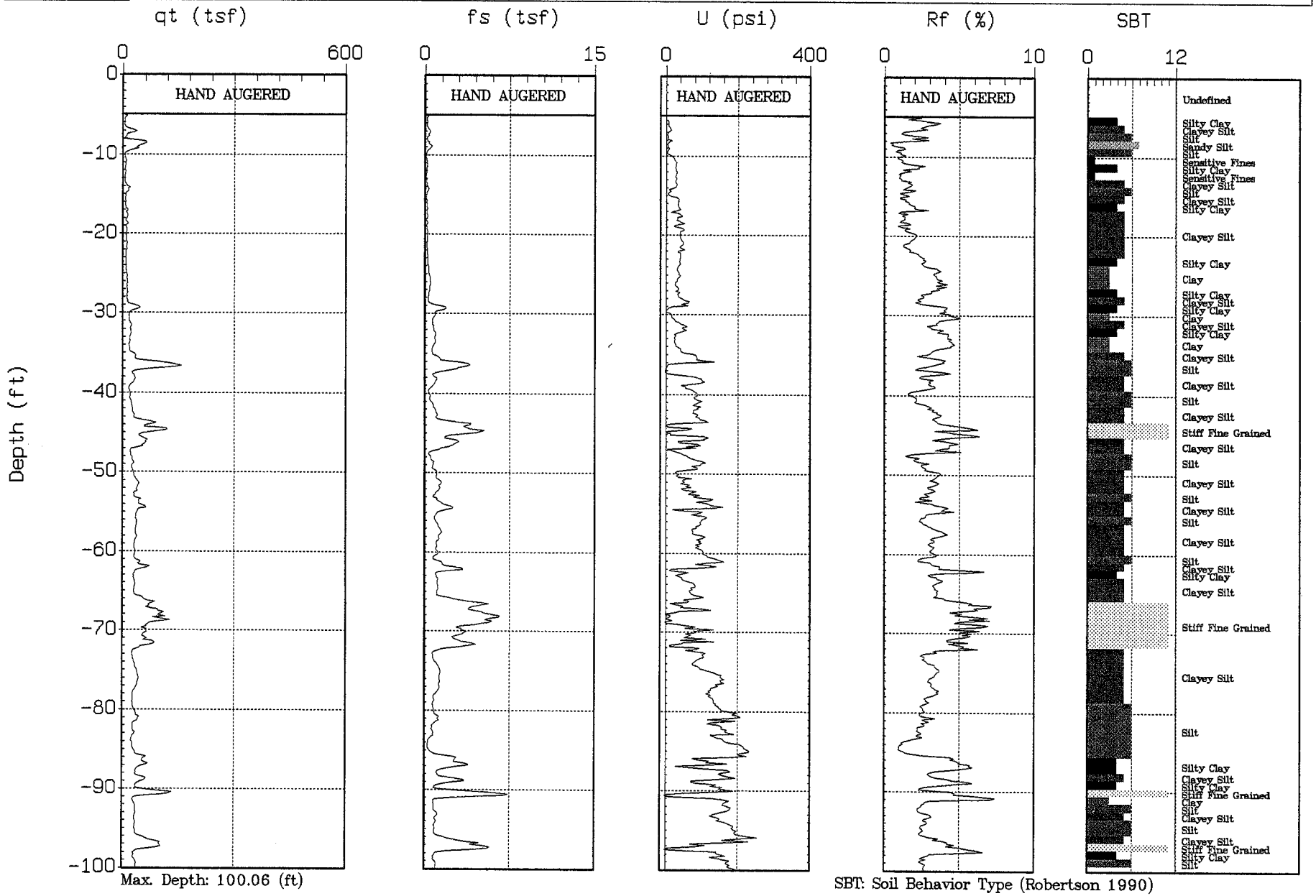
SBT: Soil Behavior Type (Robertson 1990)

GREGG

CDM

Site : SHERWIN WILLIAMS
Location : CPT-06

Engineer : H. YOUNG
Date : 01:28:03 12:49



Max. Depth: 100.06 (ft)

Depth Inc.: 0.164 (ft)

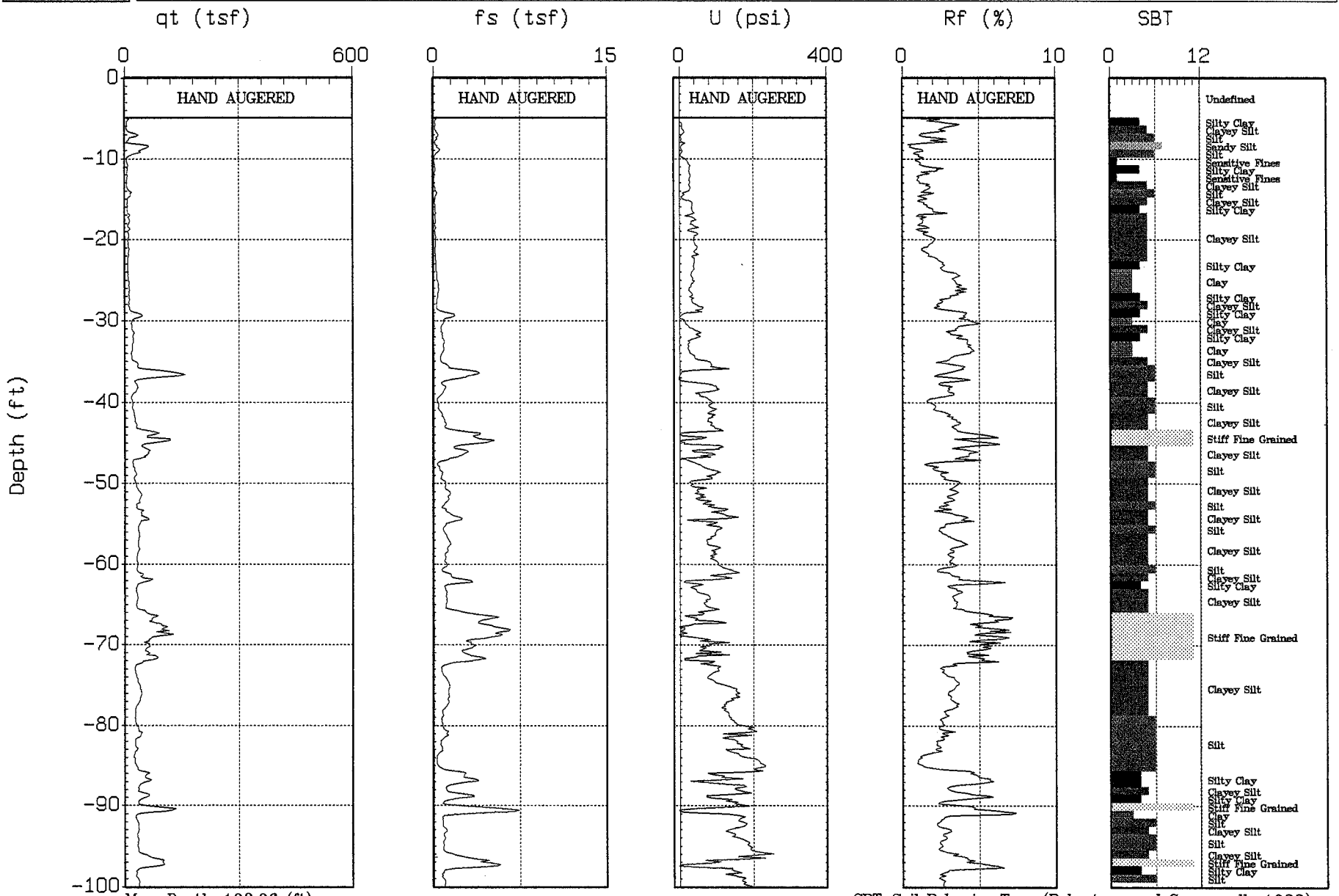
SBT: Soil Behavior Type (Robertson 1990)

GREGG

CDM

Site : SHERWIN WILLIAMS
Location : CPT-06

Engineer : H. YOUNG
Date : 01:28:03 12:49



Max. Depth: 100.06 (ft)

Depth Inc.: 0.164 (ft)

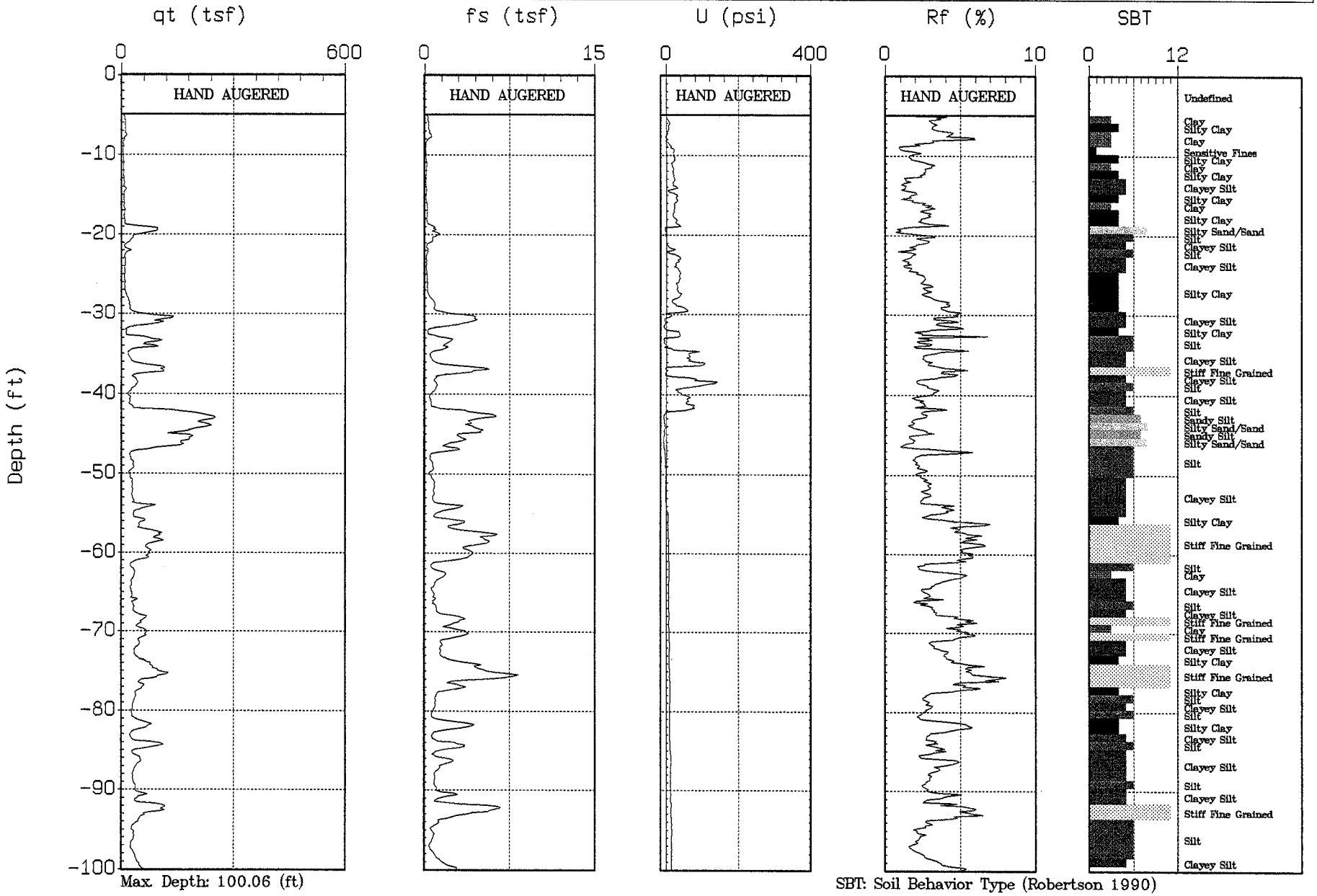
SBT: Soil Behavior Type (Robertson and Campanella 1988)

GREGG

CDM

Site : SHERWIN WILLIAMS
Location : CPT-07

Engineer : H. YOUNG
Date : 01:28:03 14:52



Max. Depth: 100.06 (ft)

Depth Inc.: 0.164 (ft)

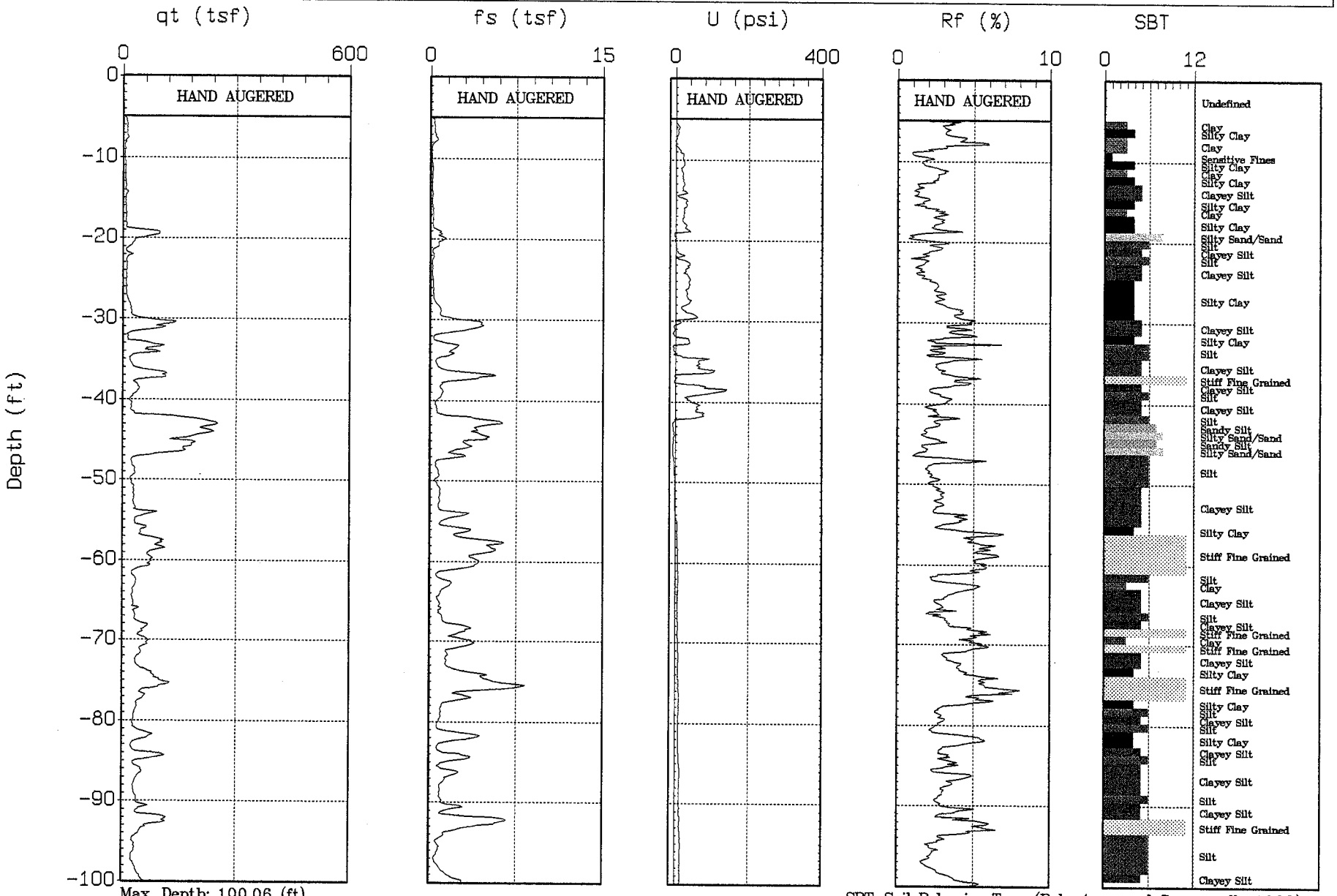
SBT: Soil Behavior Type (Robertson 1990)

GREGG

CDM

Site : SHERWIN WILLIAMS
Location : CPT-07

Engineer : H. YOUNG
Date : 01:28:03 14:52



Max. Depth: 100.06 (ft)

Depth Inc.: 0.164 (ft)

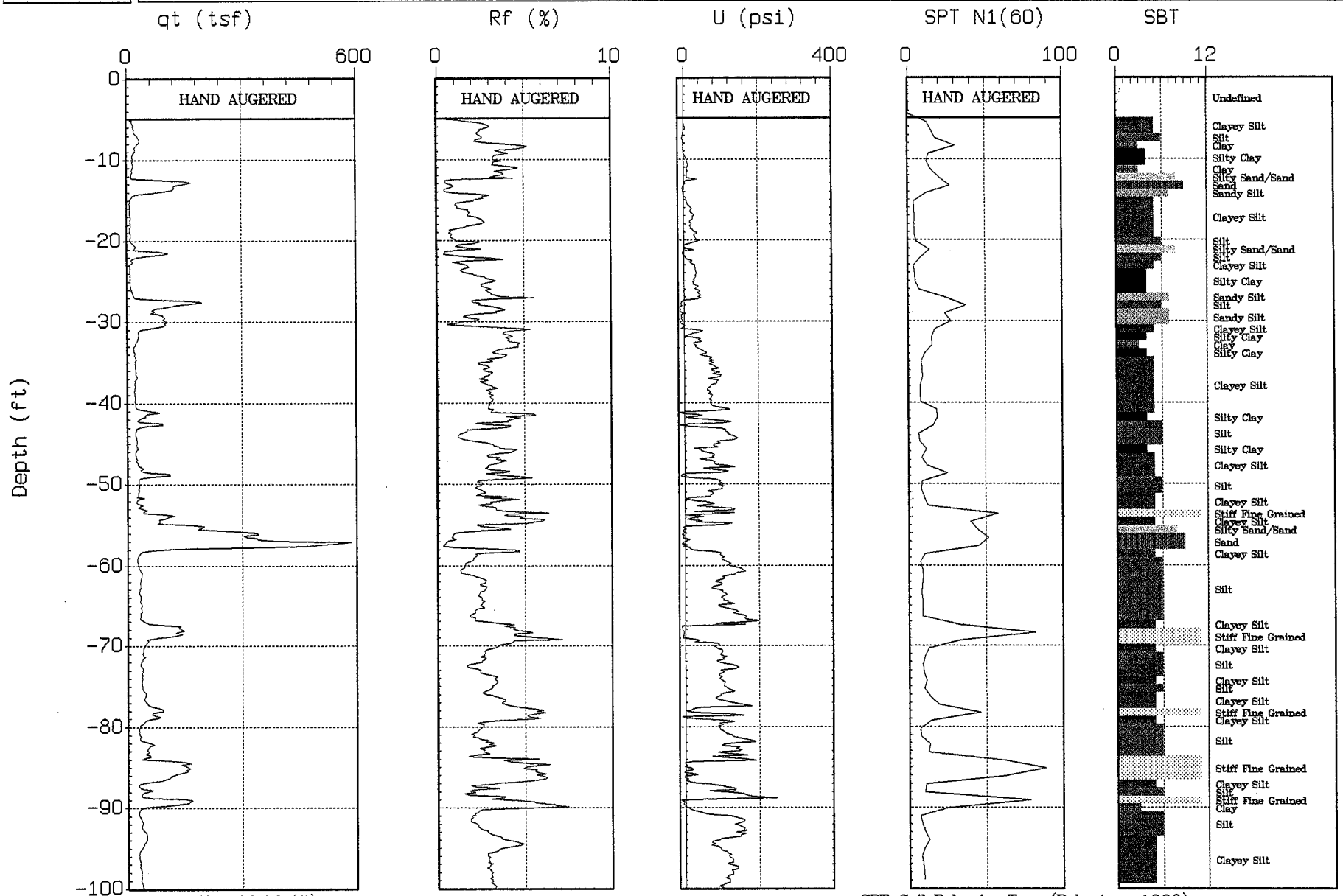
SBT: Soil Behavior Type (Robertson and Campanella 1988)

GREGG

CDM

Site : SHERWIN WILLIAMS
Location : CPT-01

Engineer : H. YOUNG
Date : 01:29:03 11:54



Max. Depth: 100.06 (ft)

Depth Inc.: 0.164 (ft)

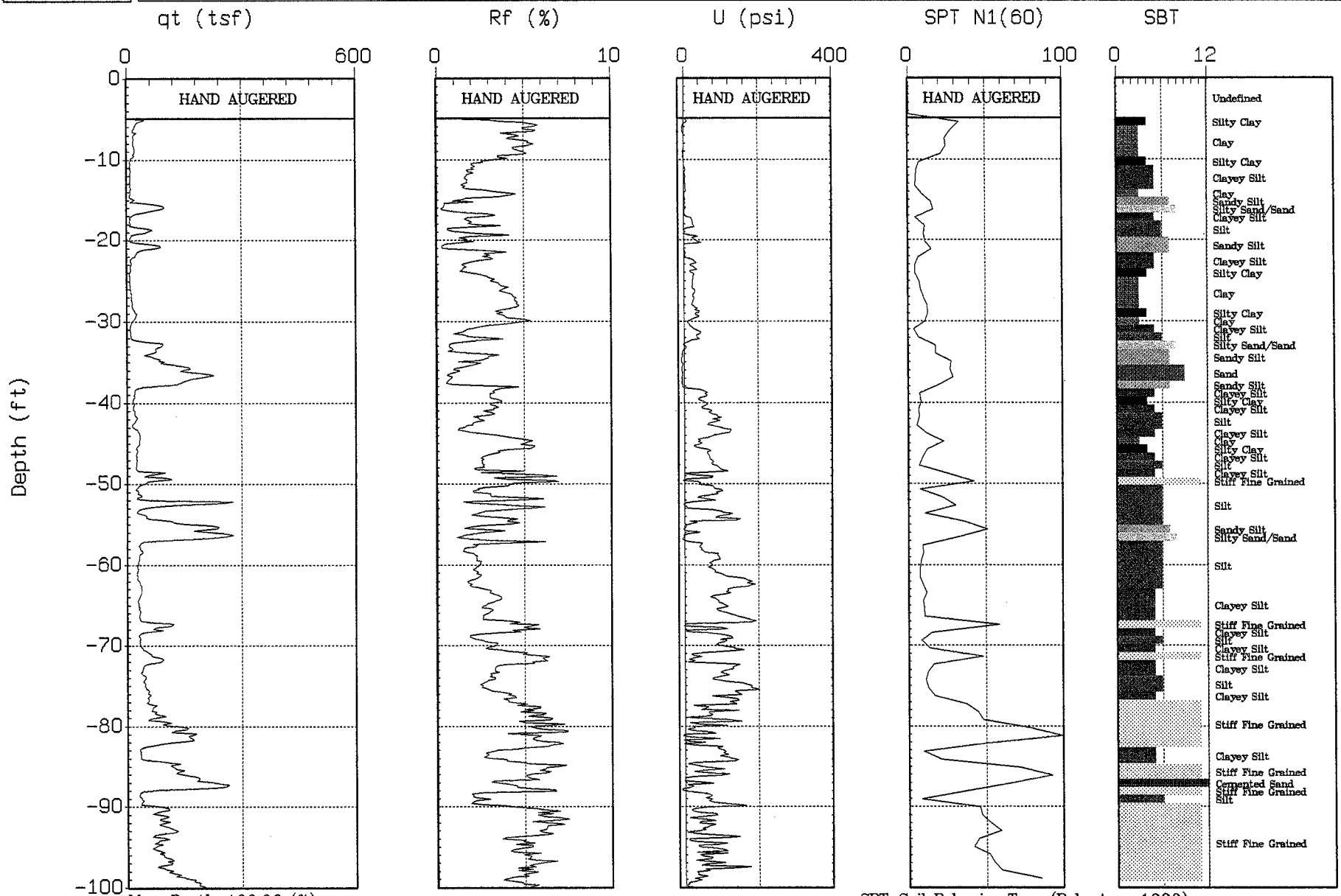
SBT: Soil Behavior Type (Robertson 1990)

GREGG

CDM

Site : SHERWIN WILLIAMS
Location : CPT-02

Engineer : H. YOUNG
Date : 01:29:03 09:33



Max. Depth: 100.06 (ft)

Depth Inc.: 0.164 (ft)

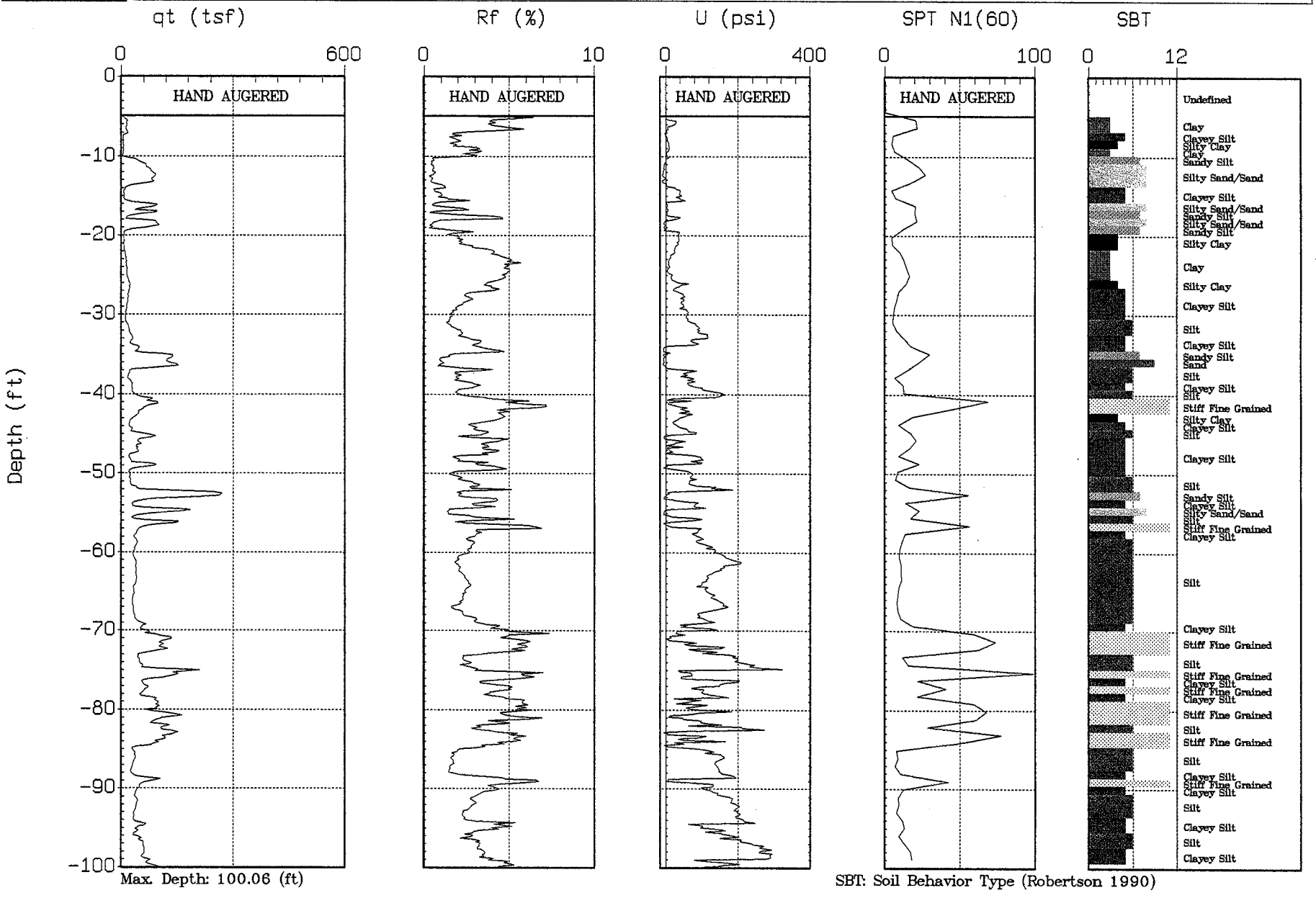
SBT: Soil Behavior Type (Robertson 1990)

GREGG

CDM

Site : SHERWIN WILLIAMS
Location : CPT-04

Engineer : H. YOUNG
Date : 01:28:03 08:29



Max. Depth: 100.06 (ft)

Depth Inc.: 0.164 (ft)

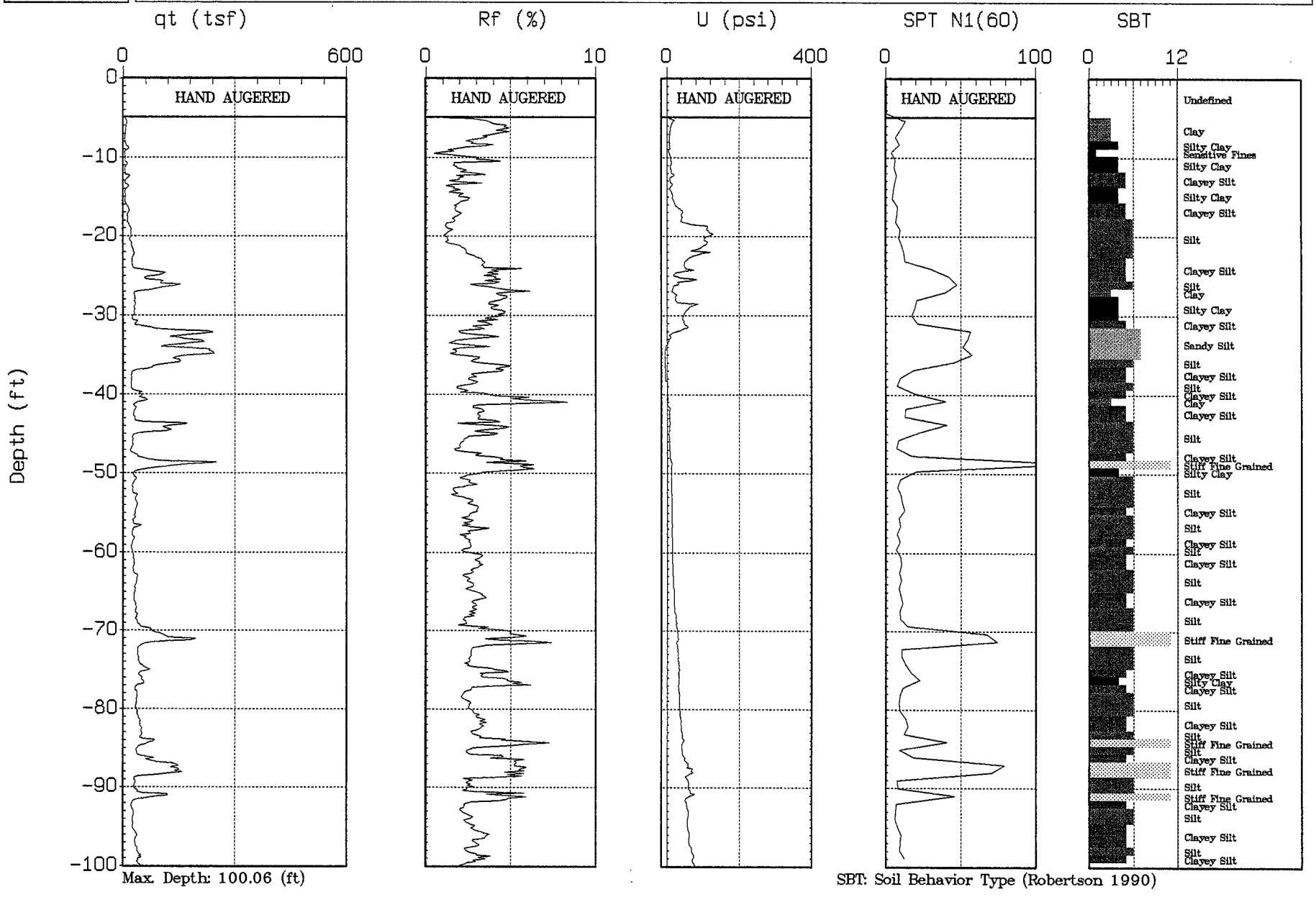
SBT: Soil Behavior Type (Robertson 1990)

GREGG

CDM

Site : SHERWIN WILLIAMS
Location : CPT-05

Engineer : H. YOUNG
Date : 01:28:03 10:52



Max. Depth: 100.06 (ft)

Depth Inc.: 0.164 (ft)

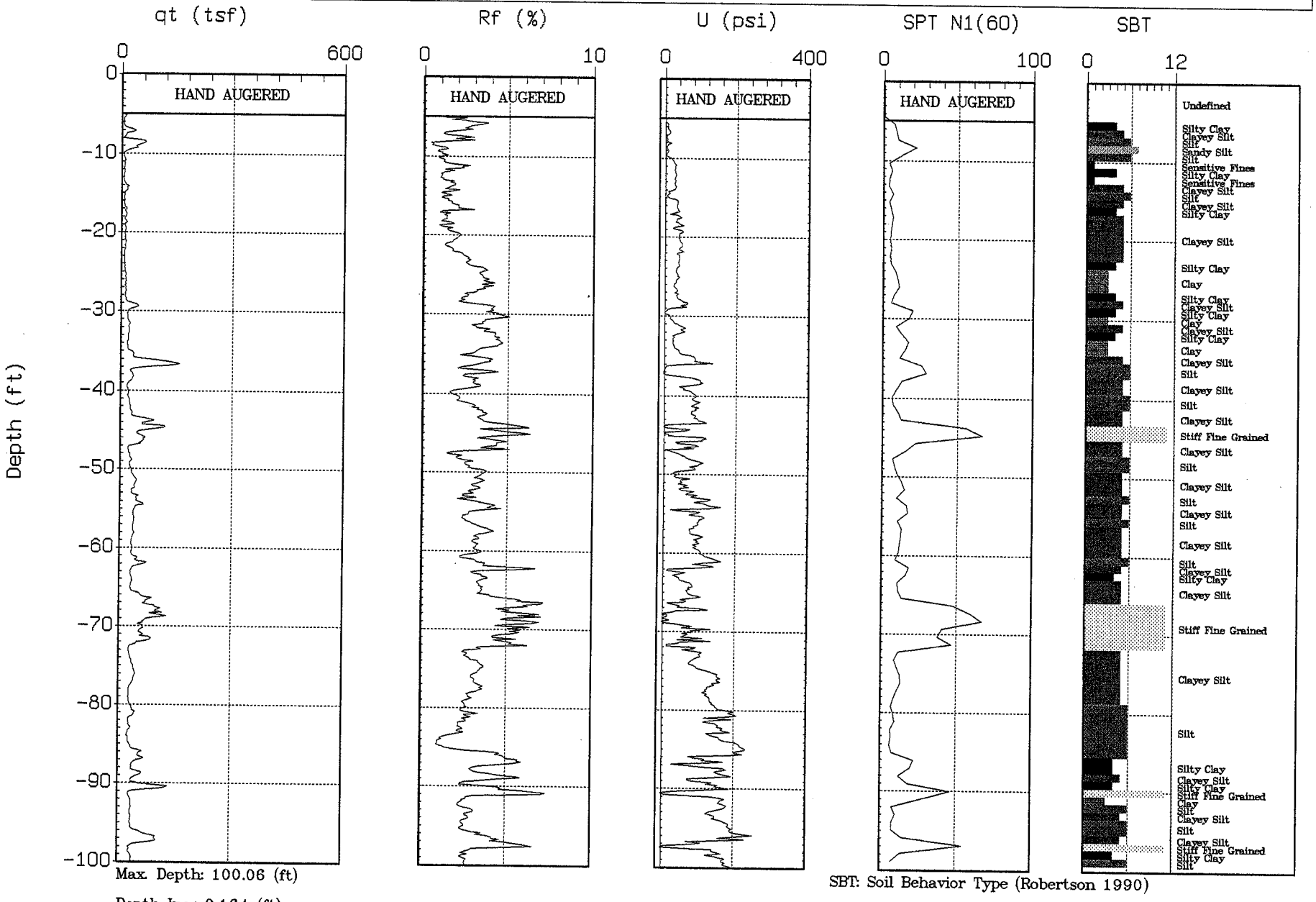
SBT: Soil Behavior Type (Robertson 1990)

GREGG

CDM

Site : SHERWIN WILLIAMS
Location : CPT-06

Engineer : H. YOUNG
Date : 01:28:03 12:49



Max. Depth: 100.06 (ft)

Depth Inc.: 0.164 (ft)

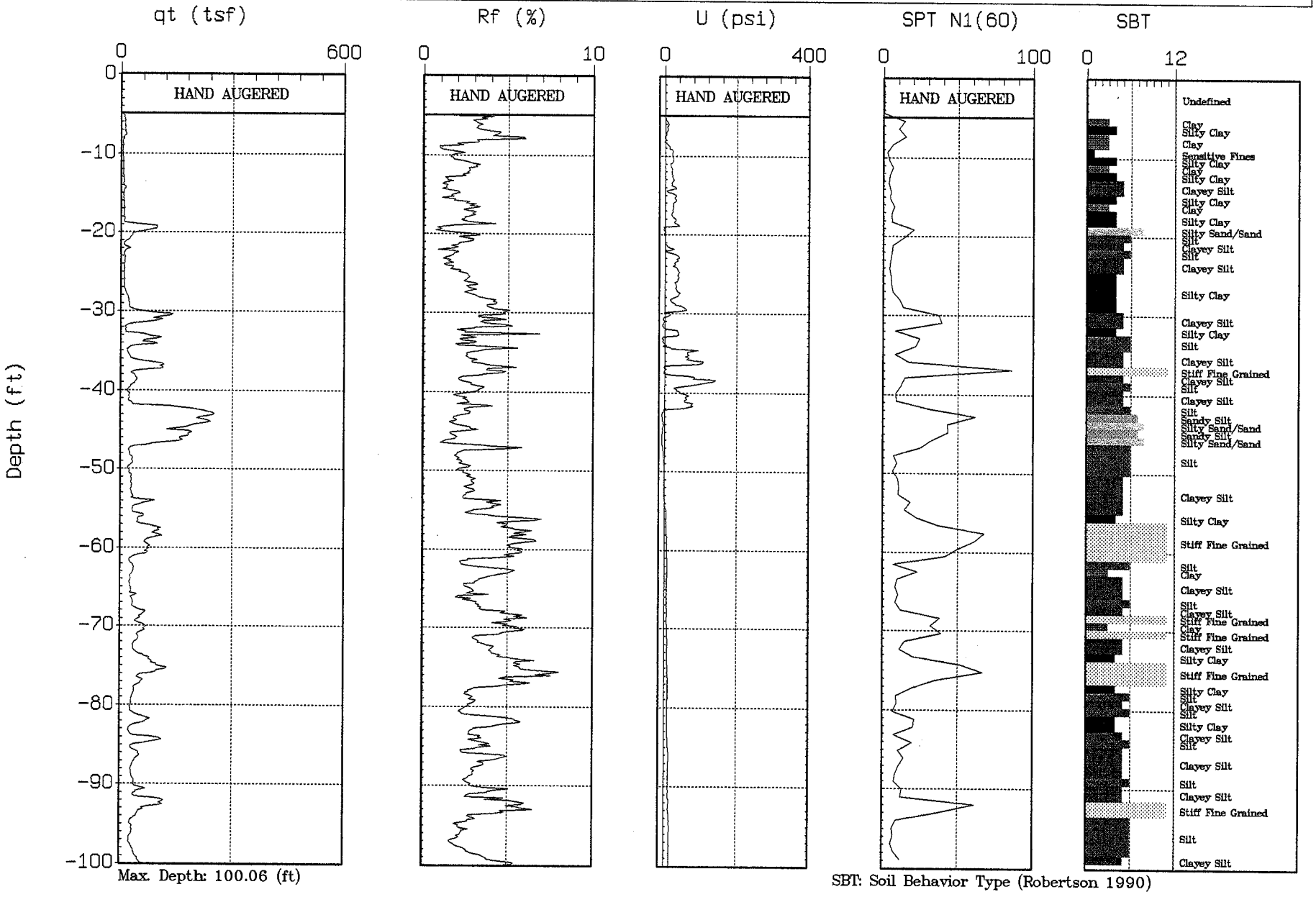
SBT: Soil Behavior Type (Robertson 1990)

GREGG

CDM

Site : SHERWIN WILLIAMS
Location : CPT-07

Engineer : H. YOUNG
Date : 01:28:03 14:52



Max. Depth: 100.06 (ft)

Depth Inc.: 0.164 (ft)

SBT: Soil Behavior Type (Robertson 1990)

3.2 INTERPRETED OUTPUT

Gregg In Situ, Inc.
Interpretation Output - Release 1.00.19e
Run No: 03-0203-1606-1781
Job No: 97-100
Client: CDM
Project: CPT SITE INVESTIGATION
Site: SHERWIN WILLIAMS
Location: CPT-07
Engineer: H. YOUNG
CPT Date: 03/28/01
CPT Time: 14:52
CPT File: 027C07.COR
Northing (m): 0.000
Easting (m): 0.000
Elevation (m): 0.000

Water Table (m): 3.35 (ft): 11.0
Su Nkt used: 12.50
Averaging Increment (m): 0.30
Phi Method : Robertson and Campanella, 1983
Dr Method : Jamiolkowski - All Sands
State Parameter M: 1.20
Used Unit Weights Assigned to Soil Zones
Values of 1.0E9 or UnDef are printed for parameters that are not valid for the material type (SBT)

Depth (ft)	AvgQt (tsf)	AvgFs (tsf)	AvgRf (%)	AvgUd (ft)	SBT	U.Wt. pcf	TStress (tsf)	EStress (tsf)	Ueq (tsf)	Cn	N60 (blows/ft)	(N1)60 (blows/ft)	Su (tsf)	CRR
0.49	0.0	0.00	0.00	0.0	UnDef	124.1	0.03	0.03	0.00	2.00	UnDef	UnDef	UnDef	0.00
1.48	0.0	0.00	0.00	0.0	UnDef	124.1	0.09	0.09	0.00	2.00	UnDef	UnDef	UnDef	0.00
2.46	0.0	0.00	0.00	0.0	UnDef	124.1	0.15	0.15	0.00	2.00	UnDef	UnDef	UnDef	0.00
3.44	0.0	0.00	0.00	0.0	UnDef	124.1	0.21	0.21	0.00	2.00	UnDef	UnDef	UnDef	0.00
4.43	0.0	0.00	0.00	0.0	UnDef	124.1	0.27	0.27	0.00	1.91	UnDef	UnDef	UnDef	0.00
5.41	8.5	0.28	3.33	9.3	3	111.4	0.33	0.33	0.00	1.73	8.2	14.1	0.65	0.12
6.40	9.9	0.33	3.31	15.2	4	114.6	0.39	0.39	0.00	1.60	6.3	10.2	0.76	0.12
7.30	10.8	0.50	4.57	3.4	3	111.4	0.44	0.44	0.00	1.51	10.4	15.7	0.83	0.00
8.20	5.0	0.18	3.55	7.1	3	111.4	0.49	0.49	0.00	1.43	4.8	6.8	0.36	0.00
9.19	3.9	0.05	1.32	39.7	1	79.6	0.54	0.54	0.00	1.37	1.9	2.6	0.27	0.00
10.17	4.2	0.08	1.80	50.1	1	79.6	0.58	0.58	0.00	1.32	2.0	2.6	0.29	0.00
11.15	5.2	0.15	2.90	38.3	3	111.4	0.62	0.62	0.00	1.27	5.0	6.4	0.37	0.00
12.14	4.8	0.12	2.54	44.0	3	111.4	0.68	0.64	0.04	1.25	4.6	5.7	0.33	0.00
13.21	6.1	0.08	1.34	47.5	5	114.6	0.74	0.67	0.07	1.22	2.9	3.6	0.43	0.08
14.27	8.4	0.12	1.47	41.9	5	114.6	0.80	0.70	0.10	1.20	4.0	4.8	0.61	0.09
15.26	5.8	0.09	1.61	67.5	4	114.6	0.86	0.72	0.13	1.18	3.7	4.4	0.40	0.08
16.24	6.5	0.18	2.82	52.8	3	111.4	0.91	0.75	0.16	1.16	6.2	7.2	0.45	0.00
17.22	7.3	0.20	2.74	45.6	4	114.6	0.97	0.77	0.19	1.14	4.7	5.3	0.51	0.09
18.21	7.8	0.22	2.80	66.6	4	114.6	1.02	0.80	0.23	1.12	5.0	5.5	0.54	0.00
19.19	78.7	0.82	1.05	11.7	8	120.9	1.08	0.83	0.26	1.10	18.8	20.7	UnDef	0.18
20.18	34.0	0.90	2.65	-1.4	6	114.6	1.14	0.85	0.29	1.08	13.0	14.1	2.63	0.24
21.16	12.5	0.29	2.33	9.2	5	114.6	1.20	0.88	0.32	1.07	6.0	6.4	0.90	0.11
22.15	14.1	0.21	1.51	41.3	6	114.6	1.25	0.90	0.35	1.05	5.4	5.7	1.03	0.12
23.13	9.3	0.13	1.44	76.0	5	114.6	1.31	0.93	0.38	1.04	4.4	4.6	0.64	0.09
24.11	8.4	0.13	1.58	70.9	5	114.6	1.36	0.96	0.41	1.02	4.0	4.1	0.56	0.09
25.10	7.8	0.19	2.47	85.3	4	114.6	1.42	0.98	0.44	1.01	5.0	5.0	0.51	0.00
26.08	8.3	0.22	2.65	72.4	4	114.6	1.48	1.01	0.47	1.00	5.3	5.3	0.55	0.00
27.07	10.0	0.27	2.70	79.7	4	114.6	1.53	1.03	0.50	0.98	6.4	6.3	0.68	0.09
28.05	17.4	0.63	3.62	54.6	4	114.6	1.59	1.06	0.53	0.97	11.1	10.8	1.26	0.00
29.04	21.8	0.87	4.01	101.7	4	114.6	1.65	1.08	0.56	0.96	13.9	13.3	1.61	0.00

Gregg In Situ, Inc.
Run No: 03-0203-1606-1781
CPT File: 027C07.COR

Depth (ft)	AvgQt (tsf)	AvgFs (tsf)	AvgRf (%)	AvgUd (ft)	SBT	U.Wt. pcf	TStress (tsf)	EStress (tsf)	Ueq (tsf)	Cn	N60 (blows/ft)	(N1)60	Su (tsf)	CRR
30.02	83.1	3.26	3.92	28.8	5	114.6	1.70	1.11	0.59	0.95	39.8	37.8	6.51	0.00
31.00	87.8	3.52	4.01	-9.4	5	114.6	1.76	1.13	0.62	0.94	42.0	39.5	6.88	0.00
31.99	13.5	0.43	3.21	39.9	4	114.6	1.82	1.16	0.66	0.93	8.6	8.0	0.94	0.00
32.97	69.7	1.81	2.60	18.3	6	114.6	1.87	1.19	0.69	0.92	26.7	24.5	5.43	0.32
33.96	62.1	1.76	2.83	9.4	6	114.6	1.93	1.21	0.72	0.91	23.8	21.6	4.82	0.37
34.94	18.7	0.54	2.92	155.8	5	114.6	1.98	1.24	0.75	0.90	8.9	8.0	1.34	0.13
35.92	40.3	1.22	3.04	193.6	5	114.6	2.04	1.26	0.78	0.89	19.3	17.2	3.06	0.00
36.91	102.9	4.45	4.33	-1.9	11	130.5	2.10	1.29	0.81	0.88	98.6	86.7	UnDef	0.00
37.89	35.0	1.03	2.94	146.2	5	114.6	2.16	1.32	0.84	0.87	16.8	14.6	2.63	0.39
38.88	36.5	1.01	2.78	192.5	6	114.6	2.22	1.35	0.87	0.86	14.0	12.0	2.74	0.42
39.86	20.6	0.57	2.79	105.7	5	114.6	2.27	1.37	0.90	0.85	9.9	8.4	1.47	0.14
40.85	21.4	0.52	2.45	140.5	5	114.6	2.33	1.40	0.93	0.85	10.2	8.7	1.52	0.14
41.83	95.9	2.53	2.64	102.0	6	114.6	2.39	1.42	0.96	0.84	36.7	30.8	7.48	0.45
42.81	233.7	5.30	2.27	-15.2	7	117.8	2.44	1.45	0.99	0.83	74.6	61.9	UnDef	0.00
43.80	221.0	4.14	1.88	-9.8	8	120.9	2.50	1.48	1.02	0.82	52.9	43.5	UnDef	0.00
44.78	168.7	3.95	2.34	-13.3	7	117.8	2.56	1.51	1.05	0.81	53.9	43.9	UnDef	0.00
45.77	171.7	2.89	1.68	-16.7	8	120.9	2.62	1.54	1.09	0.81	41.1	33.2	UnDef	0.00
46.75	82.5	2.18	2.64	-13.3	6	114.6	2.68	1.56	1.12	0.80	31.6	25.3	6.39	0.45
47.74	23.6	0.49	2.06	-7.8	6	114.6	2.74	1.59	1.15	0.79	9.0	7.2	1.67	0.15
48.72	31.2	0.68	2.19	-4.5	6	114.6	2.79	1.61	1.18	0.79	12.0	9.4	2.28	0.24
49.70	22.1	0.53	2.40	-3.3	6	114.6	2.85	1.64	1.21	0.78	8.5	6.6	1.54	0.14
50.69	26.9	0.75	2.77	-2.6	5	114.6	2.90	1.66	1.24	0.78	12.9	10.0	1.92	0.18
51.67	28.8	0.80	2.77	-2.0	5	114.6	2.96	1.69	1.27	0.77	13.8	10.6	2.06	0.20
52.66	28.1	0.76	2.71	-1.4	5	114.6	3.02	1.72	1.30	0.76	13.5	10.3	2.01	0.19
53.64	50.4	1.82	3.62	-0.3	5	114.6	3.07	1.74	1.33	0.76	24.1	18.3	3.79	0.00
54.63	40.3	1.56	3.87	6.9	5	114.6	3.13	1.77	1.36	0.75	19.3	14.5	2.98	0.00
.61	47.3	2.19	4.62	11.8	4	114.6	3.19	1.79	1.39	0.75	30.2	22.6	3.53	0.00
56.59	52.7	2.63	4.99	11.7	11	130.5	3.25	1.82	1.42	0.74	50.5	37.4	UnDef	0.00
57.58	97.0	5.57	5.75	12.3	11	130.5	3.31	1.86	1.45	0.73	92.9	68.2	UnDef	0.00
58.56	88.7	5.11	5.76	15.2	11	130.5	3.37	1.89	1.49	0.73	84.9	61.8	UnDef	0.00
59.55	73.0	3.86	5.29	15.7	11	130.5	3.44	1.92	1.52	0.72	69.9	50.4	UnDef	0.00
60.53	60.9	3.22	5.29	16.3	11	130.5	3.50	1.96	1.55	0.71	58.3	41.7	UnDef	0.00
61.52	26.4	0.64	2.42	18.0	6	114.6	3.56	1.99	1.58	0.71	10.1	7.2	1.82	0.15
62.42	34.7	1.62	4.68	18.3	3	111.4	3.61	2.01	1.61	0.71	33.3	23.5	2.49	0.00
63.32	29.3	1.20	4.11	16.9	4	114.6	3.67	2.03	1.63	0.70	18.7	13.1	2.05	0.00
64.30	25.6	0.72	2.80	15.6	5	114.6	3.72	2.06	1.66	0.70	12.3	8.6	1.75	0.14
65.29	27.5	0.82	2.99	15.5	5	114.6	3.78	2.08	1.70	0.69	13.1	9.1	1.89	0.15
66.27	33.4	0.83	2.48	16.2	6	114.6	3.83	2.11	1.73	0.69	12.8	8.8	2.37	0.21
67.26	34.3	1.14	3.31	16.5	5	114.6	3.89	2.13	1.76	0.68	16.4	11.3	2.44	0.00
68.24	58.4	3.09	5.29	16.8	11	130.5	3.95	2.16	1.79	0.68	56.0	38.0	UnDef	0.00
69.22	47.6	2.28	4.78	16.7	4	114.6	4.01	2.19	1.82	0.68	30.4	20.5	3.49	0.00
70.21	63.9	3.45	5.39	17.5	11	130.5	4.07	2.22	1.85	0.67	61.2	41.1	UnDef	0.00
71.19	47.2	1.57	3.32	18.8	5	114.6	4.13	2.25	1.88	0.67	22.6	15.1	3.44	0.42
72.18	36.7	1.39	3.78	19.6	5	114.6	4.19	2.28	1.91	0.66	17.6	11.6	2.60	0.00
73.16	43.5	1.84	4.23	19.2	5	114.6	4.25	2.30	1.94	0.66	20.8	13.7	3.14	0.00
74.15	77.6	4.39	5.65	19.4	11	130.5	4.31	2.33	1.97	0.65	74.3	48.6	UnDef	0.00
75.13	108.3	6.75	6.23	20.6	11	130.5	4.37	2.37	2.00	0.65	103.7	67.4	UnDef	0.00
76.11	62.7	3.96	6.33	22.1	11	130.5	4.43	2.40	2.03	0.65	60.0	38.7	UnDef	0.00
77.10	51.7	2.63	5.09	25.0	3	111.4	4.49	2.43	2.06	0.64	49.5	31.8	3.77	0.00
78.08	36.8	0.98	2.66	23.6	6	114.6	4.55	2.45	2.09	0.64	14.1	9.0	2.58	0.22
79.07	31.1	0.91	2.92	22.3	5	114.6	4.61	2.48	2.13	0.64	14.9	9.5	2.12	0.00
80.05	28.3	0.70	2.46	21.4	6	114.6	4.66	2.51	2.16	0.63	10.9	6.9	1.89	0.14

Depth (ft)	AvgQt (tsf)	AvgFs (tsf)	AvgRf (%)	AvgUd (ft)	SBT	U.Wt. pcf	TStress (tsf)	EStress (tsf)	Ueq (tsf)	Cn	N60 (blows/ft)	(N1)60 (blows/ft)	Su (tsf)	CRR
81.04	44.7	1.78	3.99	21.8	5	114.6	4.72	2.53	2.19	0.63	21.4	13.5	3.20	0.00
82.02	60.6	3.13	5.16	21.6	11	130.5	4.78	2.56	2.22	0.62	58.1	36.3	UnDef	0.00
83.00	24.6	0.70	2.83	21.5	5	114.6	4.84	2.59	2.25	0.62	11.8	7.3	1.58	0.00
83.99	76.2	2.44	3.20	23.5	6	114.6	4.90	2.62	2.28	0.62	29.2	18.1	5.71	0.00
84.97	42.3	1.45	3.43	25.7	5	114.6	4.95	2.64	2.31	0.62	20.3	12.5	2.99	0.00
85.96	47.4	1.81	3.81	29.6	5	114.6	5.01	2.67	2.34	0.61	22.7	13.9	3.39	0.00
86.94	38.6	1.43	3.70	28.2	5	114.6	5.06	2.69	2.37	0.61	18.5	11.3	2.68	0.00
87.93	30.3	0.90	2.97	26.0	5	114.6	5.12	2.72	2.40	0.61	14.5	8.8	2.01	0.00
88.91	32.5	0.86	2.64	25.8	6	114.6	5.18	2.74	2.43	0.60	12.4	7.5	2.18	0.16
89.89	39.9	1.36	3.42	26.7	5	114.6	5.23	2.77	2.46	0.60	19.1	11.5	2.77	0.00
90.88	46.7	1.61	3.44	27.7	5	114.6	5.29	2.80	2.49	0.60	22.3	13.4	3.31	0.00
91.86	95.4	5.01	5.26	31.0	11	130.5	5.35	2.83	2.52	0.59	91.3	54.3	UnDef	0.00
92.85	76.8	4.10	5.34	30.0	11	130.5	5.41	2.86	2.56	0.59	73.6	43.5	UnDef	0.00
93.83	42.9	1.31	3.06	33.3	5	114.6	5.47	2.89	2.59	0.59	20.5	12.1	2.99	0.26
94.82	29.0	0.63	2.17	34.4	6	114.6	5.53	2.91	2.62	0.59	11.1	6.5	1.88	0.13
95.80	32.1	0.74	2.30	34.0	6	114.6	5.59	2.94	2.65	0.58	12.3	7.2	2.12	0.15
96.78	25.0	0.45	1.81	33.2	6	114.6	5.64	2.97	2.68	0.58	9.6	5.6	1.54	0.11
97.77	31.3	0.73	2.33	33.5	6	114.6	5.70	2.99	2.71	0.58	12.0	6.9	2.04	0.14
98.75	40.5	1.39	3.42	33.0	5	114.6	5.76	3.02	2.74	0.58	19.4	11.2	2.78	0.00

Gregg In Situ, Inc.
Interpretation Output - Release 1.00.19e
Run No: 03-0203-1606-1781
Job No: 97-100
Client: CDM
Project: CPT SITE INVESTIGATION
Site: SHERWIN WILLIAMS
Location: CPT-07
Engineer: H. YOUNG
CPT Date: 03/28/01
CPT Time: 14:52
CPT File: 027C07.COR
Northing (m): 0.000
Easting (m): 0.000
Elevation (m): 0.000

Water Table (m): 3.35 (ft): 11.0
Su Nkt used: 12.50
Averaging Increment (m): 0.30
Phi Method : Robertson and Campanella, 1983
Dr Method : Jamiolkowski - All Sands
State Parameter M: 1.20
Used Unit Weights Assigned to Soil Zones
Values of 1.0E9 or UnDef are printed for parameters that are not valid for the material type (SBT)

Depth (ft)	k (cm/s)	Bq	Qtn	Rfn	SBTn	Qc1N	DeltaQc1N	Qc1Ncs	Fc (%)	Phi (Deg)	Dr (%)	OCR	State Param	Del(n1)60	(N1)60c
0.49	1.0E-15	0.00	2.4	0.10	1	0.2	UnDef	UnDef	100.0	UnDef	UnDef	1.0	UnDef	UnDef	UnDe
1.48	1.0E-15	0.00	0.1	0.10	1	0.2	UnDef	UnDef	100.0	UnDef	UnDef	1.0	UnDef	UnDef	UnDe
2.46	1.0E-15	0.00	0.1	0.10	1	0.2	UnDef	UnDef	100.0	UnDef	UnDef	1.0	UnDef	UnDef	UnDe
3.44	1.0E-15	0.00	0.0	0.10	1	0.2	UnDef	UnDef	100.0	UnDef	UnDef	1.0	UnDef	UnDef	UnDe
4.43	1.0E-15	0.00	0.0	0.10	1	0.2	UnDef	UnDef	100.0	UnDef	UnDef	1.0	UnDef	UnDef	UnDe
5.41	5.0E-08	0.04	24.6	3.47	6	14.4	57.8	72.2	41.8	UnDef	UnDef	6.0	UnDef	14.1	28.
6.40	5.0E-07	0.05	24.6	3.45	6	15.6	62.4	78.0	41.7	UnDef	UnDef	6.0	UnDef	10.2	20.
7.30	5.0E-08	0.01	23.7	4.76	1	16.0	UnDef	UnDef	100.0	UnDef	UnDef	6.0	UnDef	UnDef	UnDe
8.20	5.0E-08	0.05	9.2	3.93	1	7.0	UnDef	UnDef	100.0	UnDef	UnDef	3.0	UnDef	UnDef	UnDe
9.19	1.0E-07	0.37	6.3	1.53	4	5.2	20.9	26.1	59.7	UnDef	UnDef	3.0	UnDef	2.6	5.
10.17	1.0E-07	0.43	6.3	2.08	4	5.4	21.6	27.0	64.3	UnDef	UnDef	3.0	UnDef	2.6	5.
11.15	5.0E-08	0.26	7.5	3.30	1	6.5	UnDef	UnDef	100.0	UnDef	UnDef	3.0	UnDef	UnDef	UnDe
12.14	5.0E-08	0.33	6.4	2.96	4	5.9	23.4	29.3	69.5	UnDef	UnDef	3.0	UnDef	5.7	11.
13.21	5.0E-06	0.26	8.0	1.52	6	7.3	29.2	36.5	53.5	UnDef	UnDef	3.0	UnDef	3.6	7.
14.27	5.0E-06	0.16	10.9	1.63	6	9.8	39.3	49.1	47.4	UnDef	UnDef	3.0	UnDef	4.8	9.
15.26	5.0E-07	0.40	6.9	1.88	4	6.7	26.8	33.5	60.4	UnDef	UnDef	3.0	UnDef	4.4	8.
16.24	5.0E-08	0.26	7.5	3.28	1	7.4	UnDef	UnDef	100.0	UnDef	UnDef	3.0	UnDef	UnDef	UnDe
17.22	5.0E-07	0.19	8.2	3.16	4	8.1	32.5	40.7	64.1	UnDef	UnDef	3.0	UnDef	5.3	10.
18.21	5.0E-07	0.28	8.4	3.23	1	8.5	UnDef	UnDef	100.0	UnDef	UnDef	3.0	UnDef	UnDef	UnDe
19.19	5.0E-03	0.00	94.1	1.06	9	84.8	18.0	102.8	11.6	42	62.5	1.0	-0.19	2.6	23.
20.18	5.0E-05	-0.01	38.5	2.75	6	36.0	83.2	119.3	31.1	38	38.0	6.0	-0.20	10.9	25.
21.16	5.0E-06	0.00	12.9	2.57	6	13.0	52.2	65.2	50.1	UnDef	UnDef	6.0	UnDef	6.4	12.
22.15	5.0E-05	0.07	14.2	1.65	6	14.5	58.0	72.5	42.0	32	30.0	6.0	-0.03	5.7	11.
23.13	5.0E-06	0.25	8.6	1.68	6	9.4	37.6	47.0	53.3	UnDef	UnDef	3.0	UnDef	4.6	9.
24.11	5.0E-06	0.26	7.3	1.88	4	8.4	33.5	41.9	58.7	UnDef	UnDef	3.0	UnDef	4.1	8.
25.10	5.0E-07	0.35	6.5	3.02	1	7.7	UnDef	UnDef	100.0	UnDef	UnDef	3.0	UnDef	UnDef	UnDe
26.08	5.0E-07	0.26	6.8	3.23	1	8.1	UnDef	UnDef	100.0	UnDef	UnDef	3.0	UnDef	UnDef	UnDe
27.07	5.0E-07	0.23	8.2	3.18	4	9.7	38.7	48.4	64.1	UnDef	UnDef	3.0	UnDef	6.3	12.
28.05	5.0E-07	0.07	14.9	3.99	1	16.5	UnDef	UnDef	100.0	UnDef	UnDef	6.0	UnDef	UnDef	UnDe
29.04	5.0E-07	0.13	18.6	4.34	1	20.5	UnDef	UnDef	100.0	UnDef	UnDef	6.0	UnDef	UnDef	UnDe

Depth (ft)	k (cm/s)	Bq	Qtn	Rfn	SBTn	Qc1N	DeltaQc1N	Qc1Ncs	Fc (%)	Phi (Deg)	Dr (%)	OCR	State Param	Del(n1)60	(N1)60c
30.02	5.0E-06	0.00	73.4	4.00	6	77.2	117.1	194.3	27.6	UnDef	UnDef	10.0	UnDef	22.9	60.
31.00	5.0E-06	-0.01	75.8	4.09	6	80.6	120.9	201.5	27.5	UnDef	UnDef	10.0	UnDef	23.7	63.
31.99	5.0E-07	0.05	10.1	3.71	1	12.3	UnDef	UnDef	100.0	UnDef	UnDef	3.0	UnDef	UnDef	UnDe
32.97	5.0E-05	0.00	57.2	2.67	7	62.6	75.1	137.7	25.4	40	53.9	10.0	-0.24	12.7	37.
33.96	5.0E-05	-0.01	49.7	2.92	6	55.2	91.5	146.8	28.4	38	50.3	6.0	-0.24	13.8	35.
34.94	5.0E-06	0.25	13.5	3.26	4	16.4	65.7	82.2	52.7	UnDef	UnDef	6.0	UnDef	8.0	16.
35.92	5.0E-06	0.14	30.3	3.20	6	35.1	140.3	175.4	37.0	UnDef	UnDef	6.0	UnDef	17.2	34.
36.91	1.0E-15	-0.01	78.0	4.42	6	88.6	144.2	232.8	28.2	42	63.8	1.0	-0.43	54.8	141.
37.89	5.0E-06	0.11	24.9	3.13	6	29.8	119.2	149.0	40.0	UnDef	UnDef	6.0	UnDef	14.6	29.
38.88	5.0E-05	0.15	25.4	2.95	6	30.8	123.0	153.8	38.8	34	33.5	6.0	-0.14	12.0	24.
39.86	5.0E-06	0.13	13.3	3.14	4	17.2	68.8	86.0	52.4	UnDef	UnDef	6.0	UnDef	8.4	16.
40.85	5.0E-06	0.18	13.6	2.75	6	17.7	70.7	88.4	49.9	UnDef	UnDef	6.0	UnDef	8.7	17.
41.83	5.0E-05	0.02	65.6	2.70	7	78.6	80.2	158.8	23.9	40	60.4	10.0	-0.26	14.2	45.
42.81	5.0E-04	-0.01	159.4	2.29	7	189.8	57.1	246.9	13.7	44	85.6	1.0	-0.34	10.5	72.
43.80	5.0E-03	-0.01	147.7	1.90	9	177.8	44.6	222.4	12.5	44	83.8	1.0	-0.30	6.2	49.
44.78	5.0E-04	-0.01	110.2	2.38	7	134.5	64.2	198.6	17.1	42	75.8	1.0	-0.30	11.1	55.
45.77	5.0E-03	-0.01	110.1	1.71	7	135.6	42.7	178.3	14.0	42	76.0	1.0	-0.25	5.8	39.
46.75	5.0E-05	-0.02	51.1	2.73	7	64.6	93.3	157.9	27.1	38	54.8	10.0	-0.24	14.8	40.
47.74	5.0E-05	-0.07	13.1	2.33	6	18.3	73.3	91.6	48.2	32	30.0	6.0	-0.06	7.2	14.
48.72	5.0E-05	-0.05	17.6	2.41	6	24.1	96.3	120.3	42.6	32	30.0	6.0	-0.10	9.4	18.
49.70	5.0E-05	-0.07	11.7	2.76	4	16.9	67.6	84.5	53.2	30	30.0	3.0	-0.07	6.6	13.
50.69	5.0E-06	-0.06	14.4	3.11	4	20.4	81.6	101.9	50.6	UnDef	UnDef	6.0	UnDef	10.0	20.
51.67	5.0E-06	-0.05	15.3	3.08	6	21.6	86.6	108.2	49.2	UnDef	UnDef	6.0	UnDef	10.6	21.
52.66	5.0E-06	-0.05	14.6	3.04	6	21.0	84.0	105.0	49.9	UnDef	UnDef	6.0	UnDef	10.3	20.
53.64	5.0E-06	-0.03	27.2	3.85	6	37.4	149.5	186.9	41.6	UnDef	UnDef	6.0	UnDef	18.3	36.
54.63	5.0E-06	-0.03	21.0	4.20	1	29.7	UnDef	UnDef	100.0	UnDef	UnDef	6.0	UnDef	UnDef	UnDe
55.61	5.0E-07	-0.02	24.6	4.95	1	34.6	UnDef	UnDef	100.0	UnDef	UnDef	6.0	UnDef	UnDef	UnDe
56.59	1.0E-15	-0.02	27.2	5.31	1	38.2	UnDef	UnDef	100.0	36	39.7	1.0	-0.33	UnDef	UnDe
57.58	1.0E-15	-0.01	50.4	5.95	1	69.6	UnDef	UnDef	100.0	38	56.9	1.0	-0.57	UnDef	UnDe
58.56	1.0E-15	-0.01	45.1	5.99	1	63.1	UnDef	UnDef	100.0	38	54.1	1.0	-0.55	UnDef	UnDe
59.55	1.0E-15	-0.01	36.2	5.55	1	51.5	UnDef	UnDef	100.0	38	48.3	1.0	-0.42	UnDef	UnDe
60.53	1.0E-15	-0.02	29.3	5.62	1	42.6	UnDef	UnDef	100.0	36	42.8	1.0	-0.39	UnDef	UnDe
61.52	5.0E-05	-0.04	11.5	2.80	4	18.3	73.2	91.5	53.9	30	30.0	3.0	-0.06	7.2	14.
62.42	5.0E-08	-0.03	15.5	5.22	1	24.0	UnDef	UnDef	100.0	UnDef	UnDef	6.0	UnDef	UnDef	UnDe
63.32	5.0E-07	-0.04	12.6	4.70	1	20.1	UnDef	UnDef	100.0	UnDef	UnDef	6.0	UnDef	UnDef	UnDe
64.30	5.0E-06	-0.05	10.6	3.28	4	17.5	69.9	87.4	58.3	UnDef	UnDef	3.0	UnDef	8.6	17.
65.29	5.0E-06	-0.05	11.4	3.46	4	18.6	74.5	93.1	57.7	UnDef	UnDef	3.0	UnDef	9.1	18.
66.27	5.0E-05	-0.04	14.0	2.80	6	22.5	90.0	112.5	49.5	32	30.0	6.0	-0.09	8.8	17.
67.26	5.0E-06	-0.04	14.3	3.74	1	23.0	UnDef	UnDef	100.0	UnDef	UnDef	6.0	UnDef	UnDef	UnDe
68.24	1.0E-15	-0.02	25.2	5.68	1	38.9	UnDef	UnDef	100.0	34	40.2	1.0	-0.36	UnDef	UnDe
69.22	5.0E-07	-0.03	19.9	5.22	1	31.5	UnDef	UnDef	100.0	UnDef	UnDef	6.0	UnDef	UnDef	UnDe
70.21	1.0E-15	-0.02	26.9	5.76	1	42.0	UnDef	UnDef	100.0	36	42.4	1.0	-0.39	UnDef	UnDe
71.19	5.0E-06	-0.03	19.1	3.64	4	30.8	123.0	153.8	47.3	UnDef	UnDef	6.0	UnDef	15.1	30.
72.18	5.0E-06	-0.04	14.3	4.27	1	23.8	UnDef	UnDef	100.0	UnDef	UnDef	6.0	UnDef	UnDef	UnDe
73.16	5.0E-06	-0.03	17.0	4.69	1	28.1	UnDef	UnDef	100.0	UnDef	UnDef	6.0	UnDef	UnDef	UnDe
74.15	1.0E-15	-0.02	31.4	5.99	1	49.7	UnDef	UnDef	100.0	36	47.2	1.0	-0.46	UnDef	UnDe
75.13	1.0E-15	-0.01	43.9	6.50	1	68.9	UnDef	UnDef	100.0	38	56.6	1.0	-0.66	UnDef	UnDe
76.11	1.0E-15	-0.02	24.2	6.81	1	39.6	UnDef	UnDef	100.0	34	40.7	1.0	-0.56	UnDef	UnDe
77.10	5.0E-08	-0.03	19.4	5.57	1	32.4	UnDef	UnDef	100.0	UnDef	UnDef	6.0	UnDef	UnDef	UnDe
78.08	5.0E-05	-0.04	13.1	3.03	4	23.0	91.9	114.9	52.2	32	30.0	6.0	-0.09	9.0	18.
79.07	5.0E-06	-0.05	10.7	3.43	1	19.3	UnDef	UnDef	100.0	UnDef	UnDef	3.0	UnDef	UnDef	UnDe
80.05	5.0E-05	-0.06	9.4	2.94	4	17.5	70.1	87.6	59.3	30	30.0	3.0	-0.04	6.9	13.

Depth (ft)	k (cm/s)	Bq	Qtn	Rfn	SBTn	Qc1N	DeltaQc1N	Qc1Ncs	Fc (%)	Phi (Deg)	Dr (%)	OCR	State Param	Del(n1)60	(N1)60c
81.04	5.0E-06	-0.04	15.8	4.46	1	27.5	UnDef	UnDef	100.0	UnDef	UnDef	6.0	UnDef	UnDef	UnDe
82.02	1.0E-15	-0.03	21.8	5.60	1	37.1	UnDef	UnDef	100.0	34	38.8	1.0	-0.32	UnDef	UnDe
83.00	5.0E-06	-0.08	7.6	3.52	1	14.9	UnDef	UnDef	100.0	UnDef	UnDef	3.0	UnDef	UnDef	UnDe
83.99	5.0E-05	-0.02	27.3	3.42	6	46.1	184.5	230.6	39.7	36	45.1	6.0	-0.20	18.1	36.
84.97	5.0E-06	-0.04	14.1	3.89	1	25.5	UnDef	UnDef	100.0	UnDef	UnDef	6.0	UnDef	UnDef	UnDe
85.96	5.0E-06	-0.03	15.9	4.26	1	28.4	UnDef	UnDef	100.0	UnDef	UnDef	6.0	UnDef	UnDef	UnDe
86.94	5.0E-06	-0.04	12.4	4.26	1	23.0	UnDef	UnDef	100.0	UnDef	UnDef	3.0	UnDef	UnDef	UnDe
87.93	5.0E-06	-0.06	9.2	3.57	1	18.0	UnDef	UnDef	100.0	UnDef	UnDef	3.0	UnDef	UnDef	UnDe
88.91	5.0E-05	-0.06	9.9	3.14	4	19.2	76.7	95.9	59.2	30	30.0	3.0	-0.06	7.5	15.
89.89	5.0E-06	-0.05	12.5	3.93	1	23.5	UnDef	UnDef	100.0	UnDef	UnDef	6.0	UnDef	UnDef	UnDe
90.88	5.0E-06	-0.04	14.8	3.88	1	27.3	UnDef	UnDef	100.0	UnDef	UnDef	6.0	UnDef	UnDef	UnDe
91.86	1.0E-15	-0.02	31.9	5.57	1	55.5	UnDef	UnDef	100.0	36	50.4	1.0	-0.40	UnDef	UnDe
92.85	1.0E-15	-0.02	25.0	5.75	1	44.5	UnDef	UnDef	100.0	34	44.0	1.0	-0.37	UnDef	UnDe
93.83	5.0E-06	-0.04	13.0	3.51	4	24.7	98.8	123.5	54.9	UnDef	UnDef	6.0	UnDef	12.1	24.
94.82	5.0E-05	-0.07	8.1	2.69	4	16.6	66.6	83.2	61.8	30	30.0	3.0	-0.02	6.5	13.
95.80	5.0E-05	-0.06	9.0	2.78	4	18.3	73.2	91.5	59.6	30	30.0	3.0	-0.03	7.2	14.
96.78	5.0E-05	-0.09	6.5	2.35	4	14.2	56.7	70.9	65.2	30	30.0	3.0	0.01	5.6	11.
97.77	5.0E-05	-0.07	8.5	2.85	4	17.7	70.7	88.4	61.3	30	30.0	3.0	-0.03	6.9	13.
98.75	5.0E-06	-0.05	11.5	3.99	1	22.8	UnDef	UnDef	100.0	UnDef	UnDef	3.0	UnDef	UnDef	UnDe

Gregg In Situ, Inc.
Interpretation Output - Release 1.00.19e
Version No: 03-0203-1606-1720
Job No: 97-100
Client: CDM
Project: CPT SITE INVESTIGATION
Site: SHERWIN WILLIAMS
Location: CPT-06
Engineer: H. YOUNG
CPT Date: 03/28/01
CPT Time: 12:49
CPT File: 027C06.COR
Northing (m): 0.000
Easting (m): 0.000
Elevation (m): 0.000

Water Table (m): 3.35 (ft): 11.0
Su Nkt used: 12.50
Averaging Increment (m): 0.30
Phi Method : Robertson and Campanella, 1983
Dr Method : Jamiolkowski - All Sands
State Parameter M: 1.20
Used Unit Weights Assigned to Soil Zones
Values of 1.0E9 or UnDef are printed for parameters that are not valid for the material type (SBT)

Depth (ft)	AvgQt (tsf)	AvgFs (tsf)	AvgRf (%)	AvgUd (ft)	SBT	U.Wt. pcf	TStress (tsf)	EStress (tsf)	Ueq (tsf)	Cn	N60 (blows/ft)	(N1)60 (blows/ft)	Su (tsf)	CRR
0.49	0.0	0.00	0.00	0.0	UnDef	124.1	0.03	0.03	0.00	2.00	UnDef	UnDef	UnDef	0.00
1.48	0.0	0.00	0.00	0.0	UnDef	124.1	0.09	0.09	0.00	2.00	UnDef	UnDef	UnDef	0.00
2.46	0.0	0.00	0.00	0.0	UnDef	124.1	0.15	0.15	0.00	2.00	UnDef	UnDef	UnDef	0.00
3.44	0.0	0.00	0.00	0.0	UnDef	124.1	0.21	0.21	0.00	2.00	UnDef	UnDef	UnDef	0.00
4.43	0.0	0.00	0.00	0.0	UnDef	124.1	0.27	0.27	0.00	1.91	UnDef	UnDef	UnDef	0.00
5.41	6.3	0.16	2.58	7.6	4	114.6	0.33	0.33	0.00	1.73	4.0	6.9	0.48	0.09
6.40	10.8	0.20	1.86	21.6	5	114.6	0.39	0.39	0.00	1.60	5.2	8.3	0.83	0.10
7.30	19.1	0.30	1.58	9.1	6	114.6	0.44	0.44	0.00	1.50	7.3	11.0	1.49	0.10
8.20	40.9	0.26	0.63	16.0	7	117.8	0.49	0.49	0.00	1.42	13.0	18.6	UnDef	0.11
9.19	30.0	0.32	1.07	11.2	7	117.8	0.55	0.55	0.00	1.35	9.6	12.9	UnDef	0.10
10.17	5.3	0.06	1.10	44.2	1	79.6	0.60	0.60	0.00	1.29	2.5	3.3	0.38	0.08
11.15	7.1	0.14	1.90	62.1	5	114.6	0.65	0.64	0.00	1.25	3.4	4.3	0.52	0.09
12.14	6.0	0.07	1.13	64.1	1	79.6	0.70	0.66	0.04	1.23	2.9	3.6	0.43	0.08
13.21	6.0	0.09	1.53	63.8	5	114.6	0.75	0.68	0.07	1.21	2.9	3.5	0.42	0.08
14.27	13.9	0.20	1.43	29.1	6	114.6	0.81	0.71	0.10	1.19	5.3	6.3	1.04	0.13
15.26	6.8	0.09	1.35	60.5	5	114.6	0.87	0.73	0.13	1.17	3.3	3.8	0.48	0.09
16.24	6.8	0.14	2.07	81.1	4	114.6	0.92	0.76	0.16	1.15	4.3	5.0	0.47	0.09
17.22	11.4	0.14	1.22	73.6	5	114.6	0.98	0.78	0.19	1.13	5.5	6.2	0.83	0.10
18.21	10.3	0.13	1.25	83.4	5	114.6	1.04	0.81	0.23	1.11	4.9	5.5	0.74	0.10
19.19	9.0	0.14	1.52	89.7	5	114.6	1.09	0.84	0.26	1.09	4.3	4.7	0.63	0.09
20.18	8.4	0.16	1.95	90.8	5	114.6	1.15	0.86	0.29	1.08	4.0	4.3	0.58	0.09
21.16	9.7	0.14	1.42	101.5	5	114.6	1.20	0.89	0.32	1.06	4.6	4.9	0.68	0.09
22.15	8.6	0.18	2.03	91.1	5	114.6	1.26	0.91	0.35	1.05	4.1	4.3	0.59	0.09
23.13	7.7	0.20	2.60	88.2	4	114.6	1.32	0.94	0.38	1.03	4.9	5.1	0.51	0.00
24.11	8.2	0.27	3.31	75.4	3	111.4	1.37	0.96	0.41	1.02	7.8	8.0	0.54	0.00
25.10	10.0	0.35	3.49	80.9	3	111.4	1.43	0.99	0.44	1.01	9.5	9.6	0.68	0.00
26.08	11.2	0.42	3.74	63.6	3	111.4	1.48	1.01	0.47	0.99	10.7	10.6	0.78	0.00
27.07	11.2	0.33	2.98	76.1	4	114.6	1.54	1.04	0.50	0.98	7.2	7.0	0.77	0.00
28.05	11.3	0.26	2.31	113.2	5	114.6	1.59	1.06	0.53	0.97	5.4	5.2	0.77	0.09
29.04	32.3	1.29	3.98	52.2	4	114.6	1.65	1.09	0.56	0.96	20.6	19.8	2.45	0.40

Depth (ft)	AvgQt (tsf)	AvgFs (tsf)	AvgRf (%)	AvgUd (ft)	SBT	U.Wt. pcf	TStress (tsf)	EStress (tsf)	Ueq (tsf)	Cn	N60 (blows/ft)	(N1)60 (blows/ft)	Su (tsf)	CRR
30.02	19.3	0.84	4.34	29.8	3	111.4	1.71	1.11	0.59	0.95	18.5	17.5	1.41	0.00
31.00	19.2	0.64	3.32	90.1	5	114.6	1.76	1.14	0.62	0.94	9.2	8.6	1.40	0.14
31.99	20.7	0.78	3.77	94.8	4	114.6	1.82	1.16	0.66	0.93	13.2	12.3	1.51	0.00
32.97	19.4	0.84	4.35	55.9	3	111.4	1.87	1.19	0.69	0.92	18.6	17.0	1.40	0.00
33.96	17.3	0.69	3.99	72.9	3	111.4	1.93	1.21	0.72	0.91	16.6	15.0	1.23	0.00
34.94	25.9	0.76	2.93	161.1	5	114.6	1.98	1.24	0.75	0.90	12.4	11.2	1.92	0.22
35.92	76.4	2.55	3.34	141.6	6	114.6	2.04	1.26	0.78	0.89	29.3	26.0	5.95	0.00
36.91	86.3	2.31	2.68	0.4	6	114.6	2.10	1.29	0.81	0.88	33.1	29.1	6.74	0.41
37.89	30.8	0.85	2.77	194.6	5	114.6	2.15	1.31	0.84	0.87	14.7	12.8	2.29	0.29
38.88	22.2	0.67	3.02	146.5	5	114.6	2.21	1.34	0.87	0.86	10.6	9.2	1.60	0.16
39.86	18.9	0.34	1.81	189.8	6	114.6	2.27	1.37	0.90	0.86	7.3	6.2	1.33	0.13
40.85	20.9	0.49	2.36	198.1	6	114.6	2.32	1.39	0.93	0.85	8.0	6.8	1.49	0.14
41.83	25.5	0.83	3.25	191.1	5	114.6	2.38	1.42	0.96	0.84	12.2	10.3	1.85	0.19
42.81	31.3	1.09	3.48	211.8	5	114.6	2.44	1.44	0.99	0.83	15.0	12.5	2.31	0.27
43.80	71.0	3.41	4.81	89.6	11	130.5	2.50	1.47	1.02	0.82	68.0	56.1	UnDef	0.00
44.78	86.1	3.99	4.64	74.2	11	130.5	2.56	1.51	1.05	0.82	82.4	67.2	UnDef	0.00
45.77	57.5	2.37	4.13	184.7	5	114.6	2.62	1.53	1.09	0.81	27.5	22.2	4.39	0.00
46.75	40.9	1.65	4.03	109.5	5	114.6	2.68	1.56	1.12	0.80	19.6	15.7	3.06	0.00
47.74	22.5	0.42	1.86	138.8	6	114.6	2.73	1.59	1.15	0.79	8.6	6.8	1.58	0.14
48.72	26.6	0.69	2.59	215.0	6	114.6	2.79	1.61	1.18	0.79	10.2	8.0	1.90	0.18
49.70	26.8	0.91	3.38	99.9	5	114.6	2.85	1.64	1.21	0.78	12.9	10.0	1.92	0.00
50.69	34.7	1.17	3.36	112.5	5	114.6	2.90	1.66	1.24	0.78	16.6	12.9	2.54	0.29
51.67	40.2	1.25	3.11	140.3	5	114.6	2.96	1.69	1.27	0.77	19.2	14.8	2.98	0.40
52.66	32.4	0.88	2.73	201.8	6	114.6	3.02	1.71	1.30	0.76	12.4	9.5	2.35	0.24
53.64	44.9	1.46	3.25	273.7	5	114.6	3.07	1.74	1.33	0.76	21.5	16.3	3.35	0.00
54.63	47.0	1.71	3.64	171.8	5	114.6	3.13	1.77	1.36	0.75	22.5	16.9	3.51	0.00
55.61	35.4	0.88	2.48	236.7	6	114.6	3.18	1.79	1.39	0.75	13.6	10.1	2.58	0.28
56.59	36.3	1.17	3.23	192.1	5	114.6	3.24	1.82	1.42	0.74	17.4	12.9	2.64	0.29
57.58	35.6	1.31	3.67	205.3	5	114.6	3.30	1.84	1.45	0.74	17.1	12.6	2.59	0.00
58.56	33.6	1.06	3.16	208.9	5	114.6	3.35	1.87	1.49	0.73	16.1	11.8	2.42	0.24
59.55	32.0	1.03	3.21	224.0	5	114.6	3.41	1.89	1.52	0.73	15.3	11.1	2.29	0.22
60.53	32.5	0.87	2.69	307.9	6	114.6	3.47	1.92	1.55	0.72	12.4	9.0	2.32	0.22
61.52	52.6	2.01	3.82	219.8	5	114.6	3.52	1.95	1.58	0.72	25.2	18.1	3.93	0.00
62.42	36.9	1.68	4.56	86.4	4	114.6	3.57	1.97	1.61	0.71	23.5	16.8	2.66	0.00
63.32	30.0	1.08	3.60	119.2	5	114.6	3.63	1.99	1.63	0.71	14.4	10.2	2.11	0.00
64.30	32.5	1.10	3.38	172.5	5	114.6	3.68	2.02	1.66	0.70	15.6	11.0	2.31	0.00
65.29	35.1	1.29	3.66	186.5	5	114.6	3.74	2.04	1.70	0.70	16.8	11.8	2.51	0.00
66.27	69.5	4.19	6.03	101.5	11	130.5	3.80	2.07	1.73	0.69	66.6	46.2	UnDef	0.00
67.26	85.0	4.38	5.15	127.3	11	130.5	3.86	2.11	1.76	0.69	81.4	56.1	UnDef	0.00
68.24	104.5	6.01	5.75	16.2	11	130.5	3.93	2.14	1.79	0.68	100.1	68.4	UnDef	0.00
69.22	67.9	4.01	5.90	142.1	11	130.5	3.99	2.17	1.82	0.68	65.0	44.1	UnDef	0.00
70.21	59.3	3.14	5.30	152.7	11	130.5	4.06	2.21	1.85	0.67	56.8	38.2	UnDef	0.00
71.19	71.1	3.36	4.73	149.2	11	130.5	4.12	2.24	1.88	0.67	68.1	45.5	UnDef	0.00
72.18	43.5	1.88	4.32	168.8	4	114.6	4.18	2.27	1.91	0.66	27.8	18.4	3.15	0.00
73.16	26.8	0.71	2.63	221.1	5	114.6	4.24	2.30	1.94	0.66	12.8	8.5	1.81	0.14
74.15	31.9	1.07	3.36	193.6	5	114.6	4.29	2.32	1.97	0.66	15.3	10.0	2.21	0.00
75.13	39.1	1.32	3.39	312.1	5	114.6	4.35	2.35	2.00	0.65	18.7	12.2	2.78	0.00
76.11	42.2	1.28	3.03	353.0	5	114.6	4.41	2.37	2.03	0.65	20.2	13.1	3.02	0.30
77.10	35.6	1.21	3.41	296.4	5	114.6	4.46	2.40	2.06	0.65	17.0	11.0	2.49	0.00
78.08	27.6	0.82	2.95	285.3	5	114.6	4.52	2.42	2.09	0.64	13.2	8.5	1.85	0.00
79.07	27.0	0.71	2.64	320.7	5	114.6	4.58	2.45	2.13	0.64	12.9	8.3	1.80	0.14
80.05	32.4	0.82	2.51	407.7	6	114.6	4.63	2.48	2.16	0.64	12.4	7.9	2.23	0.18

Gregg In Situ, Inc.
Run No: 03-0203-1606-1720
CPT File: 027C06.COR

Depth (ft)	AvgQt (tsf)	AvgFs (tsf)	AvgRf (%)	AvgUd (ft)	SBT	U.Wt. pcf	TStress (tsf)	EStress (tsf)	Ueq (tsf)	Cn	N60 (blows/ft)	(N1)60 (blows/ft)	Su (tsf)	CRR
81.04	39.4	1.09	2.76	359.6	6	114.6	4.69	2.50	2.19	0.63	15.1	9.5	2.78	0.25
82.02	27.1	0.62	2.30	361.8	6	114.6	4.74	2.53	2.22	0.63	10.4	6.5	1.79	0.13
83.00	29.4	0.64	2.17	352.3	6	114.6	4.80	2.55	2.25	0.63	11.3	7.1	1.97	0.15
83.99	24.7	0.27	1.09	436.1	6	114.6	4.86	2.58	2.28	0.62	9.5	5.9	1.59	0.12
84.97	30.0	0.49	1.63	503.1	6	114.6	4.91	2.60	2.31	0.62	11.5	7.1	2.00	0.15
85.96	52.6	2.46	4.68	301.3	4	114.6	4.97	2.63	2.34	0.62	33.6	20.7	3.81	0.00
86.94	53.6	2.83	5.27	249.2	11	130.5	5.03	2.66	2.37	0.61	51.4	31.5	UnDef	0.00
87.93	37.2	1.23	3.31	385.6	5	114.6	5.09	2.69	2.40	0.61	17.8	10.9	2.56	0.00
88.91	51.5	2.42	4.69	242.9	4	114.6	5.15	2.71	2.43	0.61	32.9	20.0	3.71	0.00
89.89	65.5	2.67	4.08	305.1	5	114.6	5.20	2.74	2.46	0.60	31.3	18.9	4.82	0.00
90.88	63.7	3.84	6.04	189.7	11	130.5	5.26	2.77	2.49	0.60	61.0	36.6	UnDef	0.00
91.86	32.5	0.77	2.38	387.9	6	114.6	5.32	2.80	2.52	0.60	12.4	7.4	2.17	0.16
92.85	34.7	0.98	2.81	333.7	6	114.6	5.38	2.82	2.56	0.60	13.3	7.9	2.35	0.18
93.83	33.6	0.90	2.68	363.1	6	114.6	5.44	2.85	2.59	0.59	12.9	7.6	2.25	0.17
94.82	33.8	0.82	2.44	434.3	6	114.6	5.49	2.88	2.62	0.59	12.9	7.6	2.26	0.17
95.80	45.6	1.48	3.25	471.2	5	114.6	5.55	2.90	2.65	0.59	21.8	12.8	3.20	0.00
96.78	94.8	4.43	4.67	245.4	11	130.5	5.61	2.93	2.68	0.58	90.8	53.0	UnDef	0.00
97.77	46.1	2.29	4.97	250.9	3	111.4	5.67	2.96	2.71	0.58	44.2	25.7	3.24	0.00
98.75	31.8	0.81	2.54	361.3	6	114.6	5.72	2.98	2.74	0.58	12.2	7.0	2.08	0.15

Gregg In Situ, Inc.
Interpretation Output - Release 1.00.19e
Run No: 03-0203-1606-1720
Job No: 97-100
Client: CDM
Project: CPT SITE INVESTIGATION
Site: SHERWIN WILLIAMS
Location: CPT-06
Engineer: H. YOUNG
CPT Date: 03/28/01
CPT Time: 12:49
CPT File: 027C06.COR
Northing (m): 0.000
Easting (m): 0.000
Elevation (m): 0.000

Water Table (m): 3.35 (ft): 11.0
Su Nkt used: 12.50
Averaging Increment (m): 0.30
Phi Method : Robertson and Campanella, 1983
Dr Method : Jamiolkowski - All Sands
State Parameter M: 1.20
Used Unit Weights Assigned to Soil Zones
Values of 1.0E9 or UnDef are printed for parameters that are not valid for the material type (SBT)

Depth (ft)	k (cm/s)	Bq	Qtn	Rfn	SBTn	Qc1N	DeltaQc1N	Qc1Ncs	Fc (%)	Phi (Deg)	Dr (%)	OCR	State Param	Del(n1)60	(N1)60c
0.49	1.0E-15	0.00	2.4	0.10	1	0.2	UnDef	UnDef	100.0	UnDef	UnDef	1.0	UnDef	UnDef	UnDe
1.48	1.0E-15	0.00	0.1	0.10	1	0.2	UnDef	UnDef	100.0	UnDef	UnDef	1.0	UnDef	UnDef	UnDe
2.46	1.0E-15	0.00	0.1	0.10	1	0.2	UnDef	UnDef	100.0	UnDef	UnDef	1.0	UnDef	UnDef	UnDe
3.44	1.0E-15	0.00	0.0	0.10	1	0.2	UnDef	UnDef	100.0	UnDef	UnDef	1.0	UnDef	UnDef	UnDe
4.43	1.0E-15	0.00	0.0	0.10	1	0.2	UnDef	UnDef	100.0	UnDef	UnDef	1.0	UnDef	UnDef	UnDe
5.41	5.0E-07	0.04	17.8	2.72	6	10.6	42.6	53.2	44.2	UnDef	UnDef	6.0	UnDef	6.9	13.
6.40	5.0E-06	0.06	26.6	1.93	6	16.9	46.5	63.4	32.5	UnDef	UnDef	6.0	UnDef	7.0	15.
7.30	5.0E-05	0.02	42.3	1.62	7	28.1	28.3	56.4	23.8	38	30.9	6.0	-0.15	5.0	16.
8.20	5.0E-04	0.01	81.7	0.63	9	56.9	7.8	64.7	9.5	42	51.1	1.0	-0.13	1.5	20.
9.19	5.0E-04	0.01	53.4	1.09	7	39.5	19.5	59.0	17.4	40	40.7	1.0	-0.13	3.4	16.
10.17	1.0E-07	0.29	7.8	1.25	6	6.7	26.7	33.4	51.6	UnDef	UnDef	3.0	UnDef	3.3	6.
11.15	5.0E-06	0.30	10.1	2.09	6	8.7	34.8	43.5	52.5	UnDef	UnDef	3.0	UnDef	4.3	8.
12.14	1.0E-07	0.37	8.1	1.28	6	7.3	29.1	36.4	51.1	UnDef	UnDef	3.0	UnDef	3.6	7.
13.21	5.0E-06	0.37	7.7	1.75	4	7.1	28.5	35.6	56.3	UnDef	UnDef	3.0	UnDef	3.5	7.
14.27	5.0E-05	0.06	18.5	1.52	6	16.1	64.5	80.7	36.0	32	30.0	6.0	-0.05	6.3	12.
15.26	5.0E-06	0.29	8.1	1.54	6	7.8	31.2	39.0	53.4	UnDef	UnDef	3.0	UnDef	3.8	7.
16.24	5.0E-07	0.40	7.7	2.39	4	7.6	30.5	38.1	61.0	UnDef	UnDef	3.0	UnDef	5.0	10.
17.22	5.0E-06	0.20	13.3	1.33	6	12.6	50.4	63.0	40.7	UnDef	UnDef	6.0	UnDef	6.2	12.
18.21	5.0E-06	0.26	11.4	1.39	6	11.2	44.6	55.8	44.4	UnDef	UnDef	3.0	UnDef	5.5	10.
19.19	5.0E-06	0.32	9.5	1.73	6	9.7	38.6	48.3	51.2	UnDef	UnDef	3.0	UnDef	4.7	9.
20.18	5.0E-06	0.35	8.4	2.26	4	8.9	35.4	44.3	58.0	UnDef	UnDef	3.0	UnDef	4.3	8.
21.16	5.0E-06	0.34	9.5	1.62	6	10.1	40.2	50.3	50.2	UnDef	UnDef	3.0	UnDef	4.9	9.
22.15	5.0E-06	0.34	8.1	2.37	4	8.9	35.4	44.3	59.7	UnDef	UnDef	3.0	UnDef	4.3	8.
23.13	5.0E-07	0.37	6.8	3.13	1	7.8	UnDef	UnDef	100.0	UnDef	UnDef	3.0	UnDef	UnDef	UnDe
24.11	5.0E-08	0.29	7.1	3.98	1	8.1	UnDef	UnDef	100.0	UnDef	UnDef	3.0	UnDef	UnDef	UnDe
25.10	5.0E-08	0.24	8.6	4.07	1	9.8	UnDef	UnDef	100.0	UnDef	UnDef	3.0	UnDef	UnDef	UnDe
26.08	5.0E-08	0.16	9.6	4.31	1	10.9	UnDef	UnDef	100.0	UnDef	UnDef	3.0	UnDef	UnDef	UnDe
27.07	5.0E-07	0.19	9.3	3.45	1	10.8	UnDef	UnDef	100.0	UnDef	UnDef	3.0	UnDef	UnDef	UnDe
28.05	5.0E-06	0.31	9.1	2.69	4	10.7	42.8	53.5	58.8	UnDef	UnDef	3.0	UnDef	5.2	10.
29.04	5.0E-07	0.03	28.2	4.19	6	30.3	121.3	151.7	42.3	UnDef	UnDef	6.0	UnDef	19.8	39.

Depth (ft)	k (cm/s)	Bq	Qtn	Rfn	SBTn	Qc1N	DeltaQc1N	Qc1Ncs	Fc (%)	Phi (Deg)	Dr (%)	OCR	State Param	Del(n1)60	(N1)60c
30.02	5.0E-08	0.02	15.8	4.76	1	17.9	UnDef	UnDef	100.0	UnDef	UnDef	6.0	UnDef	UnDef	UnDe
31.00	5.0E-06	0.13	15.3	3.66	4	17.6	70.5	88.1	51.9	UnDef	UnDef	6.0	UnDef	8.6	17.
31.99	5.0E-07	0.12	16.3	4.13	1	18.8	UnDef	UnDef	100.0	UnDef	UnDef	6.0	UnDef	UnDef	UnDe
32.97	5.0E-08	0.06	14.7	4.82	1	17.4	UnDef	UnDef	100.0	UnDef	UnDef	6.0	UnDef	UnDef	UnDe
33.96	5.0E-08	0.10	12.7	4.49	1	15.4	UnDef	UnDef	100.0	UnDef	UnDef	6.0	UnDef	UnDef	UnDe
34.94	5.0E-06	0.18	19.4	3.17	6	22.8	91.2	114.0	44.8	UnDef	UnDef	6.0	UnDef	11.2	22.
35.92	5.0E-05	0.05	58.9	3.44	6	66.5	108.9	175.4	28.2	40	55.6	10.0	-0.29	16.5	42.
36.91	5.0E-05	-0.01	65.4	2.74	7	74.4	77.7	152.1	24.1	40	58.8	10.0	-0.27	13.7	42.
37.89	5.0E-06	0.18	21.8	2.97	6	26.3	105.0	131.3	41.7	UnDef	UnDef	6.0	UnDef	12.8	25.
38.88	5.0E-06	0.19	14.9	3.35	4	18.8	75.1	93.9	51.0	UnDef	UnDef	6.0	UnDef	9.2	18.
39.86	5.0E-05	0.30	12.2	2.05	6	15.9	63.5	79.3	47.9	30	30.0	3.0	0.00	6.2	12.
40.85	5.0E-05	0.28	13.4	2.66	6	17.4	69.5	86.9	49.7	32	30.0	6.0	-0.03	6.8	13.
41.83	5.0E-06	0.22	16.3	3.58	4	21.0	83.9	104.9	50.2	UnDef	UnDef	6.0	UnDef	10.3	20.
42.81	5.0E-06	0.19	20.0	3.77	4	25.5	101.9	127.4	47.0	UnDef	UnDef	6.0	UnDef	12.5	24.
43.80	1.0E-15	0.03	46.5	4.98	6	57.3	229.1	286.4	36.9	38	51.3	1.0	-0.40	56.1	112.
44.78	1.0E-15	0.02	55.5	4.78	6	68.6	226.6	295.2	33.7	40	56.5	1.0	-0.41	62.0	129.
45.77	5.0E-06	0.09	35.8	4.32	6	45.4	181.7	227.1	38.8	UnDef	UnDef	6.0	UnDef	22.2	44.
46.75	5.0E-06	0.06	24.5	4.31	4	32.0	128.1	160.1	45.3	UnDef	UnDef	6.0	UnDef	15.7	31.
47.74	5.0E-05	0.16	12.4	2.12	6	17.4	69.8	87.2	48.0	30	30.0	3.0	-0.02	6.8	13.
48.72	5.0E-05	0.23	14.8	2.89	6	20.5	82.0	102.5	48.9	32	30.0	6.0	-0.06	8.0	16.
49.70	5.0E-06	0.08	14.7	3.78	1	20.5	UnDef	UnDef	100.0	UnDef	UnDef	6.0	UnDef	UnDef	UnDe
50.69	5.0E-06	0.07	19.1	3.67	4	26.3	105.3	131.7	47.4	UnDef	UnDef	6.0	UnDef	12.9	25.
51.67	5.0E-06	0.08	22.0	3.36	6	30.2	121.0	151.2	43.3	UnDef	UnDef	6.0	UnDef	14.8	29.
52.66	5.0E-05	0.17	17.1	3.01	6	24.2	96.8	121.1	46.5	32	30.0	6.0	-0.09	9.5	19.
53.64	5.0E-06	0.17	24.0	3.49	6	33.3	133.3	166.6	42.3	UnDef	UnDef	6.0	UnDef	16.3	32.
54.63	5.0E-06	0.09	24.9	3.90	6	34.6	138.5	173.2	43.4	UnDef	UnDef	6.0	UnDef	16.9	33.
.61	5.0E-05	0.19	18.0	2.72	6	25.9	103.7	129.6	44.0	32	30.0	6.0	-0.08	10.1	20.
56.59	5.0E-06	0.14	18.2	3.55	4	26.4	105.4	131.8	47.8	UnDef	UnDef	6.0	UnDef	12.9	25.
57.58	5.0E-06	0.15	17.5	4.05	1	25.7	UnDef	UnDef	100.0	UnDef	UnDef	6.0	UnDef	UnDef	UnDe
58.56	5.0E-06	0.17	16.2	3.51	4	24.0	96.1	120.1	50.1	UnDef	UnDef	6.0	UnDef	11.8	23.
59.55	5.0E-06	0.19	15.1	3.59	4	22.8	91.1	113.8	51.9	UnDef	UnDef	6.0	UnDef	11.1	22.
60.53	5.0E-05	0.28	15.1	3.01	6	22.9	91.7	114.7	49.0	32	30.0	6.0	-0.06	9.0	18.
61.52	5.0E-06	0.11	25.2	4.10	6	36.9	147.7	184.6	43.9	UnDef	UnDef	6.0	UnDef	18.1	36.
62.42	5.0E-07	0.03	16.9	5.05	1	25.7	UnDef	UnDef	100.0	UnDef	UnDef	6.0	UnDef	UnDef	UnDe
63.32	5.0E-06	0.08	13.2	4.10	1	20.8	UnDef	UnDef	100.0	UnDef	UnDef	6.0	UnDef	UnDef	UnDe
64.30	5.0E-06	0.13	14.3	3.81	1	22.4	UnDef	UnDef	100.0	UnDef	UnDef	6.0	UnDef	UnDef	UnDe
65.29	5.0E-06	0.13	15.4	4.10	1	24.1	UnDef	UnDef	100.0	UnDef	UnDef	6.0	UnDef	UnDef	UnDe
66.27	1.0E-15	0.02	31.7	6.38	1	47.2	UnDef	UnDef	100.0	36	45.8	1.0	-0.52	UnDef	UnDe
67.26	1.0E-15	0.03	38.5	5.40	1	57.3	UnDef	UnDef	100.0	38	51.3	1.0	-0.41	UnDef	UnDe
68.24	1.0E-15	-0.01	47.0	5.97	1	69.9	UnDef	UnDef	100.0	38	57.0	1.0	-0.55	UnDef	UnDe
69.22	1.0E-15	0.04	29.4	6.27	1	45.1	UnDef	UnDef	100.0	36	44.4	1.0	-0.47	UnDef	UnDe
70.21	1.0E-15	0.05	25.0	5.69	1	39.1	UnDef	UnDef	100.0	34	40.3	1.0	-0.34	UnDef	UnDe
71.19	1.0E-15	0.04	29.9	5.02	1	46.5	UnDef	UnDef	100.0	36	45.3	1.0	-0.31	UnDef	UnDe
72.18	5.0E-07	0.09	17.3	4.78	1	28.3	UnDef	UnDef	100.0	UnDef	UnDef	6.0	UnDef	UnDef	UnDe
73.16	5.0E-06	0.22	9.8	3.13	4	17.3	69.3	86.6	59.4	UnDef	UnDef	3.0	UnDef	8.5	17.
74.15	5.0E-06	0.15	11.9	3.88	1	20.5	UnDef	UnDef	100.0	UnDef	UnDef	3.0	UnDef	UnDef	UnDe
75.13	5.0E-06	0.22	14.8	3.81	1	25.0	UnDef	UnDef	100.0	UnDef	UnDef	6.0	UnDef	UnDef	UnDe
76.11	5.0E-06	0.24	15.9	3.38	4	26.8	107.1	133.9	49.8	UnDef	UnDef	6.0	UnDef	13.1	26.
77.10	5.0E-06	0.23	13.0	3.90	1	22.5	UnDef	UnDef	100.0	UnDef	UnDef	6.0	UnDef	UnDef	UnDe
78.08	5.0E-06	0.29	9.5	3.53	1	17.4	UnDef	UnDef	100.0	UnDef	UnDef	3.0	UnDef	UnDef	UnDe
79.07	5.0E-06	0.35	9.2	3.18	4	16.9	67.6	84.5	61.3	UnDef	UnDef	3.0	UnDef	8.3	16.
80.05	5.0E-05	0.38	11.2	2.93	4	20.2	80.7	100.9	55.1	30	30.0	3.0	0.00	7.9	15.

Gregg In Situ, Inc.
Run No: 03-0203-1606-1720
CPT File: 027C06.COR

Depth (ft)	k (cm/s)	Bq	Qtn	Rfn	SBTn	Qc1N	DeltaQc1N	Qc1Ncs	Fc (%)	Phi (Deg)	Dr (%)	OCR	State Param	Del(n1)60	(N1)60c
81.04	5.0E-05	0.26	13.9	3.13	4	24.4	97.5	121.8	51.5	32	30.0	6.0	-0.05	9.5	19.
82.02	5.0E-05	0.41	8.9	2.79	4	16.7	66.8	83.5	60.0	30	30.0	3.0	0.04	6.5	13.
83.00	5.0E-05	0.36	9.6	2.60	4	18.0	72.1	90.1	56.8	30	30.0	3.0	0.02	7.1	14.
83.99	5.0E-05	0.57	7.7	1.36	6	15.1	60.2	75.3	53.0	30	30.0	3.0	0.12	5.9	11.
84.97	5.0E-05	0.53	9.6	1.95	6	18.2	72.7	90.9	52.6	30	30.0	3.0	0.07	7.1	14.
85.96	5.0E-07	0.15	18.1	5.16	1	31.7	UnDef	UnDef	100.0	UnDef	UnDef	6.0	UnDef	UnDef	UnDe
86.94	1.0E-15	0.11	18.3	5.81	1	32.2	UnDef	UnDef	100.0	32	34.8	1.0	-0.27	UnDef	UnDe
87.93	5.0E-06	0.30	11.9	3.83	1	22.2	UnDef	UnDef	100.0	UnDef	UnDef	3.0	UnDef	UnDef	UnDe
88.91	5.0E-07	0.11	17.1	5.21	1	30.6	UnDef	UnDef	100.0	UnDef	UnDef	6.0	UnDef	UnDef	UnDe
89.89	5.0E-06	0.12	22.0	4.44	1	38.7	UnDef	UnDef	100.0	UnDef	UnDef	6.0	UnDef	UnDef	UnDe
90.88	1.0E-15	0.06	21.1	6.58	1	37.4	UnDef	UnDef	100.0	34	39.1	1.0	-0.43	UnDef	UnDe
91.86	5.0E-05	0.35	9.7	2.84	4	19.0	76.0	95.0	58.1	30	30.0	3.0	0.02	7.4	14.
92.85	5.0E-05	0.27	10.4	3.33	4	20.2	80.9	101.1	59.1	30	30.0	3.0	-0.02	7.9	15.
93.83	5.0E-05	0.31	9.9	3.20	4	19.5	77.9	97.4	59.6	30	30.0	3.0	0.00	7.6	15.
94.82	5.0E-05	0.39	9.8	2.91	4	19.5	77.9	97.4	58.2	30	30.0	3.0	0.02	7.6	15.
95.80	5.0E-06	0.30	13.8	3.70	1	26.2	UnDef	UnDef	100.0	UnDef	UnDef	6.0	UnDef	UnDef	UnDe
96.78	1.0E-15	0.06	30.4	4.96	1	54.2	UnDef	UnDef	100.0	36	49.7	1.0	-0.31	UnDef	UnDe
97.77	5.0E-08	0.13	13.7	5.67	1	26.2	UnDef	UnDef	100.0	UnDef	UnDef	6.0	UnDef	UnDef	UnDe
98.75	5.0E-05	0.33	8.7	3.10	4	18.0	72.0	90.0	62.2	30	30.0	3.0	0.02	7.0	14.

Gregg In Situ, Inc.
Interpretation Output - Release 1.00.19e
Job No: 03-0203-1606-1660
Job No: 97-100
Client: CDM
Project: CPT SITE INVESTIGATION
Site: SHERWIN WILLIAMS
Location: CPT-05
Engineer: H. YOUNG
CPT Date: 03/28/01
CPT Time: 10:52
CPT File: 027C05.COR
Northing (m): 0.000
Easting (m): 0.000
Elevation (m): 0.000

Water Table (m): 1.83 (ft): 6.0
Su Nkt used: 12.50
Averaging Increment (m): 0.30
Phi Method : Robertson and Campanella, 1983
Dr Method : Jamiolkowski - All Sands
State Parameter M: 1.20
Used Unit Weights Assigned to Soil Zones
Values of 1.0E9 or UnDef are printed for parameters that are not valid for the material type (SBT)

Depth (ft)	AvgQt (tsf)	AvgFs (tsf)	AvgRf (%)	AvgUd (ft)	SBT	U.Wt. pcf	TStress (tsf)	EStress (tsf)	Ueq (tsf)	Cn	N60 (blows/ft)	(N1)60 (blows/ft)	Su (tsf)	CRR
0.49	0.0	0.00	0.00	0.0	UnDef	124.1	0.03	0.03	0.00	2.00	UnDef	UnDef	UnDef	0.00
1.48	0.0	0.00	0.00	0.0	UnDef	124.1	0.09	0.09	0.00	2.00	UnDef	UnDef	UnDef	0.00
2.46	0.0	0.00	0.00	0.0	UnDef	124.1	0.15	0.15	0.00	2.00	UnDef	UnDef	UnDef	0.00
3.44	0.0	0.00	0.00	0.0	UnDef	124.1	0.21	0.21	0.00	2.00	UnDef	UnDef	UnDef	0.00
4.43	0.0	0.00	0.00	0.0	UnDef	124.1	0.27	0.27	0.00	1.91	UnDef	UnDef	UnDef	0.00
5.41	7.7	0.29	3.72	33.1	3	111.4	0.33	0.33	0.00	1.73	7.4	12.8	0.59	0.11
6.40	6.2	0.28	4.56	20.5	3	111.4	0.39	0.38	0.01	1.63	5.9	9.7	0.46	0.00
7.30	4.2	0.14	3.40	16.7	3	111.4	0.44	0.40	0.04	1.59	4.1	6.4	0.30	0.00
8.20	7.4	0.22	2.92	16.5	4	114.6	0.49	0.42	0.07	1.54	4.8	7.3	0.56	0.10
9.19	6.9	0.10	1.46	14.3	5	114.6	0.55	0.45	0.10	1.50	3.3	4.9	0.51	0.09
10.17	5.6	0.16	2.79	24.9	3	111.4	0.60	0.47	0.13	1.46	5.3	7.8	0.40	0.09
11.15	7.0	0.13	1.86	24.1	5	114.6	0.66	0.50	0.16	1.42	3.4	4.8	0.51	0.09
12.14	10.1	0.22	2.22	31.5	5	114.6	0.71	0.52	0.19	1.39	4.8	6.7	0.75	0.11
13.21	8.9	0.15	1.75	25.2	5	114.6	0.77	0.55	0.22	1.35	4.2	5.7	0.65	0.10
14.27	5.9	0.11	1.77	26.5	4	114.6	0.84	0.58	0.26	1.32	3.8	5.0	0.41	0.09
15.26	5.3	0.12	2.22	40.1	4	114.6	0.89	0.60	0.29	1.29	3.4	4.3	0.35	0.08
16.24	12.5	0.22	1.74	70.0	5	114.6	0.95	0.63	0.32	1.26	6.0	7.6	0.92	0.12
17.22	12.5	0.23	1.85	94.9	5	114.6	1.00	0.65	0.35	1.24	6.0	7.4	0.92	0.12
18.21	13.6	0.19	1.39	136.1	6	114.6	1.06	0.68	0.38	1.21	5.2	6.3	1.00	0.13
19.19	20.8	0.28	1.34	265.0	6	114.6	1.12	0.71	0.41	1.19	8.0	9.5	1.57	0.10
20.18	19.3	0.23	1.19	249.2	6	114.6	1.17	0.73	0.44	1.17	7.4	8.6	1.45	0.10
21.16	23.6	0.46	1.94	227.4	6	114.6	1.23	0.76	0.47	1.15	9.1	10.4	1.79	0.15
22.15	27.4	0.70	2.57	197.4	6	114.6	1.29	0.78	0.50	1.13	10.5	11.9	2.09	0.24
23.13	23.7	0.79	3.33	118.1	5	114.6	1.34	0.81	0.53	1.11	11.3	12.6	1.79	0.28
24.11	56.7	2.25	3.97	112.7	5	114.6	1.40	0.83	0.57	1.10	27.2	29.7	4.42	0.00
25.10	81.5	3.17	3.89	97.4	5	114.6	1.46	0.86	0.60	1.08	39.0	42.1	6.41	0.00
26.08	115.7	4.13	3.56	55.2	6	114.6	1.51	0.88	0.63	1.06	44.3	47.1	9.14	0.00
27.07	39.4	1.92	4.89	45.1	3	111.4	1.57	0.91	0.66	1.05	37.7	39.6	3.03	0.00
28.05	31.2	1.30	4.18	81.1	4	114.6	1.62	0.93	0.69	1.03	20.0	20.6	2.37	0.45
29.04	29.7	1.24	4.17	138.8	4	114.6	1.68	0.96	0.72	1.02	18.9	19.3	2.24	0.38

Gregg In Situ, Inc.
Run No: 03-0203-1606-1660
CPT File: 027C05.COR

Depth (ft)	AvgQt (tsf)	AvgFs (tsf)	AvgRf (%)	AvgUd (ft)	SBT	U.Wt. pcf	TStress (tsf)	EStress (tsf)	Ueq (tsf)	Cn	N60 (blows/ft)	(N1)60	Su (tsf)	CRR
30.02	26.6	1.12	4.20	104.6	4	114.6	1.74	0.99	0.75	1.01	17.0	17.1	1.99	0.00
31.00	44.4	1.43	3.23	117.2	5	114.6	1.79	1.01	0.78	0.99	21.3	21.2	3.41	0.00
31.99	179.8	4.43	2.46	56.1	7	117.8	1.85	1.04	0.81	0.98	57.4	56.4	UnDef	0.00
32.97	176.4	4.05	2.29	15.2	7	117.8	1.91	1.07	0.84	0.97	56.3	54.6	UnDef	0.00
33.96	167.9	3.63	2.16	-7.7	7	117.8	1.97	1.09	0.87	0.96	53.6	51.3	UnDef	0.00
34.94	190.3	3.94	2.07	-14.2	7	117.8	2.02	1.12	0.90	0.95	60.7	57.4	UnDef	0.00
35.92	125.8	4.18	3.32	-14.0	6	114.6	2.08	1.15	0.93	0.93	48.2	45.0	9.90	0.00
36.91	41.8	1.71	4.09	-11.5	5	114.6	2.14	1.17	0.97	0.92	20.0	18.5	3.17	0.00
37.89	21.7	0.60	2.76	-8.2	5	114.6	2.19	1.20	1.00	0.91	10.4	9.5	1.56	0.17
38.88	21.5	0.48	2.24	3.7	6	114.6	2.25	1.22	1.03	0.90	8.2	7.5	1.54	0.16
39.86	44.3	1.61	3.64	4.6	5	114.6	2.31	1.25	1.06	0.90	21.2	19.0	3.36	0.00
40.85	46.5	2.80	6.01	4.6	3	111.4	2.36	1.27	1.09	0.89	44.5	39.5	3.53	0.00
41.83	31.0	0.96	3.08	15.1	5	114.6	2.42	1.30	1.12	0.88	14.9	13.0	2.29	0.30
42.81	30.0	0.98	3.28	16.2	5	114.6	2.47	1.32	1.15	0.87	14.4	12.5	2.20	0.27
43.80	123.1	4.27	3.47	16.7	6	114.6	2.53	1.35	1.18	0.86	47.1	40.6	9.64	0.00
44.78	67.3	2.24	3.33	13.4	6	114.6	2.59	1.38	1.21	0.85	25.8	22.0	5.18	0.00
45.77	25.2	0.55	2.19	15.3	6	114.6	2.64	1.40	1.24	0.84	9.7	8.2	1.81	0.19
46.75	21.6	0.42	1.94	16.5	6	114.6	2.70	1.43	1.27	0.84	8.3	6.9	1.51	0.14
47.74	43.6	1.67	3.82	19.3	5	114.6	2.76	1.45	1.30	0.83	20.9	17.3	3.27	0.00
48.72	159.6	8.07	5.06	28.3	11	130.5	2.82	1.48	1.33	0.82	152.8	125.6	UnDef	0.00
49.70	38.6	1.80	4.67	26.8	4	114.6	2.88	1.51	1.36	0.81	24.7	20.1	2.86	0.00
50.69	30.9	0.72	2.34	27.7	6	114.6	2.93	1.54	1.40	0.81	11.8	9.5	2.23	0.25
51.67	24.5	0.51	2.06	27.4	6	114.6	2.99	1.56	1.43	0.80	9.4	7.5	1.72	0.16
52.66	31.9	0.60	1.87	28.8	6	114.6	3.05	1.59	1.46	0.79	12.2	9.7	2.31	0.26
53.64	35.2	0.95	2.71	29.2	6	114.6	3.10	1.61	1.49	0.79	13.5	10.6	2.56	0.31
54.63	32.5	0.94	2.89	29.5	5	114.6	3.16	1.64	1.52	0.78	15.5	12.1	2.35	0.26
55.61	28.6	0.70	2.46	30.9	6	114.6	3.21	1.67	1.55	0.77	10.9	8.5	2.03	0.20
56.59	32.7	0.87	2.66	31.5	6	114.6	3.27	1.69	1.58	0.77	12.5	9.6	2.35	0.25
57.58	25.2	0.59	2.36	31.2	6	114.6	3.33	1.72	1.61	0.76	9.6	7.4	1.75	0.16
58.56	25.0	0.64	2.55	32.3	5	114.6	3.38	1.74	1.64	0.76	12.0	9.1	1.73	0.15
59.55	23.0	0.55	2.41	32.4	6	114.6	3.44	1.77	1.67	0.75	8.8	6.6	1.57	0.14
60.53	27.4	0.86	3.13	33.2	5	114.6	3.50	1.79	1.70	0.75	13.1	9.8	1.92	0.17
61.52	28.2	0.87	3.10	34.5	5	114.6	3.55	1.82	1.73	0.74	13.5	10.0	1.97	0.18
62.42	29.5	0.75	2.54	35.7	6	114.6	3.60	1.84	1.76	0.74	11.3	8.3	2.07	0.19
63.32	36.4	0.89	2.45	38.4	6	114.6	3.66	1.87	1.79	0.73	13.9	10.2	2.62	0.29
64.30	31.6	0.83	2.63	40.9	6	114.6	3.71	1.89	1.82	0.73	12.1	8.8	2.23	0.21
65.29	29.3	0.96	3.26	43.6	5	114.6	3.77	1.92	1.85	0.72	14.1	10.1	2.05	0.00
66.27	30.8	0.89	2.88	44.9	5	114.6	3.83	1.94	1.88	0.72	14.8	10.6	2.16	0.20
67.26	33.8	0.94	2.78	47.8	6	114.6	3.88	1.97	1.91	0.71	12.9	9.2	2.39	0.23
68.24	35.3	0.85	2.40	56.0	6	114.6	3.94	1.99	1.94	0.71	13.5	9.6	2.51	0.25
69.22	47.6	1.29	2.70	59.7	6	114.6	3.99	2.02	1.97	0.70	18.2	12.8	3.49	0.00
70.21	92.7	4.73	5.11	66.5	11	130.5	4.05	2.05	2.00	0.70	88.7	62.0	UnDef	0.00
71.19	124.2	6.16	4.96	65.8	11	130.5	4.12	2.08	2.04	0.69	119.0	82.4	UnDef	0.00
72.18	40.8	1.20	2.94	66.5	6	114.6	4.18	2.11	2.07	0.69	15.6	10.8	2.93	0.32
73.16	39.7	1.03	2.60	70.8	6	114.6	4.24	2.14	2.10	0.68	15.2	10.4	2.83	0.30
74.15	46.5	1.18	2.53	73.8	6	114.6	4.29	2.16	2.13	0.68	17.8	12.1	3.38	0.42
75.13	54.5	2.21	4.05	76.0	5	114.6	4.35	2.19	2.16	0.68	26.1	17.6	4.01	0.00
76.11	50.2	2.21	4.41	77.2	5	114.6	4.40	2.22	2.19	0.67	24.0	16.2	3.66	0.00
77.10	37.4	1.54	4.13	73.3	4	114.6	4.46	2.24	2.22	0.67	23.9	16.0	2.64	0.00
78.08	36.2	0.79	2.17	78.4	6	114.6	4.52	2.27	2.25	0.66	13.9	9.2	2.54	0.23
79.07	34.7	0.86	2.48	80.0	6	114.6	4.57	2.29	2.28	0.66	13.3	8.8	2.41	0.21
80.05	35.8	0.95	2.65	81.4	6	114.6	4.63	2.32	2.31	0.66	13.7	9.0	2.49	0.22

Gregg In Situ, Inc.
Run No: 03-0203-1606-1660
CPT File: 027C05.COR

Depth (ft)	AvgQt (tsf)	AvgFs (tsf)	AvgRf (%)	AvgUd (ft)	SBT	U.Wt. pcf	TStress (tsf)	EStress (tsf)	Ueq (tsf)	Cn	N60 (blows/ft)	(N1)60 (blows/ft)	Su (tsf)	CRR
81.04	41.4	1.30	3.15	85.6	5	114.6	4.69	2.34	2.34	0.65	19.8	13.0	2.94	0.30
82.02	45.9	1.50	3.27	89.9	5	114.6	4.74	2.37	2.37	0.65	22.0	14.3	3.29	0.37
83.00	48.6	1.39	2.86	94.8	6	114.6	4.80	2.40	2.40	0.65	18.6	12.0	3.50	0.42
83.99	65.3	3.47	5.31	100.7	11	130.5	4.86	2.42	2.44	0.64	62.5	40.1	UnDef	0.00
84.97	38.5	1.23	3.21	94.5	5	114.6	4.92	2.45	2.47	0.64	18.4	11.8	2.68	0.00
85.96	53.0	2.18	4.11	105.4	5	114.6	4.98	2.48	2.50	0.64	25.4	16.1	3.84	0.00
86.94	118.7	6.37	5.36	128.4	11	130.5	5.04	2.51	2.53	0.63	113.7	71.8	UnDef	0.00
87.93	134.6	7.20	5.35	152.5	11	130.5	5.10	2.54	2.56	0.63	128.9	80.9	UnDef	0.00
88.91	32.2	1.06	3.31	128.7	5	114.6	5.16	2.57	2.59	0.62	15.4	9.6	2.16	0.00
89.89	30.9	0.75	2.43	138.5	6	114.6	5.22	2.60	2.62	0.62	11.9	7.4	2.06	0.16
90.88	78.0	3.58	4.59	146.0	11	130.5	5.28	2.63	2.65	0.62	74.7	46.1	UnDef	0.00
91.86	25.2	0.82	3.26	120.6	5	114.6	5.34	2.66	2.68	0.61	12.1	7.4	1.59	0.00
92.85	25.6	0.55	2.13	132.9	6	114.6	5.39	2.68	2.71	0.61	9.8	6.0	1.62	0.12
93.83	25.4	0.63	2.50	131.3	6	114.6	5.45	2.71	2.74	0.61	9.7	5.9	1.60	0.00
94.82	25.7	0.69	2.68	130.3	5	114.6	5.51	2.73	2.77	0.60	12.3	7.4	1.62	0.00
95.80	34.0	1.16	3.41	139.7	5	114.6	5.56	2.76	2.80	0.60	16.3	9.8	2.27	0.00
96.78	31.3	0.93	2.98	138.4	5	114.6	5.62	2.79	2.83	0.60	15.0	9.0	2.05	0.00
97.77	37.1	0.92	2.49	155.0	6	114.6	5.68	2.81	2.87	0.60	14.2	8.5	2.51	0.20
98.75	42.9	1.35	3.16	165.7	5	114.6	5.73	2.84	2.90	0.59	20.5	12.2	2.97	0.00

Gregg In Situ, Inc.
Interpretation Output - Release 1.00.19e
Run No: 03-0203-1606-1660
Job No: 97-100
Client: CDM
Project: CPT SITE INVESTIGATION
Site: SHERWIN WILLIAMS
Location: CPT-05
Engineer: H. YOUNG
CPT Date: 03/28/01
CPT Time: 10:52
CPT File: 027C05.COR
Northing (m): 0.000
Easting (m): 0.000
Elevation (m): 0.000

Water Table (m): 1.83 (ft): 6.0
Su Nkt used: 12.50
Averaging Increment (m): 0.30
Phi Method : Robertson and Campanella, 1983
Dr Method : Jamiolkowski - All Sands
State Parameter M: 1.20
Used Unit Weights Assigned to Soil Zones
Values of 1.0E9 or UnDef are printed for parameters that are not valid for the material type (SBT)

Depth (ft)	k (cm/s)	Bq	Qtn	Rfn	SBTn	Qc1N	DeltaQc1N	Qc1Ncs	Fc (%)	Phi (Deg)	Dr (%)	OCR	State Param	Del(n1)60	(N1)60c
0.49	1.0E-15	0.00	2.4	0.10	1	0.2	UnDef	UnDef	100.0	UnDef	UnDef	1.0	UnDef	UnDef	UnDe
1.48	1.0E-15	0.00	0.1	0.10	1	0.2	UnDef	UnDef	100.0	UnDef	UnDef	1.0	UnDef	UnDef	UnDe
2.46	1.0E-15	0.00	0.1	0.10	1	0.2	UnDef	UnDef	100.0	UnDef	UnDef	1.0	UnDef	UnDef	UnDe
3.44	1.0E-15	0.00	0.0	0.10	1	0.2	UnDef	UnDef	100.0	UnDef	UnDef	1.0	UnDef	UnDef	UnDe
4.43	1.0E-15	0.00	0.0	0.10	1	0.2	UnDef	UnDef	100.0	UnDef	UnDef	1.0	UnDef	UnDef	UnDe
5.41	5.0E-08	0.14	22.1	3.89	6	13.0	52.1	65.2	45.5	UnDef	UnDef	6.0	UnDef	12.8	25.
6.40	5.0E-08	0.11	15.5	4.87	1	9.9	UnDef	UnDef	100.0	UnDef	UnDef	6.0	UnDef	UnDef	UnDe
7.30	5.0E-08	0.13	9.6	3.79	1	6.6	UnDef	UnDef	100.0	UnDef	UnDef	3.0	UnDef	UnDef	UnDe
8.20	5.0E-07	0.06	16.6	3.12	6	11.2	45.0	56.2	47.7	UnDef	UnDef	6.0	UnDef	7.3	14.
9.19	5.0E-06	0.06	14.2	1.59	6	10.1	40.2	50.3	41.5	UnDef	UnDef	6.0	UnDef	4.9	9.
10.17	5.0E-08	0.13	10.5	3.13	4	7.9	31.8	39.7	57.7	UnDef	UnDef	3.0	UnDef	7.8	15.
11.15	5.0E-06	0.09	12.8	2.05	6	9.8	39.1	48.8	46.8	UnDef	UnDef	6.0	UnDef	4.8	9.
12.14	5.0E-06	0.08	18.0	2.38	6	13.7	54.8	68.5	42.1	UnDef	UnDef	6.0	UnDef	6.7	13.
13.21	5.0E-06	0.07	14.7	1.91	6	11.7	46.8	58.5	43.1	UnDef	UnDef	6.0	UnDef	5.7	11.
14.27	5.0E-07	0.11	8.8	2.06	4	7.7	30.6	38.3	55.4	UnDef	UnDef	3.0	UnDef	5.0	10.
15.26	5.0E-07	0.22	7.3	2.67	4	6.7	26.6	33.3	64.3	UnDef	UnDef	3.0	UnDef	4.3	8.
16.24	5.0E-06	0.16	18.4	1.88	6	15.4	61.8	77.2	38.5	UnDef	UnDef	6.0	UnDef	7.6	15.
17.22	5.0E-06	0.23	17.5	2.01	6	15.1	60.4	75.5	40.3	UnDef	UnDef	6.0	UnDef	7.4	14.
18.21	5.0E-05	0.31	18.4	1.51	6	16.1	64.3	80.4	36.0	32	30.0	6.0	-0.02	6.3	12.
19.19	5.0E-05	0.40	27.9	1.42	7	24.2	39.9	64.1	28.3	36	30.0	6.0	-0.04	6.0	15.
20.18	5.0E-05	0.41	24.8	1.26	7	22.1	39.3	61.4	29.0	34	30.0	6.0	-0.02	5.8	14.
21.16	5.0E-05	0.30	29.6	2.05	7	26.6	64.4	90.9	31.5	36	30.0	6.0	-0.10	8.3	18.
22.15	5.0E-05	0.22	33.4	2.69	6	30.3	90.6	120.9	33.1	36	33.1	6.0	-0.15	10.5	22.
23.13	5.0E-06	0.14	27.6	3.53	6	25.8	103.0	128.8	40.0	UnDef	UnDef	6.0	UnDef	12.6	25.
24.11	5.0E-06	0.05	66.4	4.07	6	60.8	108.8	169.6	29.0	UnDef	UnDef	10.0	UnDef	19.9	49.
25.10	5.0E-06	0.03	93.2	3.96	12	86.1	UnDef	UnDef	0.0	UnDef	UnDef	10.0	UnDef	UnDef	UnDe
26.08	5.0E-05	0.01	129.1	3.61	12	120.4	UnDef	UnDef	0.0	44	72.6	10.0	-0.42	UnDef	UnDe
27.07	5.0E-08	0.02	41.6	5.09	6	40.4	161.7	202.1	39.0	UnDef	UnDef	6.0	UnDef	39.6	79.
28.05	5.0E-07	0.06	31.7	4.40	6	31.6	126.5	158.2	41.1	UnDef	UnDef	6.0	UnDef	20.6	41.
29.04	5.0E-07	0.13	29.1	4.42	6	29.6	118.5	148.1	42.6	UnDef	UnDef	6.0	UnDef	19.3	38.

Gregg In Situ, Inc.
Run No: 03-0203-1606-1660
CPT File: 027C05.COR

Depth (ft)	k (cm/s)	Bq	Qtn	Rfn	SBTn	Qc1N	DeltaQc1N	Qc1Ncs	Fc (%)	Phi (Deg)	Dr (%)	OCR	State Param	Del(n1)60	(N1)60c
30.02	5.0E-07	0.10	25.2	4.49	1	26.2	UnDef	UnDef	100.0	UnDef	UnDef	6.0	UnDef	UnDef	UnDe
31.00	5.0E-06	0.07	42.2	3.36	6	43.2	120.1	163.3	32.5	UnDef	UnDef	6.0	UnDef	18.0	39.
31.99	5.0E-04	0.01	171.5	2.49	7	172.8	53.8	226.6	13.9	44	82.9	1.0	-0.36	9.8	66.
32.97	5.0E-04	0.00	163.8	2.32	7	167.2	49.6	216.8	13.6	44	82.0	1.0	-0.34	9.1	63.
33.96	5.0E-04	-0.01	151.9	2.19	7	157.2	46.7	203.9	13.6	44	80.2	1.0	-0.32	8.6	59.
34.94	5.0E-04	-0.01	168.2	2.09	9	176.0	43.6	219.6	12.4	44	83.5	1.0	-0.33	8.1	65.
35.92	5.0E-05	-0.01	108.0	3.37	7	115.0	87.4	202.4	21.2	42	71.3	10.0	-0.38	16.7	61.
36.91	5.0E-06	-0.03	33.8	4.31	6	37.8	151.0	188.8	39.6	UnDef	UnDef	6.0	UnDef	18.5	37.
37.89	5.0E-06	-0.06	16.3	3.07	6	19.4	77.6	97.0	47.8	UnDef	UnDef	6.0	UnDef	9.5	19.
38.88	5.0E-05	-0.05	15.8	2.51	6	19.0	76.2	95.2	45.4	32	30.0	6.0	-0.09	7.5	14.
39.86	5.0E-06	-0.02	33.7	3.84	6	38.8	155.3	194.1	37.9	UnDef	UnDef	6.0	UnDef	19.0	38.
40.85	5.0E-08	-0.02	34.7	6.33	1	40.3	UnDef	UnDef	100.0	UnDef	UnDef	6.0	UnDef	UnDef	UnDe
41.83	5.0E-06	-0.02	22.0	3.34	6	26.7	106.6	133.3	43.2	UnDef	UnDef	6.0	UnDef	13.0	26.
42.81	5.0E-06	-0.02	20.8	3.57	6	25.5	102.0	127.6	45.3	UnDef	UnDef	6.0	UnDef	12.5	25.
43.80	5.0E-05	-0.01	89.3	3.54	7	103.7	103.7	207.3	23.7	42	68.3	10.0	-0.37	18.5	59.
44.78	5.0E-05	-0.01	47.1	3.46	6	56.2	133.3	189.5	31.4	38	50.7	6.0	-0.27	17.3	39.
45.77	5.0E-05	-0.03	16.1	2.45	6	20.8	83.4	104.2	44.7	32	30.0	6.0	-0.09	8.2	16.
46.75	5.0E-05	-0.04	13.3	2.22	6	17.7	70.8	88.6	47.3	32	30.0	6.0	-0.06	6.9	13.
47.74	5.0E-06	-0.02	28.1	4.08	6	35.4	141.7	177.1	41.9	UnDef	UnDef	6.0	UnDef	17.3	34.
48.72	1.0E-15	0.00	105.8	5.15	11	128.3	UnDef	UnDef	0.0	42	74.4	1.0	-0.58	UnDef	UnDe
49.70	5.0E-07	-0.01	23.7	5.05	1	30.8	UnDef	UnDef	100.0	UnDef	UnDef	6.0	UnDef	UnDef	UnDe
50.69	5.0E-05	-0.02	18.2	2.58	6	24.4	97.5	121.8	43.1	32	30.0	6.0	-0.11	9.5	19.
51.67	5.0E-05	-0.03	13.8	2.35	6	19.2	76.8	96.1	47.3	32	30.0	6.0	-0.07	7.5	15.
52.66	5.0E-05	-0.02	18.2	2.07	6	24.8	99.1	123.8	40.0	32	30.0	6.0	-0.08	9.7	19.
53.64	5.0E-05	-0.02	19.9	2.97	6	27.1	108.3	135.4	43.4	34	30.0	6.0	-0.13	10.6	21.
54.63	5.0E-06	-0.02	17.9	3.20	6	24.8	99.3	124.1	46.6	UnDef	UnDef	6.0	UnDef	12.1	24.
.61	5.0E-05	-0.02	15.2	2.77	6	21.7	86.7	108.4	47.6	32	30.0	6.0	-0.09	8.5	17.
56.59	5.0E-05	-0.02	17.4	2.96	6	24.6	98.3	122.9	45.9	32	30.0	6.0	-0.12	9.6	19.
57.58	5.0E-05	-0.03	12.7	2.72	6	18.8	75.2	94.1	51.2	32	30.0	6.0	-0.07	7.4	14.
58.56	5.0E-06	-0.03	12.4	2.95	4	18.5	74.1	92.6	53.0	UnDef	UnDef	3.0	UnDef	9.1	18.
59.55	5.0E-05	-0.03	11.1	2.83	4	17.0	67.8	84.8	54.9	30	30.0	3.0	-0.06	6.6	13.
60.53	5.0E-06	-0.03	13.4	3.59	4	20.1	80.2	100.3	54.6	UnDef	UnDef	6.0	UnDef	9.8	19.
61.52	5.0E-06	-0.03	13.5	3.54	4	20.4	81.8	102.2	54.0	UnDef	UnDef	6.0	UnDef	10.0	20.
62.42	5.0E-05	-0.02	14.0	2.90	6	21.3	85.0	106.3	50.0	32	30.0	6.0	-0.09	8.3	16.
63.32	5.0E-05	-0.02	17.5	2.72	6	26.1	104.2	130.3	44.5	32	30.0	6.0	-0.11	10.2	20.
64.30	5.0E-05	-0.02	14.8	2.98	6	22.5	90.0	112.5	49.4	32	30.0	6.0	-0.10	8.8	17.
65.29	5.0E-06	-0.02	13.3	3.74	1	20.7	UnDef	UnDef	100.0	UnDef	UnDef	6.0	UnDef	UnDef	UnDe
66.27	5.0E-06	-0.02	13.9	3.29	4	21.6	86.6	108.2	52.2	UnDef	UnDef	6.0	UnDef	10.6	21.
67.26	5.0E-05	-0.01	15.2	3.15	4	23.6	94.2	117.8	49.6	32	30.0	6.0	-0.11	9.2	18.
68.24	5.0E-05	-0.01	15.7	2.70	6	24.4	97.8	122.2	46.6	32	30.0	6.0	-0.09	9.6	19.
69.22	5.0E-05	0.00	21.6	2.95	6	32.8	131.2	164.0	41.7	34	35.3	6.0	-0.14	12.8	25.
70.21	1.0E-15	0.00	43.2	5.34	1	63.3	UnDef	UnDef	100.0	38	54.2	1.0	-0.43	UnDef	UnDe
71.19	1.0E-15	0.00	57.7	5.13	6	84.2	302.8	387.0	34.3	40	62.4	1.0	-0.46	79.0	161.
72.18	5.0E-05	0.00	17.3	3.27	6	27.5	110.0	137.5	47.5	32	30.3	6.0	-0.13	10.8	21.
73.16	5.0E-05	0.00	16.6	2.92	6	26.5	106.1	132.7	46.7	32	30.0	6.0	-0.11	10.4	20.
74.15	5.0E-05	0.00	19.5	2.79	6	30.9	123.7	154.7	42.8	34	33.6	6.0	-0.12	12.1	24.
75.13	5.0E-06	0.00	22.9	4.40	1	36.0	UnDef	UnDef	100.0	UnDef	UnDef	6.0	UnDef	UnDef	UnDe
76.11	5.0E-06	0.00	20.7	4.83	1	33.0	UnDef	UnDef	100.0	UnDef	UnDef	6.0	UnDef	UnDef	UnDe
77.10	5.0E-07	0.00	14.7	4.69	1	24.5	UnDef	UnDef	100.0	UnDef	UnDef	6.0	UnDef	UnDef	UnDe
78.08	5.0E-05	0.01	14.0	2.48	6	23.5	94.2	117.7	47.7	32	30.0	6.0	-0.07	9.2	18.
79.07	5.0E-05	0.01	13.1	2.86	4	22.4	89.7	112.1	51.2	32	30.0	6.0	-0.07	8.8	17.
80.05	5.0E-05	0.01	13.4	3.05	4	23.0	92.0	115.0	51.8	32	30.0	6.0	-0.08	9.0	18.

Gregg In Situ, Inc.
Run No: 03-0203-1606-1660
CPT File: 027C05.COR

Depth (ft)	k (cm/s)	Bq	Qtn	Rfn	SBTn	Qc1N	DeltaQc1N	Qc1Ncs	Fc (%)	Phi (Deg)	Dr (%)	OCR	State Param	Del(n1)60	(N1)60c
81.04	5.0E-06	0.01	15.7	3.55	4	26.5	105.9	132.3	50.9	UnDef	UnDef	6.0	UnDef	13.0	25.
82.02	5.0E-06	0.01	17.4	3.65	4	29.2	116.7	145.9	49.2	UnDef	UnDef	6.0	UnDef	14.3	28.
83.00	5.0E-05	0.01	18.3	3.17	6	30.7	123.0	153.7	46.0	32	33.5	6.0	-0.13	12.0	24.
83.99	1.0E-15	0.01	24.9	5.74	1	41.0	UnDef	UnDef	100.0	34	41.7	1.0	-0.36	UnDef	UnDe
84.97	5.0E-06	0.01	13.7	3.68	1	24.0	UnDef	UnDef	100.0	UnDef	UnDef	6.0	UnDef	UnDef	UnDe
85.96	5.0E-06	0.02	19.3	4.54	1	32.9	UnDef	UnDef	100.0	UnDef	UnDef	6.0	UnDef	UnDef	UnDe
86.94	1.0E-15	0.01	45.3	5.60	1	73.3	UnDef	UnDef	100.0	38	58.4	1.0	-0.47	UnDef	UnDe
87.93	1.0E-15	0.02	50.9	5.56	6	82.6	330.4	413.1	37.3	38	61.8	1.0	-0.49	80.9	161.
88.91	5.0E-06	0.05	10.5	3.94	1	19.6	UnDef	UnDef	100.0	UnDef	UnDef	3.0	UnDef	UnDef	UnDe
89.89	5.0E-05	0.07	9.9	2.92	4	18.8	75.1	93.9	58.1	30	30.0	3.0	-0.03	7.4	14.
90.88	1.0E-15	0.03	27.7	4.92	1	47.1	UnDef	UnDef	100.0	36	45.7	1.0	-0.29	UnDef	UnDe
91.86	5.0E-06	0.05	7.5	4.13	1	15.2	UnDef	UnDef	100.0	UnDef	UnDef	3.0	UnDef	UnDef	UnDe
92.85	5.0E-05	0.07	7.5	2.70	4	15.3	61.2	76.5	63.7	30	30.0	3.0	0.01	6.0	12.
93.83	5.0E-05	0.07	7.4	3.18	1	15.1	UnDef	UnDef	100.0	30	30.0	3.0	0.00	UnDef	UnDe
94.82	5.0E-06	0.06	7.4	3.42	1	15.2	UnDef	UnDef	100.0	UnDef	UnDef	3.0	UnDef	UnDef	UnDe
95.80	5.0E-06	0.05	10.3	4.08	1	20.0	UnDef	UnDef	100.0	UnDef	UnDef	3.0	UnDef	UnDef	UnDe
96.78	5.0E-06	0.06	9.2	3.63	1	18.3	UnDef	UnDef	100.0	UnDef	UnDef	3.0	UnDef	UnDef	UnDe
97.77	5.0E-05	0.06	11.2	2.94	4	21.6	86.6	108.2	55.3	30	30.0	3.0	-0.05	8.5	16.
98.75	5.0E-06	0.06	13.1	3.64	1	24.9	UnDef	UnDef	100.0	UnDef	UnDef	6.0	UnDef	UnDef	UnDe

Gregg In Situ, Inc.
Interpretation Output - Release 1.00.19e
n No: 03-0203-1606-1605
ob No: 97-100
Client: CDM
Project: CPT SITE INVESTIGATION
Site: SHERWIN WILLIAMS
Location: CPT-04
Engineer: H. YOUNG
CPT Date: 03/28/01
CPT Time: 08:29
CPT File: 027C04.COR
Northing (m): 0.000
Easting (m): 0.000
Elevation (m): 0.000

Water Table (m): 2.44 (ft): 8.0
Su Nkt used: 12.50
Averaging Increment (m): 0.30
Phi Method : Robertson and Campanella, 1983
Dr Method : Jamiolkowski - All Sands
State Parameter M: 1.20
Used Unit Weights Assigned to Soil Zones
Values of 1.0E9 or UnDef are printed for parameters that are not valid for the material type (SBT)

Depth (ft)	AvgQt (tsf)	AvgFs (tsf)	AvgRf (%)	AvgUd (ft)	SBT	U.Wt. pcf	TStress (tsf)	EStress (tsf)	Ueq (tsf)	Cn	N60 (blows/ft)	(N1)60 (blows/ft)	Su (tsf)	CRR
0.49	0.0	0.00	0.00	0.0	UnDef	124.1	0.03	0.03	0.00	2.00	UnDef	UnDef	UnDef	0.00
1.48	0.0	0.00	0.00	0.0	UnDef	124.1	0.09	0.09	0.00	2.00	UnDef	UnDef	UnDef	0.00
2.46	0.0	0.00	0.00	0.0	UnDef	124.1	0.15	0.15	0.00	2.00	UnDef	UnDef	UnDef	0.00
3.44	0.0	0.00	0.00	0.0	UnDef	124.1	0.21	0.21	0.00	2.00	UnDef	UnDef	UnDef	0.00
).43	0.0	0.00	0.00	0.0	UnDef	124.1	0.27	0.27	0.00	1.91	UnDef	UnDef	UnDef	0.00
5.41	12.4	0.53	4.30	34.6	3	111.4	0.33	0.33	0.00	1.73	11.9	20.6	0.96	0.19
6.40	13.9	0.60	4.34	16.0	3	111.4	0.39	0.39	0.00	1.61	13.3	21.4	1.08	0.20
7.30	8.2	0.14	1.74	1.6	5	114.6	0.44	0.44	0.00	1.51	3.9	5.9	0.62	0.10
8.20	5.2	0.10	1.82	15.8	4	114.6	0.49	0.48	0.01	1.44	3.3	4.8	0.38	0.08
9.19	5.3	0.16	2.95	13.9	3	111.4	0.55	0.51	0.04	1.40	5.0	7.1	0.38	0.08
10.17	25.6	0.15	0.59	6.5	7	117.8	0.60	0.53	0.07	1.37	8.2	11.2	UnDef	0.09
11.15	67.8	0.33	0.49	-10.2	8	120.9	0.66	0.56	0.10	1.33	16.2	21.6	UnDef	0.14
12.14	86.8	0.43	0.49	-16.9	8	120.9	0.72	0.59	0.13	1.30	20.8	27.0	UnDef	0.21
13.21	61.5	0.33	0.54	-5.9	8	120.9	0.78	0.62	0.16	1.27	14.7	18.7	UnDef	0.13
14.27	7.7	0.07	0.84	80.5	5	114.6	0.85	0.65	0.20	1.24	3.7	4.6	0.55	0.09
15.26	12.1	0.17	1.41	79.1	5	114.6	0.90	0.68	0.23	1.21	5.8	7.1	0.90	0.11
16.24	71.3	0.76	1.06	8.0	8	120.9	0.96	0.70	0.26	1.19	17.1	20.3	UnDef	0.17
17.22	53.5	0.62	1.17	22.9	7	117.8	1.02	0.73	0.29	1.17	17.1	20.0	UnDef	0.13
18.21	77.0	0.53	0.69	11.5	8	120.9	1.08	0.76	0.32	1.15	18.4	21.1	UnDef	0.16
19.19	33.4	0.24	0.73	22.6	7	117.8	1.14	0.79	0.35	1.13	10.7	12.0	UnDef	0.10
20.18	6.4	0.12	1.90	80.5	4	114.6	1.20	0.82	0.38	1.11	4.1	4.5	0.42	0.08
21.16	6.8	0.18	2.67	67.7	4	114.6	1.25	0.84	0.41	1.09	4.4	4.8	0.45	0.00
22.15	9.8	0.41	4.19	46.2	3	111.4	1.31	0.87	0.44	1.07	9.4	10.1	0.68	0.00
23.13	12.5	0.63	5.02	20.3	3	111.4	1.36	0.89	0.47	1.06	12.0	12.7	0.89	0.00
24.11	14.3	0.70	4.89	15.2	3	111.4	1.42	0.91	0.50	1.05	13.7	14.3	1.03	0.00
25.10	16.4	0.76	4.64	34.0	3	111.4	1.47	0.94	0.53	1.03	15.7	16.2	1.20	0.00
26.08	21.6	0.82	3.79	88.2	4	114.6	1.53	0.96	0.56	1.02	13.8	14.1	1.61	0.20
27.07	19.4	0.64	3.30	78.7	5	114.6	1.58	0.99	0.60	1.01	9.3	9.3	1.42	0.16
28.05	17.0	0.44	2.58	106.3	5	114.6	1.64	1.01	0.63	0.99	8.2	8.1	1.23	0.13
29.04	13.6	0.26	1.93	115.3	5	114.6	1.70	1.04	0.66	0.98	6.5	6.4	0.95	0.11

Depth (ft)	AvgQt (tsf)	AvgFs (tsf)	AvgRf (%)	AvgUd (ft)	SBT	U.Wt. pcf	TStress (tsf)	EStress (tsf)	Ueq (tsf)	Cn	N60 (blows/ft)	(N1)60 (blows/ft)	Su (tsf)	CRR
30.02	11.6	0.18	1.58	136.3	5	114.6	1.75	1.07	0.69	0.97	5.6	5.4	0.79	0.10
31.00	14.5	0.21	1.47	173.0	6	114.6	1.81	1.09	0.72	0.96	5.6	5.3	1.02	0.11
31.99	21.5	0.45	2.08	218.6	6	114.6	1.87	1.12	0.75	0.95	8.2	7.8	1.57	0.17
32.97	27.7	0.75	2.69	216.4	5	114.6	1.92	1.14	0.78	0.94	13.3	12.4	2.06	0.27
33.96	39.4	1.36	3.44	60.2	5	114.6	1.98	1.17	0.81	0.93	18.9	17.5	3.00	0.00
34.94	102.0	1.79	1.76	-4.9	7	117.8	2.04	1.19	0.84	0.91	32.6	29.8	UnDef	0.30
35.92	133.2	1.26	0.95	-12.7	9	124.1	2.10	1.22	0.87	0.90	25.5	23.1	UnDef	0.31
36.91	44.5	1.00	2.25	91.5	6	114.6	2.15	1.25	0.90	0.89	17.1	15.2	3.39	0.28
37.89	19.9	0.40	2.01	148.0	6	114.6	2.21	1.28	0.93	0.88	7.6	6.8	1.42	0.14
38.88	29.0	0.82	2.81	179.9	5	114.6	2.27	1.30	0.96	0.88	13.9	12.2	2.14	0.26
39.86	38.1	0.92	2.41	332.5	6	114.6	2.32	1.33	0.99	0.87	14.6	12.7	2.87	0.00
40.85	83.6	4.47	5.35	51.2	11	130.5	2.38	1.36	1.03	0.86	80.1	68.7	UnDef	0.00
41.83	55.3	3.07	5.56	110.0	11	130.5	2.45	1.39	1.06	0.85	53.0	44.9	UnDef	0.00
42.81	34.4	1.55	4.51	107.3	4	114.6	2.51	1.42	1.09	0.84	21.9	18.4	2.55	0.00
43.80	23.3	0.69	2.97	77.2	5	114.6	2.56	1.45	1.12	0.83	11.2	9.3	1.66	0.16
44.78	53.6	1.62	3.03	115.7	6	114.6	2.62	1.47	1.15	0.82	20.5	16.9	4.08	0.00
45.77	53.6	2.08	3.88	45.2	5	114.6	2.68	1.50	1.18	0.82	25.7	21.0	4.08	0.00
46.75	42.7	1.64	3.84	34.7	5	114.6	2.73	1.52	1.21	0.81	20.5	16.6	3.20	0.00
47.74	24.2	0.63	2.60	164.7	5	114.6	2.79	1.55	1.24	0.80	11.6	9.3	1.71	0.16
48.72	59.3	2.08	3.50	102.2	5	114.6	2.85	1.58	1.27	0.80	28.4	22.6	4.52	0.00
49.70	23.0	0.62	2.71	131.0	5	114.6	2.90	1.60	1.30	0.79	11.0	8.7	1.61	0.15
50.69	23.4	0.56	2.39	159.3	6	114.6	2.96	1.63	1.33	0.78	9.0	7.0	1.63	0.15
51.67	54.6	1.63	2.98	258.6	6	114.6	3.02	1.65	1.36	0.78	20.9	16.3	4.13	0.00
52.66	225.0	5.10	2.27	2.1	7	117.8	3.07	1.68	1.39	0.77	71.8	55.4	UnDef	0.00
53.64	38.0	1.43	3.76	156.9	5	114.6	3.13	1.70	1.43	0.77	18.2	13.9	2.79	0.35
54.63	125.0	1.96	1.57	42.5	8	120.9	3.19	1.73	1.46	0.76	29.9	22.7	UnDef	0.34
55.61	59.0	1.58	2.67	107.2	6	114.6	3.25	1.76	1.49	0.75	22.6	17.0	4.46	0.00
56.59	78.4	3.59	4.58	80.3	11	130.5	3.31	1.79	1.52	0.75	75.1	56.1	UnDef	0.00
57.58	38.2	1.16	3.04	197.5	5	114.6	3.37	1.82	1.55	0.74	18.3	13.6	2.79	0.33
58.56	40.6	1.12	2.76	223.4	6	114.6	3.42	1.84	1.58	0.74	15.6	11.5	2.98	0.37
59.55	34.7	0.92	2.65	304.3	6	114.6	3.48	1.87	1.61	0.73	13.3	9.7	2.50	0.26
60.53	34.1	0.69	2.02	394.5	6	114.6	3.54	1.90	1.64	0.73	13.0	9.5	2.44	0.24
61.52	39.3	0.77	1.97	410.1	6	114.6	3.59	1.92	1.67	0.72	15.0	10.9	2.85	0.33
62.42	39.4	0.85	2.15	308.2	6	114.6	3.64	1.94	1.70	0.72	15.1	10.8	2.86	0.33
63.32	40.4	1.00	2.47	257.9	6	114.6	3.70	1.97	1.73	0.71	15.5	11.0	2.94	0.34
64.30	34.6	0.89	2.59	237.3	6	114.6	3.75	1.99	1.76	0.71	13.2	9.4	2.46	0.24
65.29	32.8	0.76	2.31	286.1	6	114.6	3.81	2.02	1.79	0.70	12.5	8.8	2.32	0.21
66.27	29.8	0.63	2.12	347.5	6	114.6	3.86	2.05	1.82	0.70	11.4	8.0	2.08	0.18
67.26	32.6	0.63	1.92	307.8	6	114.6	3.92	2.07	1.85	0.69	12.5	8.7	2.29	0.21
68.24	37.0	1.02	2.77	230.0	6	114.6	3.98	2.10	1.88	0.69	14.2	9.8	2.64	0.26
69.22	55.1	2.09	3.79	187.5	5	114.6	4.03	2.12	1.91	0.69	26.4	18.1	4.09	0.00
70.21	77.5	4.20	5.42	112.4	11	130.5	4.09	2.15	1.94	0.68	74.2	50.6	UnDef	0.00
71.19	118.3	6.52	5.51	78.7	11	130.5	4.16	2.19	1.97	0.68	113.3	76.7	UnDef	0.00
72.18	104.5	5.80	5.55	257.9	11	130.5	4.22	2.22	2.00	0.67	100.0	67.2	UnDef	0.00
73.16	48.0	1.32	2.75	402.8	6	114.6	4.28	2.25	2.03	0.67	18.4	12.3	3.49	0.44
74.15	52.6	1.33	2.54	518.6	6	114.6	4.34	2.27	2.07	0.66	20.1	13.4	3.86	0.00
75.13	152.3	7.48	4.91	232.0	11	130.5	4.40	2.30	2.10	0.66	145.9	96.1	UnDef	0.00
76.11	80.7	4.11	5.09	271.3	11	130.5	4.46	2.34	2.13	0.65	77.3	50.6	UnDef	0.00
77.10	65.2	3.09	4.74	256.4	11	130.5	4.53	2.37	2.16	0.65	62.5	40.6	UnDef	0.00
78.08	63.8	2.70	4.23	255.7	5	114.6	4.59	2.40	2.19	0.65	30.5	19.7	4.74	0.00
79.07	96.2	5.55	5.77	173.6	11	130.5	4.65	2.43	2.22	0.64	92.1	59.1	UnDef	0.00
80.05	98.9	5.15	5.21	219.4	11	130.5	4.71	2.46	2.25	0.64	94.7	60.3	UnDef	0.00

Gregg In Situ, Inc.
Run No: 03-0203-1606-1605
CPT File: 027C04.COR

Depth (ft)	AvgQt (tsf)	AvgFs (tsf)	AvgRf (%)	AvgUd (ft)	SBT	U.Wt. pcf	TStress (tsf)	EStress (tsf)	Ueq (tsf)	Cn	N60 (blows/ft)	(N1)60 (blows/ft)	Su (tsf)	CRR
81.04	113.9	6.12	5.37	117.5	11	130.5	4.78	2.50	2.28	0.63	109.1	69.1	UnDef	0.00
82.02	108.4	3.70	3.41	391.0	6	114.6	4.84	2.53	2.31	0.63	41.5	26.1	8.29	0.00
83.00	132.3	6.58	4.97	105.6	11	130.5	4.90	2.56	2.34	0.63	126.7	79.2	UnDef	0.00
83.99	96.2	4.65	4.83	123.1	11	130.5	4.96	2.59	2.37	0.62	92.1	57.3	UnDef	0.00
84.97	33.6	0.80	2.39	195.3	6	114.6	5.02	2.62	2.40	0.62	12.9	8.0	2.29	0.18
85.96	36.2	0.60	1.66	353.0	6	114.6	5.08	2.64	2.43	0.62	13.9	8.5	2.49	0.20
86.94	29.9	0.48	1.60	321.2	6	114.6	5.13	2.67	2.46	0.61	11.4	7.0	1.98	0.15
87.93	29.1	0.60	2.08	369.9	6	114.6	5.19	2.70	2.50	0.61	11.1	6.8	1.91	0.14
88.91	75.5	4.18	5.54	160.3	11	130.5	5.25	2.73	2.53	0.61	72.3	43.8	UnDef	0.00
89.89	44.7	1.78	3.99	274.0	5	114.6	5.31	2.75	2.56	0.60	21.4	12.9	3.15	0.00
90.88	38.0	1.13	2.97	375.5	5	114.6	5.37	2.78	2.59	0.60	18.2	10.9	2.61	0.21
91.86	40.8	1.17	2.88	440.3	6	114.6	5.42	2.81	2.62	0.60	15.6	9.3	2.83	0.24
92.85	35.1	0.83	2.37	453.7	6	114.6	5.48	2.83	2.65	0.59	13.5	8.0	2.37	0.18
93.83	35.9	1.14	3.17	488.8	5	114.6	5.54	2.86	2.68	0.59	17.2	10.2	2.43	0.00
94.82	50.0	2.14	4.27	255.6	5	114.6	5.59	2.88	2.71	0.59	23.9	14.1	3.55	0.00
95.80	39.9	1.04	2.60	365.0	6	114.6	5.65	2.91	2.74	0.59	15.3	9.0	2.74	0.22
96.78	55.2	1.75	3.16	526.5	6	114.6	5.71	2.93	2.77	0.58	21.1	12.3	3.96	0.44
97.77	61.0	2.05	3.36	628.9	5	114.6	5.76	2.96	2.80	0.58	29.2	17.0	4.42	0.00
98.75	62.3	2.41	3.86	513.4	5	114.6	5.82	2.99	2.83	0.58	29.8	17.3	4.52	0.00

Gregg In Situ, Inc.
Interpretation Output - Release 1.00.19e
Run No: 03-0203-1606-1605
Job No: 97-100
Client: CDM
Project: CPT SITE INVESTIGATION
Site: SHERWIN WILLIAMS
Location: CPT-04
Engineer: H. YOUNG
CPT Date: 03/28/01
CPT Time: 08:29
CPT File: 027C04.COR
Northing (m): 0.000
Easting (m): 0.000
Elevation (m): 0.000

Water Table (m): 2.44 (ft): 8.0
Su Nkt used: 12.50
Averaging Increment (m): 0.30
Phi Method : Robertson and Campanella, 1983
Dr Method : Jamiolkowski - All Sands
State Parameter M: 1.20
Used Unit Weights Assigned to Soil Zones
Values of 1.0E9 or UnDef are printed for parameters that are not valid for the material type (SBT)

Depth (ft)	k (cm/s)	Bq	Qtn	Rfn	SBTn	Qc1N	DeltaQc1N	Qc1Ncs	Fc (%)	Phi (Deg)	Dr (%)	OCR	State Param	Del(n1)60	(N1)60c
0.49	1.0E-15	0.00	2.4	0.10	1	0.2	UnDef	UnDef	100.0	UnDef	UnDef	1.0	UnDef	UnDef	UnDe
1.48	1.0E-15	0.00	0.1	0.10	1	0.2	UnDef	UnDef	100.0	UnDef	UnDef	1.0	UnDef	UnDef	UnDe
2.46	1.0E-15	0.00	0.1	0.10	1	0.2	UnDef	UnDef	100.0	UnDef	UnDef	1.0	UnDef	UnDef	UnDe
3.44	1.0E-15	0.00	0.0	0.10	1	0.2	UnDef	UnDef	100.0	UnDef	UnDef	1.0	UnDef	UnDef	UnDe
4.43	1.0E-15	0.00	0.0	0.10	1	0.2	UnDef	UnDef	100.0	UnDef	UnDef	1.0	UnDef	UnDef	UnDe
5.41	5.0E-08	0.09	36.2	4.42	6	21.0	84.1	105.1	38.9	UnDef	UnDef	6.0	UnDef	20.6	41.
6.40	5.0E-08	0.04	35.0	4.46	6	21.9	87.6	109.5	39.6	UnDef	UnDef	6.0	UnDef	21.4	42.
7.30	5.0E-06	0.01	17.7	1.84	6	12.1	48.4	60.5	39.0	UnDef	UnDef	6.0	UnDef	5.9	11.
8.20	5.0E-07	0.10	9.8	2.01	6	7.4	29.5	36.8	52.5	UnDef	UnDef	3.0	UnDef	4.8	9.
9.19	5.0E-08	0.08	9.3	3.29	4	7.2	28.9	36.2	61.6	UnDef	UnDef	3.0	UnDef	7.1	14.
10.17	5.0E-04	0.01	46.7	0.61	9	34.2	11.9	46.2	14.7	38	36.5	1.0	-0.07	2.2	13.
11.15	5.0E-03	-0.01	119.4	0.49	9	88.5	0.0	88.5	5.0	42	63.8	1.0	-0.14	0.0	21.
12.14	5.0E-03	-0.01	145.6	0.49	9	110.5	0.0	110.5	4.3	44	70.1	1.0	-0.16	0.0	27.
13.21	5.0E-03	-0.01	97.5	0.55	9	76.2	5.1	81.4	7.4	42	59.5	1.0	-0.13	0.8	19.
14.27	5.0E-06	0.34	10.6	0.95	6	9.4	37.5	46.9	41.7	UnDef	UnDef	3.0	UnDef	4.6	9.
15.26	5.0E-06	0.20	16.6	1.52	6	14.4	57.7	72.1	37.9	UnDef	UnDef	6.0	UnDef	7.1	14.
16.24	5.0E-03	0.00	99.7	1.08	9	83.1	16.4	99.5	11.2	42	62.0	1.0	-0.19	2.3	22.
17.22	5.0E-04	0.01	71.6	1.19	7	61.2	22.1	83.3	14.9	40	53.2	1.0	-0.17	4.0	23.
18.21	5.0E-03	0.00	99.8	0.70	9	86.4	8.7	95.1	8.4	42	63.1	1.0	-0.15	1.3	22.
19.19	5.0E-04	0.01	40.9	0.75	7	36.8	18.7	55.4	17.6	38	38.6	1.0	-0.08	3.2	15.
20.18	5.0E-07	0.41	6.4	2.34	4	6.9	27.8	34.7	65.7	UnDef	UnDef	3.0	UnDef	4.5	9.
21.16	5.0E-07	0.30	6.6	3.26	1	7.3	UnDef	UnDef	100.0	UnDef	UnDef	3.0	UnDef	UnDef	UnDe
22.15	5.0E-08	0.12	9.8	4.83	1	10.3	UnDef	UnDef	100.0	UnDef	UnDef	3.0	UnDef	UnDef	UnDe
23.13	5.0E-08	0.01	12.5	5.64	1	13.0	UnDef	UnDef	100.0	UnDef	UnDef	6.0	UnDef	UnDef	UnDe
24.11	5.0E-08	0.00	14.1	5.43	1	14.6	UnDef	UnDef	100.0	UnDef	UnDef	6.0	UnDef	UnDef	UnDe
25.10	5.0E-08	0.04	15.9	5.10	1	16.6	UnDef	UnDef	100.0	UnDef	UnDef	6.0	UnDef	UnDef	UnDe
26.08	5.0E-07	0.11	20.9	4.08	4	21.6	86.3	107.9	47.4	UnDef	UnDef	6.0	UnDef	14.1	28.
27.07	5.0E-06	0.10	18.0	3.60	4	19.1	76.3	95.4	48.3	UnDef	UnDef	6.0	UnDef	9.3	18.
28.05	5.0E-06	0.17	15.2	2.85	6	16.6	66.2	82.8	48.1	UnDef	UnDef	6.0	UnDef	8.1	16.
29.04	5.0E-06	0.25	11.5	2.20	6	13.1	52.3	65.4	50.3	UnDef	UnDef	3.0	UnDef	6.4	12.

Depth (ft)	k (cm/s)	Bq	Qtn	Rfn	SBTn	Qc1N	DeltaQc1N	Qc1Ncs	Fc (%)	Phi (Deg)	Dr (%)	OCR	State Param	Del(n1)60	(N1)60c
30.02	5.0E-06	0.36	9.3	1.86	6	11.0	44.2	55.2	52.7	UnDef	UnDef	3.0	UnDef	5.4	10.
31.00	5.0E-05	0.37	11.6	1.68	6	13.6	54.3	67.9	46.3	30	30.0	3.0	0.03	5.3	10.
31.99	5.0E-05	0.31	17.6	2.27	6	19.9	79.5	99.4	41.9	32	30.0	6.0	-0.05	7.8	15.
32.97	5.0E-06	0.23	22.6	2.89	6	25.4	101.5	126.9	40.6	UnDef	UnDef	6.0	UnDef	12.4	24.
33.96	5.0E-06	0.03	32.1	3.62	6	35.7	142.8	178.5	37.9	UnDef	UnDef	6.0	UnDef	17.5	34.
34.94	5.0E-04	-0.01	83.7	1.80	7	91.3	42.8	134.1	17.0	42	64.7	1.0	-0.23	7.4	37.
35.92	5.0E-02	-0.01	107.1	0.96	9	117.8	17.5	135.4	9.9	42	72.0	1.0	-0.19	2.0	25.
36.91	5.0E-05	0.05	33.9	2.36	6	38.9	90.2	129.2	31.2	36	40.2	6.0	-0.16	11.8	27.
37.89	5.0E-05	0.21	13.9	2.26	6	17.3	69.0	86.3	46.6	32	30.0	6.0	-0.03	6.8	13.
38.88	5.0E-06	0.17	20.5	3.05	6	24.9	99.4	124.3	43.2	UnDef	UnDef	6.0	UnDef	12.2	24.
39.86	5.0E-05	0.26	27.0	2.57	6	32.4	129.5	161.9	35.9	36	35.0	6.0	-0.11	12.7	25.
40.85	1.0E-15	0.01	59.8	5.51	6	70.2	278.8	349.0	34.9	40	57.1	1.0	-0.52	68.6	137.
41.83	1.0E-15	0.04	38.0	5.82	1	45.9	UnDef	UnDef	100.0	38	44.9	1.0	-0.46	UnDef	UnDe
42.81	5.0E-07	0.07	22.4	4.86	1	28.2	UnDef	UnDef	100.0	UnDef	UnDef	6.0	UnDef	UnDef	UnDe
43.80	5.0E-06	0.06	14.4	3.34	4	19.0	75.9	94.9	51.8	UnDef	UnDef	6.0	UnDef	9.3	18.
44.78	5.0E-05	0.05	34.6	3.18	6	43.2	167.3	210.5	34.8	38	43.2	6.0	-0.21	16.7	33.
45.77	5.0E-06	0.00	34.0	4.08	6	42.9	171.5	214.4	38.7	UnDef	UnDef	6.0	UnDef	21.0	42.
46.75	5.0E-06	0.00	26.3	4.10	6	33.9	135.6	169.5	43.2	UnDef	UnDef	6.0	UnDef	16.6	33.
47.74	5.0E-06	0.18	13.8	2.94	4	19.0	76.1	95.1	50.6	UnDef	UnDef	6.0	UnDef	9.3	18.
48.72	5.0E-06	0.03	35.8	3.68	6	46.2	185.0	231.2	36.3	UnDef	UnDef	6.0	UnDef	22.6	45.
49.70	5.0E-06	0.14	12.6	3.10	4	17.8	71.3	89.1	53.5	UnDef	UnDef	6.0	UnDef	8.7	17.
50.69	5.0E-05	0.18	12.6	2.74	4	18.0	71.8	89.8	51.6	32	30.0	6.0	-0.04	7.0	14.
51.67	5.0E-05	0.13	31.2	3.16	6	41.6	166.3	207.8	36.3	36	42.1	6.0	-0.18	16.3	32.
52.66	5.0E-04	-0.01	132.2	2.30	7	169.9	63.3	233.3	15.2	44	82.5	1.0	-0.32	11.3	66.
53.64	5.0E-06	0.10	20.4	4.10	4	28.5	113.8	142.3	47.9	UnDef	UnDef	6.0	UnDef	13.9	27.
54.63	5.0E-03	0.00	70.3	1.61	7	92.9	47.8	140.7	17.7	40	65.2	1.0	-0.20	6.1	28.
55.61	5.0E-05	0.03	31.7	2.83	6	43.5	162.5	206.0	34.5	36	43.4	6.0	-0.18	16.6	33.
56.59	1.0E-15	0.01	42.0	4.78	6	57.3	229.4	286.7	37.8	38	51.3	1.0	-0.36	56.1	112.
57.58	5.0E-06	0.13	19.1	3.33	6	27.7	110.9	138.6	45.8	UnDef	UnDef	6.0	UnDef	13.6	27.
58.56	5.0E-05	0.14	20.2	3.01	6	29.3	117.1	146.4	43.3	34	32.1	6.0	-0.11	11.5	22.
59.55	5.0E-05	0.25	16.7	2.95	6	24.9	99.4	124.3	46.6	32	30.0	6.0	-0.07	9.7	19.
60.53	5.0E-05	0.35	16.1	2.26	6	24.2	96.8	121.0	43.5	32	30.0	6.0	-0.03	9.5	19.
61.52	5.0E-05	0.31	18.6	2.16	6	27.7	110.9	138.6	40.2	32	30.5	6.0	-0.05	10.9	21.
62.42	5.0E-05	0.22	18.4	2.37	6	27.6	110.5	138.1	41.6	32	30.4	6.0	-0.07	10.8	21.
63.32	5.0E-05	0.17	18.6	2.72	6	28.2	112.7	140.9	43.3	32	31.0	6.0	-0.09	11.0	22.
64.30	5.0E-05	0.18	15.4	2.90	6	23.9	95.8	119.7	48.0	32	30.0	6.0	-0.07	9.4	18.
65.29	5.0E-05	0.25	14.3	2.61	6	22.6	90.2	112.8	48.0	32	30.0	6.0	-0.04	8.8	17.
66.27	5.0E-05	0.35	12.7	2.43	6	20.4	81.6	102.0	49.5	32	30.0	6.0	-0.01	8.0	16.
67.26	5.0E-05	0.27	13.8	2.19	6	22.2	88.7	110.8	46.1	32	30.0	6.0	-0.02	8.7	17.
68.24	5.0E-05	0.16	15.7	3.11	6	25.0	99.9	124.9	48.7	32	30.0	6.0	-0.08	9.8	19.
69.22	5.0E-06	0.08	24.1	4.09	6	37.0	148.1	185.2	44.7	UnDef	UnDef	6.0	UnDef	18.1	36.
70.21	1.0E-15	0.02	34.1	5.72	1	51.7	UnDef	UnDef	100.0	38	48.4	1.0	-0.43	UnDef	UnDe
71.19	1.0E-15	0.00	52.2	5.71	1	78.3	UnDef	UnDef	100.0	40	60.3	1.0	-0.53	UnDef	UnDe
72.18	1.0E-15	0.06	45.2	5.79	1	68.6	UnDef	UnDef	100.0	38	56.5	1.0	-0.49	UnDef	UnDe
73.16	5.0E-05	0.24	19.4	3.02	6	31.3	125.2	156.5	44.0	34	34.0	6.0	-0.09	12.3	24.
74.15	5.0E-05	0.29	21.2	2.77	6	34.1	136.5	170.7	41.1	34	36.5	6.0	-0.09	13.4	26.
75.13	1.0E-15	0.03	64.2	5.05	6	98.2	275.7	373.9	32.6	40	66.8	1.0	-0.46	82.3	178.
76.11	1.0E-15	0.08	32.6	5.39	1	51.7	UnDef	UnDef	100.0	36	48.4	1.0	-0.36	UnDef	UnDe
77.10	1.0E-15	0.10	25.6	5.10	1	41.5	UnDef	UnDef	100.0	36	42.0	1.0	-0.28	UnDef	UnDe
78.08	5.0E-06	0.10	24.7	4.55	1	40.3	UnDef	UnDef	100.0	UnDef	UnDef	6.0	UnDef	UnDef	UnDe
79.07	1.0E-15	0.03	37.7	6.06	1	60.4	UnDef	UnDef	100.0	38	52.8	1.0	-0.50	UnDef	UnDe
80.05	1.0E-15	0.05	38.2	5.47	1	61.6	UnDef	UnDef	100.0	38	53.4	1.0	-0.41	UnDef	UnDe

Depth (ft)	k (cm/s)	Bq	Qtn	Rfn	SBTn	Qc1N	DeltaQc1N	Qc1Ncs	Fc (%)	Phi (Deg)	Dr (%)	OCR	State Param	Del(n1)60	(N1)60c
81.04	1.0E-15	0.01	43.7	5.61	1	70.6	UnDef	UnDef	100.0	38	57.3	1.0	-0.47	UnDef	UnDe
82.02	5.0E-05	0.10	41.0	3.57	6	66.8	221.9	288.7	33.8	38	55.7	6.0	-0.24	24.2	50.
83.00	1.0E-15	0.01	49.8	5.17	6	81.0	323.9	404.8	36.5	38	61.2	1.0	-0.43	79.2	158.
83.99	1.0E-15	0.02	35.2	5.09	1	58.5	UnDef	UnDef	100.0	38	51.9	1.0	-0.36	UnDef	UnDe
84.97	5.0E-05	0.13	10.9	2.81	4	20.3	81.3	101.6	55.1	30	30.0	3.0	-0.03	8.0	15.
85.96	5.0E-05	0.28	11.8	1.93	6	21.8	87.1	108.9	47.9	30	30.0	3.0	0.00	8.5	17.
86.94	5.0E-05	0.31	9.3	1.94	6	17.9	71.6	89.5	53.4	30	30.0	3.0	0.03	7.0	14.
87.93	5.0E-05	0.38	8.9	2.53	4	17.3	69.4	86.7	58.4	30	30.0	3.0	0.04	6.8	13.
88.91	1.0E-15	0.04	25.8	5.95	1	44.7	UnDef	UnDef	100.0	36	44.2	1.0	-0.39	UnDef	UnDe
89.89	5.0E-06	0.15	14.3	4.53	1	26.4	UnDef	UnDef	100.0	UnDef	UnDef	6.0	UnDef	UnDef	UnDe
90.88	5.0E-06	0.28	11.7	3.46	4	22.3	89.2	111.5	56.9	UnDef	UnDef	3.0	UnDef	10.9	21.
91.86	5.0E-05	0.31	12.6	3.32	4	23.8	95.2	119.0	54.6	32	30.0	6.0	-0.03	9.3	18.
92.85	5.0E-05	0.39	10.5	2.81	4	20.4	81.7	102.2	56.1	30	30.0	3.0	0.01	8.0	16.
93.83	5.0E-06	0.41	10.6	3.75	1	20.8	UnDef	UnDef	100.0	UnDef	UnDef	3.0	UnDef	UnDef	UnDe
94.82	5.0E-06	0.12	15.4	4.81	1	28.8	UnDef	UnDef	100.0	UnDef	UnDef	6.0	UnDef	UnDef	UnDe
95.80	5.0E-05	0.25	11.8	3.03	4	22.9	91.5	114.4	54.6	30	30.0	3.0	-0.03	9.0	17.
96.78	5.0E-05	0.28	16.9	3.53	4	31.5	126.2	157.7	49.3	32	34.2	6.0	-0.09	12.3	24.
97.77	5.0E-06	0.30	18.7	3.71	4	34.7	138.8	173.6	48.0	UnDef	UnDef	6.0	UnDef	17.0	34.
98.75	5.0E-06	0.23	18.9	4.26	1	35.3	UnDef	UnDef	100.0	UnDef	UnDef	6.0	UnDef	UnDef	UnDe

Interpretation Output - Release 1.00.19e

Job No: 03-0203-1606-1545
Job No: 97-100
Client: CDM
Project: CPT SITE INVESTIGATION
Site: SHERWIN WILLIAMS
Location: CPT-02
Engineer: H. YOUNG
CPT Date: 03/29/01
CPT Time: 09:33
CPT File: 027C02.COR
Northing (m): 0.000
Easting (m): 0.000
Elevation (m): 0.000

Water Table (m): 4.57 (ft): 15.0
Su Nkt used: 12.50
Averaging Increment (m): 0.30
Phi Method : Robertson and Campanella, 1983
Dr Method : Jamiolkowski - All Sands
State Parameter M: 1.20
Used Unit Weights Assigned to Soil Zones
Values of 1.0E9 or UnDef are printed for parameters that are not valid for the material type (SBT)

Depth (ft)	AvgQt (tsf)	AvgFs (tsf)	AvgRf (%)	AvgUd (ft)	SBT	U.Wt. pcf	TStress (tsf)	EStress (tsf)	Ueq (tsf)	Cn	N60 (blows/ft)	(N1)60 (blows/ft)	Su (tsf)	CRR
0.49	0.0	0.00	0.00	0.0	UnDef	124.1	0.03	0.03	0.00	2.00	UnDef	UnDef	UnDef	0.00
1.48	0.0	0.00	0.00	0.0	UnDef	124.1	0.09	0.09	0.00	2.00	UnDef	UnDef	UnDef	0.00
2.46	0.0	0.00	0.00	0.0	UnDef	124.1	0.15	0.15	0.00	2.00	UnDef	UnDef	UnDef	0.00
3.44	0.0	0.00	0.00	0.0	UnDef	124.1	0.21	0.21	0.00	2.00	UnDef	UnDef	UnDef	0.00
4.43	0.0	0.00	0.00	0.0	UnDef	124.1	0.27	0.27	0.00	1.91	UnDef	UnDef	UnDef	0.00
5.41	29.8	1.31	4.40	7.8	4	114.6	0.33	0.33	0.00	1.73	19.1	33.0	2.36	0.00
6.40	18.1	0.86	4.75	-5.6	3	111.4	0.39	0.39	0.00	1.60	17.4	27.8	1.42	0.35
7.30	16.5	0.76	4.58	0.6	3	111.4	0.44	0.44	0.00	1.51	15.8	23.9	1.29	0.25
8.20	17.7	0.87	4.91	-0.1	3	111.4	0.49	0.49	0.00	1.43	16.9	24.2	1.37	0.00
9.19	18.2	0.82	4.49	-3.8	3	111.4	0.54	0.54	0.00	1.36	17.5	23.7	1.42	0.24
10.17	8.9	0.25	2.76	-1.2	4	114.6	0.60	0.60	0.00	1.29	5.7	7.3	0.66	0.10
11.15	8.5	0.17	1.98	5.2	5	114.6	0.66	0.66	0.00	1.23	4.1	5.0	0.63	0.09
12.14	8.8	0.15	1.69	7.2	5	114.6	0.71	0.71	0.00	1.18	4.2	5.0	0.65	0.09
13.21	8.4	0.15	1.74	9.1	5	114.6	0.77	0.77	0.00	1.14	4.0	4.6	0.61	0.09
14.27	8.5	0.29	3.41	6.0	3	111.4	0.83	0.83	0.00	1.09	8.2	8.9	0.62	0.00
15.26	43.0	0.25	0.59	4.4	7	117.8	0.89	0.88	0.01	1.06	13.7	14.6	UnDef	0.10
16.24	65.3	0.44	0.67	5.9	8	120.9	0.95	0.91	0.04	1.05	15.6	16.4	UnDef	0.13
17.22	9.0	0.21	2.33	36.8	5	114.6	1.01	0.94	0.07	1.03	4.3	4.5	0.64	0.09
18.21	27.7	0.31	1.11	42.7	6	114.6	1.06	0.96	0.10	1.02	10.6	10.8	2.13	0.10
19.19	26.4	0.45	1.72	27.4	6	114.6	1.12	0.99	0.13	1.01	10.1	10.2	2.02	0.16
20.18	33.4	0.22	0.65	56.4	7	117.8	1.18	1.02	0.16	0.99	10.7	10.6	UnDef	0.09
21.16	48.4	0.64	1.32	3.9	7	117.8	1.24	1.04	0.19	0.98	15.4	15.1	UnDef	0.13
22.15	14.1	0.39	2.78	28.4	5	114.6	1.29	1.07	0.22	0.97	6.8	6.5	1.03	0.11
23.13	9.6	0.15	1.54	60.6	5	114.6	1.35	1.10	0.25	0.96	4.6	4.4	0.66	0.09
24.11	7.1	0.16	2.27	52.1	4	114.6	1.41	1.12	0.28	0.94	4.5	4.3	0.46	0.08
25.10	7.7	0.26	3.39	53.8	3	111.4	1.46	1.15	0.32	0.93	7.4	6.9	0.50	0.00
26.08	9.1	0.36	3.89	60.0	3	111.4	1.52	1.17	0.35	0.92	8.8	8.1	0.61	0.00
27.07	11.3	0.51	4.46	58.0	3	111.4	1.57	1.19	0.38	0.92	10.9	9.9	0.78	0.00
28.05	14.0	0.61	4.34	62.0	3	111.4	1.63	1.22	0.41	0.91	13.4	12.2	0.99	0.00
29.04	22.2	0.82	3.71	82.1	4	114.6	1.68	1.24	0.44	0.90	14.2	12.7	1.64	0.00

Depth (ft)	AvgQt (tsf)	AvgFs (tsf)	AvgRf (%)	AvgUd (ft)	SBT	U.Wt. pcf	TStress (tsf)	EStress (tsf)	Ueq (tsf)	Cn	N60 (blows/ft)	(N1)60 (blows/ft)	Su (tsf)	CRR
30.02	12.7	0.58	4.56	32.6	3	111.4	1.74	1.27	0.47	0.89	12.1	10.8	0.87	0.00
31.00	7.9	0.13	1.65	77.2	5	114.6	1.79	1.29	0.50	0.88	3.8	3.3	0.49	0.08
31.99	19.3	0.40	2.07	66.4	6	114.6	1.85	1.32	0.53	0.87	7.4	6.4	1.39	0.13
32.97	85.2	0.66	0.78	2.6	8	120.9	1.91	1.35	0.56	0.86	20.4	17.6	UnDef	0.15
33.96	63.9	1.39	2.17	-11.0	7	117.8	1.97	1.37	0.59	0.85	20.4	17.4	UnDef	0.26
34.94	102.1	2.15	2.10	-13.6	7	117.8	2.02	1.40	0.62	0.85	32.6	27.5	UnDef	0.35
35.92	167.5	1.75	1.04	-13.7	9	124.1	2.08	1.43	0.65	0.84	32.1	26.8	UnDef	0.44
36.91	182.3	1.28	0.70	-13.1	9	124.1	2.14	1.46	0.68	0.83	34.9	28.9	UnDef	0.43
37.89	73.5	1.23	1.67	8.9	7	117.8	2.20	1.49	0.71	0.82	23.5	19.2	UnDef	0.21
38.88	18.3	0.56	3.09	128.4	5	114.6	2.26	1.51	0.75	0.81	8.8	7.1	1.28	0.00
39.86	15.6	0.52	3.36	119.9	4	114.6	2.32	1.54	0.78	0.81	9.9	8.0	1.06	0.00
40.85	16.9	0.53	3.14	143.1	5	114.6	2.37	1.57	0.81	0.80	8.1	6.5	1.16	0.00
41.83	22.4	0.54	2.43	204.0	6	114.6	2.43	1.59	0.84	0.79	8.6	6.8	1.60	0.14
42.81	17.0	0.26	1.55	202.4	6	114.6	2.49	1.62	0.87	0.79	6.5	5.1	1.16	0.11
43.80	30.9	0.94	3.02	216.5	5	114.6	2.54	1.64	0.90	0.78	14.8	11.6	2.27	0.23
44.78	30.5	1.57	5.17	88.8	3	111.4	2.60	1.67	0.93	0.77	29.2	22.6	2.23	0.00
45.77	24.2	1.01	4.15	128.3	4	114.6	2.65	1.69	0.96	0.77	15.5	11.9	1.73	0.00
46.75	24.0	0.63	2.62	162.9	5	114.6	2.71	1.72	0.99	0.76	11.5	8.8	1.70	0.15
47.74	23.2	0.57	2.47	201.4	6	114.6	2.77	1.74	1.02	0.76	8.9	6.7	1.64	0.14
48.72	68.5	2.81	4.11	130.8	5	114.6	2.82	1.77	1.05	0.75	32.8	24.7	5.26	0.00
49.70	59.5	3.02	5.08	74.9	11	130.5	2.88	1.80	1.08	0.75	57.0	42.5	UnDef	0.00
50.69	25.8	0.63	2.45	205.8	6	114.6	2.94	1.83	1.11	0.74	9.9	7.3	1.83	0.16
51.67	77.4	1.96	2.53	120.3	6	114.6	3.00	1.85	1.15	0.73	29.6	21.8	5.95	0.00
52.66	108.2	3.84	3.55	32.8	6	114.6	3.06	1.88	1.18	0.73	41.4	30.2	8.41	0.00
53.64	37.2	0.98	2.62	239.5	6	114.6	3.11	1.91	1.21	0.72	14.3	10.3	2.73	0.29
54.63	128.1	4.83	3.77	135.9	6	114.6	3.17	1.93	1.24	0.72	49.1	35.3	10.00	0.00
55.61	223.8	5.32	2.38	20.0	7	117.8	3.23	1.96	1.27	0.71	71.4	51.1	UnDef	0.00
56.59	184.8	3.29	1.78	-0.2	8	120.9	3.28	1.99	1.30	0.71	44.2	31.4	UnDef	0.00
57.58	32.8	0.74	2.24	101.6	6	114.6	3.34	2.01	1.33	0.70	12.6	8.9	2.36	0.21
58.56	34.5	0.67	1.95	180.3	6	114.6	3.40	2.04	1.36	0.70	13.2	9.3	2.49	0.23
59.55	28.8	0.68	2.37	178.9	6	114.6	3.46	2.06	1.39	0.70	11.0	7.7	2.03	0.17
60.53	26.3	0.57	2.19	183.2	6	114.6	3.51	2.09	1.42	0.69	10.1	7.0	1.82	0.15
61.52	26.4	0.57	2.14	334.1	6	114.6	3.57	2.12	1.45	0.69	10.1	7.0	1.83	0.15
62.42	34.5	0.68	1.98	386.7	6	114.6	3.62	2.14	1.48	0.68	13.2	9.0	2.47	0.22
63.32	35.6	1.09	3.07	251.8	5	114.6	3.67	2.16	1.51	0.68	17.1	11.6	2.56	0.23
64.30	29.1	0.98	3.37	202.2	5	114.6	3.73	2.19	1.54	0.68	14.0	9.4	2.03	0.00
65.29	30.3	0.87	2.86	230.7	5	114.6	3.78	2.21	1.57	0.67	14.5	9.8	2.12	0.17
66.27	31.1	0.83	2.68	326.9	6	114.6	3.84	2.24	1.60	0.67	11.9	8.0	2.18	0.18
67.26	87.1	4.28	4.91	179.7	11	130.5	3.90	2.27	1.63	0.66	83.4	55.4	UnDef	0.00
68.24	52.4	2.21	4.21	147.0	5	114.6	3.96	2.30	1.66	0.66	25.1	16.5	3.87	0.00
69.22	31.6	0.78	2.47	253.3	6	114.6	4.02	2.32	1.69	0.66	12.1	7.9	2.20	0.18
70.21	39.3	1.32	3.37	279.9	5	114.6	4.07	2.35	1.72	0.65	18.8	12.3	2.82	0.26
71.19	71.3	4.12	5.78	68.0	11	130.5	4.13	2.38	1.75	0.65	68.3	44.2	UnDef	0.00
72.18	60.4	3.01	4.98	210.1	11	130.5	4.20	2.41	1.79	0.64	57.8	37.2	UnDef	0.00
73.16	38.1	1.23	3.24	257.1	5	114.6	4.26	2.44	1.82	0.64	18.2	11.7	2.71	0.24
74.15	44.6	1.32	2.96	233.3	6	114.6	4.32	2.47	1.85	0.64	17.1	10.9	3.22	0.33
75.13	48.8	1.33	2.73	401.4	6	114.6	4.37	2.49	1.88	0.63	18.7	11.8	3.55	0.40
76.11	54.9	2.25	4.09	296.4	5	114.6	4.43	2.52	1.91	0.63	26.3	16.6	4.04	0.00
77.10	59.8	2.82	4.71	238.3	4	114.6	4.48	2.55	1.94	0.63	38.2	23.9	4.43	0.00
78.08	69.0	3.83	5.56	173.2	11	130.5	4.54	2.58	1.97	0.62	66.1	41.2	UnDef	0.00
79.07	82.1	4.52	5.50	161.3	11	130.5	4.61	2.61	2.00	0.62	78.6	48.7	UnDef	0.00
80.05	128.3	7.97	6.21	86.6	11	130.5	4.67	2.64	2.03	0.62	122.9	75.6	UnDef	0.00

Depth (ft)	AvgQt (tsf)	AvgFs (tsf)	AvgRf (%)	AvgUd (ft)	SBT	U.Wt. pcf	TStress (tsf)	EStress (tsf)	Ueq (tsf)	Cn	N60 (blows/ft)	(N1)60 (blows/ft)	Su (tsf)	CRR
81.04	160.3	8.67	5.41	96.4	11	130.5	4.74	2.68	2.06	0.61	153.5	93.8	UnDef	0.00
82.02	106.7	6.70	6.28	70.2	11	130.5	4.80	2.71	2.09	0.61	102.2	62.1	UnDef	0.00
83.00	32.9	1.19	3.63	236.3	5	114.6	4.86	2.74	2.12	0.60	15.7	9.5	2.24	0.00
83.99	55.3	2.15	3.89	245.0	5	114.6	4.92	2.76	2.15	0.60	26.5	15.9	4.03	0.00
84.97	126.5	7.91	6.25	115.2	11	130.5	4.98	2.79	2.18	0.60	121.2	72.5	UnDef	0.00
85.96	153.9	8.46	5.50	124.4	11	130.5	5.04	2.83	2.22	0.59	147.4	87.6	UnDef	0.00
86.94	224.3	9.11	4.06	52.4	12	120.9	5.10	2.86	2.25	0.59	107.4	63.5	UnDef	0.00
87.93	101.6	5.09	5.01	38.5	11	130.5	5.17	2.89	2.28	0.59	97.3	57.2	UnDef	0.00
88.91	35.3	0.79	2.24	154.0	6	114.6	5.23	2.92	2.31	0.59	13.5	7.9	2.40	0.18
89.89	73.4	3.45	4.70	197.0	11	130.5	5.29	2.95	2.34	0.58	70.3	40.9	UnDef	0.00
90.88	85.3	5.44	6.38	114.3	11	130.5	5.35	2.98	2.37	0.58	81.7	47.3	UnDef	0.00
91.86	91.6	5.93	6.47	136.8	11	130.5	5.42	3.02	2.40	0.58	87.7	50.5	UnDef	0.00
92.85	114.3	7.01	6.14	89.5	11	130.5	5.48	3.05	2.43	0.57	109.4	62.7	UnDef	0.00
93.83	82.1	3.78	4.60	155.8	11	130.5	5.54	3.08	2.46	0.57	78.7	44.8	UnDef	0.00
94.82	74.3	3.69	4.97	174.0	11	130.5	5.61	3.12	2.49	0.57	71.2	40.3	UnDef	0.00
95.80	91.4	4.56	4.99	160.1	11	130.5	5.67	3.15	2.52	0.56	87.5	49.3	UnDef	0.00
96.78	108.7	6.24	5.74	138.4	11	130.5	5.74	3.18	2.55	0.56	104.1	58.3	UnDef	0.00
97.77	102.1	5.26	5.15	184.6	11	130.5	5.80	3.22	2.58	0.56	97.8	54.5	UnDef	0.00
98.75	152.2	6.60	4.34	89.0	11	130.5	5.87	3.25	2.61	0.55	145.8	80.9	UnDef	0.00

Gregg In Situ, Inc.
Interpretation Output - Release 1.00.19e
Run No: 03-0203-1606-1545
Job No: 97-100
Client: CDM
Project: CPT SITE INVESTIGATION
Site: SHERWIN WILLIAMS
Location: CPT-02
Engineer: H. YOUNG
CPT Date: 03/29/01
CPT Time: 09:33
CPT File: 027C02.COR
Northing (m): 0.000
Easting (m): 0.000
Elevation (m): 0.000

Water Table (m): 4.57 (ft): 15.0
Su Nkt used: 12.50
Averaging Increment (m): 0.30
Phi Method : Robertson and Campanella, 1983
Dr Method : Jamiolkowski - All Sands
State Parameter M: 1.20
Used Unit Weights Assigned to Soil Zones
Values of 1.0E9 or UnDef are printed for parameters that are not valid for the material type (SBT)

Depth (ft)	k (cm/s)	Bq	Qtn	Rfn	SBTn	Qc1N	DeltaQc1N	Qc1Ncs	Fc (%)	Phi (Deg)	Dr (%)	OCR	State Param	Del(n1)60	(N1)60c
0.49	1.0E-15	0.00	2.4	0.10	1	0.2	UnDef	UnDef	100.0	UnDef	UnDef	1.0	UnDef	UnDef	UnDe
1.48	1.0E-15	0.00	0.1	0.10	1	0.2	UnDef	UnDef	100.0	UnDef	UnDef	1.0	UnDef	UnDef	UnDe
2.46	1.0E-15	0.00	0.1	0.10	1	0.2	UnDef	UnDef	100.0	UnDef	UnDef	1.0	UnDef	UnDef	UnDe
3.44	1.0E-15	0.00	0.0	0.10	1	0.2	UnDef	UnDef	100.0	UnDef	UnDef	1.0	UnDef	UnDef	UnDe
4.43	1.0E-15	0.00	0.0	0.10	1	0.2	UnDef	UnDef	100.0	UnDef	UnDef	1.0	UnDef	UnDef	UnDe
5.41	5.0E-07	0.01	88.5	4.45	11	50.6	UnDef	UnDef	0.0	UnDef	UnDef	10.0	UnDef	UnDef	UnDe
6.40	5.0E-08	-0.01	45.6	4.85	6	28.4	113.7	142.2	36.8	UnDef	UnDef	6.0	UnDef	27.8	55.
7.30	5.0E-08	0.00	36.6	4.70	6	24.4	97.5	121.9	39.7	UnDef	UnDef	6.0	UnDef	23.9	47.
8.20	5.0E-08	0.00	35.1	5.05	1	24.7	UnDef	UnDef	100.0	UnDef	UnDef	6.0	UnDef	UnDef	UnDe
9.19	5.0E-08	-0.01	32.5	4.63	6	24.2	96.8	121.0	41.4	UnDef	UnDef	6.0	UnDef	23.7	47.
10.17	5.0E-07	0.00	13.8	2.96	4	11.3	45.0	56.3	50.6	UnDef	UnDef	6.0	UnDef	7.3	14.
11.15	5.0E-06	0.02	12.0	2.14	6	10.3	41.2	51.5	48.9	UnDef	UnDef	3.0	UnDef	5.0	10.
12.14	5.0E-06	0.03	11.4	1.83	6	10.2	40.9	51.1	48.0	UnDef	UnDef	3.0	UnDef	5.0	10.
13.21	5.0E-06	0.04	9.8	1.92	6	9.3	37.3	46.7	51.8	UnDef	UnDef	3.0	UnDef	4.6	9.
14.27	5.0E-08	0.02	9.2	3.78	1	9.1	UnDef	UnDef	100.0	UnDef	UnDef	3.0	UnDef	UnDef	UnDe
15.26	5.0E-04	0.00	47.8	0.60	9	44.8	14.9	59.7	14.3	38	44.3	1.0	-0.08	2.7	17.
16.24	5.0E-03	0.00	70.7	0.68	9	67.0	13.2	80.2	11.2	40	55.8	1.0	-0.12	1.9	18.
17.22	5.0E-06	0.13	8.6	2.62	4	9.1	36.5	45.6	59.9	UnDef	UnDef	3.0	UnDef	4.5	8.
18.21	5.0E-05	0.05	27.6	1.15	7	27.6	36.8	64.4	26.4	36	30.4	6.0	-0.07	6.0	16.
19.19	5.0E-05	0.03	25.5	1.79	7	26.0	69.5	95.5	32.3	34	30.0	6.0	-0.10	8.5	18.
20.18	5.0E-04	0.05	31.7	0.68	7	32.5	21.9	54.3	20.1	36	35.0	1.0	-0.04	3.6	14.
21.16	5.0E-04	0.00	45.2	1.35	7	46.3	35.2	81.6	21.2	38	45.2	1.0	-0.14	5.6	20.
22.15	5.0E-06	0.05	12.0	3.06	4	13.4	53.5	66.9	54.3	UnDef	UnDef	3.0	UnDef	6.5	13.
23.13	5.0E-06	0.20	7.6	1.79	4	9.0	36.1	45.1	57.2	UnDef	UnDef	3.0	UnDef	4.4	8.
24.11	5.0E-07	0.23	5.1	2.83	4	6.6	26.3	32.9	75.3	UnDef	UnDef	1.5	UnDef	4.3	8.
25.10	5.0E-08	0.22	5.5	4.18	1	7.1	UnDef	UnDef	100.0	UnDef	UnDef	1.5	UnDef	UnDef	UnDe
26.08	5.0E-08	0.20	6.5	4.67	1	8.3	UnDef	UnDef	100.0	UnDef	UnDef	3.0	UnDef	UnDef	UnDe
27.07	5.0E-08	0.15	8.2	5.18	1	10.2	UnDef	UnDef	100.0	UnDef	UnDef	3.0	UnDef	UnDef	UnDe
28.05	5.0E-08	0.12	10.2	4.90	1	12.4	UnDef	UnDef	100.0	UnDef	UnDef	3.0	UnDef	UnDef	UnDe
29.04	5.0E-07	0.10	16.5	4.01	1	19.5	UnDef	UnDef	100.0	UnDef	UnDef	6.0	UnDef	UnDef	UnDe

Depth (ft)	k (cm/s)	Bq	Qtn	Rfn	SBTn	Qc1N	DeltaQc1N	Qc1Ncs	Fc (%)	Phi (Deg)	Dr (%)	OCR	State Param	Del(n1)60	(N1)60c
30.02	5.0E-08	0.05	8.6	5.28	1	11.0	UnDef	UnDef	100.0	UnDef	UnDef	3.0	UnDef	UnDef	UnDe
31.00	5.0E-06	0.31	4.7	2.13	4	6.8	27.2	34.0	72.7	UnDef	UnDef	1.5	UnDef	3.3	6.
31.99	5.0E-05	0.09	13.2	2.29	6	16.4	65.6	82.0	47.8	32	30.0	6.0	-0.05	6.4	12.
32.97	5.0E-03	-0.01	61.9	0.80	9	71.9	21.0	92.9	13.5	40	57.8	1.0	-0.12	2.9	20.
33.96	5.0E-04	-0.02	45.1	2.24	7	53.4	71.4	124.8	26.4	38	49.3	1.0	-0.19	9.7	27.
34.94	5.0E-04	-0.01	71.4	2.14	7	84.4	58.7	143.1	20.4	40	62.4	1.0	-0.24	9.5	37.
35.92	5.0E-02	-0.01	115.8	1.06	9	137.1	20.5	157.6	9.9	42	76.3	1.0	-0.21	2.4	29.
36.91	5.0E-02	-0.01	123.4	0.71	9	147.7	8.4	156.0	7.0	42	78.4	1.0	-0.18	1.0	29.
37.89	5.0E-04	-0.01	47.9	1.72	7	59.0	53.2	112.2	22.8	38	52.1	1.0	-0.17	8.1	27.
38.88	5.0E-06	0.20	10.6	3.52	1	14.5	UnDef	UnDef	100.0	UnDef	UnDef	3.0	UnDef	UnDef	UnDe
39.86	5.0E-07	0.22	8.6	3.94	1	12.3	UnDef	UnDef	100.0	UnDef	UnDef	3.0	UnDef	UnDef	UnDe
40.85	5.0E-06	0.25	9.3	3.65	1	13.2	UnDef	UnDef	100.0	UnDef	UnDef	3.0	UnDef	UnDef	UnDe
41.83	5.0E-05	0.28	12.6	2.72	4	17.4	69.6	87.0	51.5	30	30.0	6.0	-0.03	6.8	13.
42.81	5.0E-05	0.38	8.9	1.81	6	13.1	52.2	65.3	53.3	30	30.0	3.0	0.05	5.1	10.
43.80	5.0E-06	0.21	17.3	3.30	6	23.6	94.5	118.1	47.7	UnDef	UnDef	6.0	UnDef	11.6	23.
44.78	5.0E-08	0.07	16.7	5.65	1	23.1	UnDef	UnDef	100.0	UnDef	UnDef	6.0	UnDef	UnDef	UnDe
45.77	5.0E-07	0.14	12.7	4.66	1	18.2	UnDef	UnDef	100.0	UnDef	UnDef	6.0	UnDef	UnDef	UnDe
46.75	5.0E-06	0.19	12.4	2.95	4	17.9	71.7	89.6	53.0	UnDef	UnDef	3.0	UnDef	8.8	17.
47.74	5.0E-05	0.26	11.7	2.81	4	17.2	68.9	86.1	53.5	30	30.0	3.0	-0.02	6.7	13.
48.72	5.0E-06	0.05	37.1	4.28	6	50.4	201.6	252.0	38.0	UnDef	UnDef	6.0	UnDef	24.7	49.
49.70	1.0E-15	0.02	31.5	5.34	1	43.4	UnDef	UnDef	100.0	36	43.3	1.0	-0.36	UnDef	UnDe
50.69	5.0E-05	0.23	12.5	2.76	4	18.7	74.7	93.4	51.8	30	30.0	6.0	-0.03	7.3	14.
51.67	5.0E-05	0.04	40.1	2.63	6	55.6	112.0	167.6	30.0	38	50.4	6.0	-0.20	15.6	37.
52.66	5.0E-05	0.00	55.9	3.65	6	77.2	150.5	227.7	29.8	40	59.9	10.0	-0.31	21.3	51.
53.64	5.0E-05	0.18	17.9	2.86	6	26.4	105.6	132.0	44.8	32	30.0	6.0	-0.09	10.3	20.
54.63	5.0E-05	0.02	64.7	3.87	6	90.2	154.5	244.7	28.6	40	64.3	10.0	-0.34	23.0	58.
55.61	5.0E-04	0.00	112.6	2.41	7	156.5	74.1	230.6	17.0	42	80.1	1.0	-0.31	12.8	63.
56.59	5.0E-03	-0.01	91.4	1.81	7	128.3	54.7	182.9	16.2	42	74.4	1.0	-0.24	7.2	38.
57.58	5.0E-05	0.06	14.6	2.50	6	22.6	90.5	113.1	46.9	32	30.0	6.0	-0.07	8.9	17.
58.56	5.0E-05	0.14	15.3	2.16	6	23.7	94.6	118.3	44.0	32	30.0	6.0	-0.05	9.3	18.
59.55	5.0E-05	0.17	12.3	2.69	4	19.6	78.5	98.1	51.8	30	30.0	3.0	-0.04	7.7	15.
60.53	5.0E-05	0.19	10.9	2.53	4	17.8	71.1	88.8	53.6	30	30.0	3.0	-0.02	7.0	13.
61.52	5.0E-05	0.39	10.8	2.48	4	17.8	71.1	88.9	53.4	30	30.0	3.0	0.02	7.0	13.
62.42	5.0E-05	0.34	14.4	2.21	6	23.1	92.4	115.5	45.4	32	30.0	6.0	-0.02	9.0	18.
63.32	5.0E-06	0.20	14.8	3.42	4	23.7	94.8	118.5	51.6	UnDef	UnDef	6.0	UnDef	11.6	23.
64.30	5.0E-06	0.19	11.6	3.87	1	19.3	UnDef	UnDef	100.0	UnDef	UnDef	3.0	UnDef	UnDef	UnDe
65.29	5.0E-06	0.21	12.0	3.26	4	19.9	79.7	99.7	55.4	UnDef	UnDef	3.0	UnDef	9.8	19.
66.27	5.0E-05	0.32	12.2	3.06	4	20.3	81.4	101.7	54.0	30	30.0	3.0	-0.02	8.0	15.
67.26	1.0E-15	0.05	36.7	5.14	1	56.6	UnDef	UnDef	100.0	38	51.0	1.0	-0.36	UnDef	UnDe
68.24	5.0E-06	0.06	21.1	4.55	1	33.8	UnDef	UnDef	100.0	UnDef	UnDef	6.0	UnDef	UnDef	UnDe
69.22	5.0E-05	0.23	11.8	2.83	4	20.2	81.0	101.2	53.4	30	30.0	3.0	-0.03	7.9	15.
70.21	5.0E-06	0.20	15.0	3.75	4	25.1	100.4	125.5	52.8	UnDef	UnDef	6.0	UnDef	12.3	24.
71.19	1.0E-15	0.01	28.2	6.13	1	45.2	UnDef	UnDef	100.0	36	44.5	1.0	-0.45	UnDef	UnDe
72.18	1.0E-15	0.09	23.3	5.36	1	38.0	UnDef	UnDef	100.0	34	39.6	1.0	-0.28	UnDef	UnDe
73.16	5.0E-06	0.18	13.8	3.65	4	23.8	95.4	119.2	54.0	UnDef	UnDef	6.0	UnDef	11.7	23.
74.15	5.0E-05	0.13	16.3	3.28	6	27.8	111.1	138.9	48.8	32	30.6	6.0	-0.10	10.9	21.
75.13	5.0E-05	0.24	17.8	3.00	6	30.2	121.0	151.2	45.6	32	33.0	6.0	-0.08	11.8	23.
76.11	5.0E-06	0.15	20.0	4.45	1	33.9	UnDef	UnDef	100.0	UnDef	UnDef	6.0	UnDef	UnDef	UnDe
77.10	5.0E-07	0.10	21.7	5.09	1	36.7	UnDef	UnDef	100.0	UnDef	UnDef	6.0	UnDef	UnDef	UnDe
78.08	1.0E-15	0.05	25.0	5.95	1	42.1	UnDef	UnDef	100.0	34	42.5	1.0	-0.37	UnDef	UnDe
79.07	1.0E-15	0.04	29.7	5.83	1	49.7	UnDef	UnDef	100.0	36	47.3	1.0	-0.40	UnDef	UnDe
80.05	1.0E-15	0.01	46.8	6.45	1	77.2	UnDef	UnDef	100.0	38	59.9	1.0	-0.66	UnDef	UnDe

epth (ft)	k (cm/s)	Bq	Qtn	Rfn	SBTn	Qc1N	DeltaQc1N	Qc1Ncs	Fc (%)	Phi (Deg)	Dr (%)	OCR	State Param	Del(n1)60	(N1)60c
81.04	1.0E-15	0.01	58.1	5.58	6	95.9	383.5	479.4	35.5	40	66.1	1.0	-0.53	93.8	187.
82.02	1.0E-15	0.00	37.6	6.58	1	63.5	UnDef	UnDef	100.0	38	54.2	1.0	-0.63	UnDef	UnDe
83.00	5.0E-06	0.19	10.2	4.26	1	19.4	UnDef	UnDef	100.0	UnDef	UnDef	3.0	UnDef	UnDef	UnDe
83.99	5.0E-06	0.11	18.2	4.27	1	32.5	UnDef	UnDef	100.0	UnDef	UnDef	6.0	UnDef	UnDef	UnDe
84.97	1.0E-15	0.01	43.5	6.51	1	74.1	UnDef	UnDef	100.0	38	58.7	1.0	-0.65	UnDef	UnDe
85.96	1.0E-15	0.01	52.6	5.69	1	89.6	UnDef	UnDef	100.0	40	64.1	1.0	-0.52	UnDef	UnDe
86.94	1.0E-15	0.00	76.7	4.16	6	129.8	196.6	326.4	27.6	40	74.8	1.0	-0.40	38.4	101.
87.93	1.0E-15	-0.01	33.4	5.28	1	58.5	UnDef	UnDef	100.0	36	51.9	1.0	-0.37	UnDef	UnDe
88.91	5.0E-05	0.08	10.3	2.62	4	20.2	80.8	101.0	55.4	30	30.0	3.0	-0.03	7.9	15.
89.89	1.0E-15	0.06	23.1	5.06	1	41.8	UnDef	UnDef	100.0	34	42.3	1.0	-0.26	UnDef	UnDe
90.88	1.0E-15	0.02	26.8	6.80	1	48.4	UnDef	UnDef	100.0	36	46.4	1.0	-0.58	UnDef	UnDe
91.86	1.0E-15	0.02	28.6	6.88	1	51.6	UnDef	UnDef	100.0	36	48.3	1.0	-0.62	UnDef	UnDe
92.85	1.0E-15	0.00	35.7	6.45	1	64.0	UnDef	UnDef	100.0	38	54.5	1.0	-0.58	UnDef	UnDe
93.83	1.0E-15	0.03	24.8	4.93	1	45.8	UnDef	UnDef	100.0	34	44.9	1.0	-0.27	UnDef	UnDe
94.82	1.0E-15	0.04	22.1	5.37	1	41.2	UnDef	UnDef	100.0	34	41.9	1.0	-0.28	UnDef	UnDe
95.80	1.0E-15	0.03	27.2	5.32	1	50.4	UnDef	UnDef	100.0	36	47.6	1.0	-0.32	UnDef	UnDe
96.78	1.0E-15	0.02	32.3	6.06	1	59.6	UnDef	UnDef	100.0	36	52.4	1.0	-0.47	UnDef	UnDe
97.77	1.0E-15	0.03	30.0	5.46	1	55.7	UnDef	UnDef	100.0	36	50.5	1.0	-0.36	UnDef	UnDe
98.75	1.0E-15	0.00	45.0	4.51	6	82.6	330.5	413.1	35.9	38	61.8	1.0	-0.35	80.9	161.

Gregg In Situ, Inc.
Interpretation Output - Release 1.00.19e
Run No: 03-0203-1606-1479
Job No: 97-100
Client: CDM
Project: CPT SITE INVESTIGATION
Site: SHERWIN WILLIAMS
Location: CPT-01
Engineer: H. YOUNG
CPT Date: 03/29/01
CPT Time: 11:54
CPT File: 027C01.COR
Northing (m): 0.000
Easting (m): 0.000
Elevation (m): 0.000

Water Table (m): 4.57 (ft): 15.0
Su Nkt used: 12.50
Averaging Increment (m): 0.30
Phi Method : Robertson and Campanella, 1983
Dr Method : Jamiolkowski - All Sands
State Parameter M: 1.20
Used Unit Weights Assigned to Soil Zones
Values of 1.0E9 or UnDef are printed for parameters that are not valid for the material type (SBT)

Depth (ft)	AvgQt (tsf)	AvgFs (tsf)	AvgRf (%)	AvgUd (ft)	SBT	U.Wt. pcf	TStress (tsf)	EStress (tsf)	Ueq (tsf)	Cn	N60 (blows/ft)	(N1)60 (blows/ft)	Su (tsf)	CRR
0.49	0.0	0.00	0.00	0.0	UnDef	124.1	0.03	0.03	0.00	2.00	UnDef	UnDef	UnDef	0.00
1.48	0.0	0.00	0.00	0.0	UnDef	124.1	0.09	0.09	0.00	2.00	UnDef	UnDef	UnDef	0.00
2.46	0.0	0.00	0.00	0.0	UnDef	124.1	0.15	0.15	0.00	2.00	UnDef	UnDef	UnDef	0.00
3.44	0.0	0.00	0.00	0.0	UnDef	124.1	0.21	0.21	0.00	2.00	UnDef	UnDef	UnDef	0.00
4.43	0.0	0.00	0.00	0.0	UnDef	124.1	0.27	0.27	0.00	1.91	UnDef	UnDef	UnDef	0.00
5.41	14.8	0.35	2.34	1.3	5	114.6	0.33	0.33	0.00	1.73	7.1	12.2	1.15	0.10
6.40	19.8	0.49	2.46	1.7	5	114.6	0.39	0.39	0.00	1.60	9.5	15.2	1.55	0.12
7.30	31.3	0.75	2.41	-5.4	6	114.6	0.44	0.44	0.00	1.50	12.0	18.0	2.47	0.14
8.20	24.4	1.03	4.21	-1.5	4	114.6	0.49	0.49	0.00	1.42	15.6	22.2	1.91	0.40
9.19	16.9	0.60	3.58	2.2	4	114.6	0.55	0.55	0.00	1.35	10.8	14.6	1.31	0.21
10.17	14.8	0.49	3.29	21.1	4	114.6	0.61	0.61	0.00	1.28	9.5	12.1	1.14	0.16
11.15	13.7	0.55	3.99	22.4	3	111.4	0.66	0.66	0.00	1.23	13.1	16.2	1.04	0.00
12.14	46.7	0.54	1.15	29.4	7	117.8	0.72	0.72	0.00	1.18	14.9	17.6	UnDef	0.12
13.21	132.5	0.85	0.65	-0.6	9	124.1	0.78	0.78	0.00	1.13	25.4	28.7	UnDef	0.37
14.27	32.6	0.40	1.23	1.1	7	117.8	0.85	0.85	0.00	1.09	10.4	11.3	UnDef	0.11
15.26	7.1	0.11	1.54	21.5	5	114.6	0.90	0.90	0.01	1.06	3.4	3.6	0.49	0.08
16.24	7.7	0.13	1.62	46.1	5	114.6	0.96	0.92	0.04	1.04	3.7	3.9	0.54	0.09
17.22	8.9	0.21	2.36	50.8	5	114.6	1.02	0.95	0.07	1.03	4.2	4.4	0.63	0.09
18.21	8.1	0.14	1.68	44.2	5	114.6	1.07	0.97	0.10	1.01	3.9	4.0	0.57	0.09
19.19	8.2	0.07	0.79	71.1	5	114.6	1.13	1.00	0.13	1.00	3.9	3.9	0.57	0.09
20.18	14.1	0.21	1.47	48.8	6	114.6	1.19	1.02	0.16	0.99	5.4	5.3	1.03	0.11
21.16	59.5	0.39	0.66	11.7	8	120.9	1.24	1.05	0.19	0.98	14.2	13.9	UnDef	0.12
22.15	21.8	0.38	1.74	20.1	6	114.6	1.30	1.08	0.22	0.96	8.4	8.1	1.64	0.18
23.13	7.4	0.12	1.57	64.8	5	114.6	1.36	1.10	0.25	0.95	3.5	3.3	0.48	0.08
24.11	7.3	0.16	2.16	72.7	4	114.6	1.42	1.13	0.28	0.94	4.7	4.4	0.47	0.08
25.10	7.9	0.23	2.89	64.2	4	114.6	1.47	1.16	0.32	0.93	5.0	4.7	0.51	0.00
26.08	11.9	0.35	2.97	83.8	4	114.6	1.53	1.18	0.35	0.92	7.6	7.0	0.83	0.00
27.07	82.6	2.00	2.43	59.6	7	117.8	1.59	1.21	0.38	0.91	26.4	24.0	UnDef	0.33
28.05	108.2	3.16	2.92	-21.7	6	114.6	1.64	1.23	0.41	0.90	41.5	37.3	8.53	0.00
29.04	82.7	1.87	2.26	-15.5	7	117.8	1.70	1.26	0.44	0.89	26.4	23.5	UnDef	0.31

Depth (ft)	AvgQt (tsf)	AvgFs (tsf)	AvgRf (%)	AvgUd (ft)	SBT	U.Wt. pcf	TStress (tsf)	EStress (tsf)	Ueq (tsf)	Cn	N60 (blows/ft)	(N1)60 (blows/ft)	Su (tsf)	CRR
30.02	97.7	1.52	1.56	-12.2	7	117.8	1.76	1.29	0.47	0.88	31.2	27.5	UnDef	0.26
31.00	40.8	1.66	4.07	47.7	5	114.6	1.81	1.31	0.50	0.87	19.6	17.1	3.12	0.00
31.99	27.3	1.13	4.13	63.6	4	114.6	1.87	1.34	0.53	0.86	17.4	15.1	2.03	0.00
32.97	18.6	0.81	4.36	76.9	3	111.4	1.93	1.37	0.56	0.86	17.8	15.2	1.33	0.00
33.96	19.3	0.69	3.57	133.0	4	114.6	1.98	1.39	0.59	0.85	12.3	10.4	1.38	0.00
34.94	20.4	0.56	2.76	168.3	5	114.6	2.04	1.42	0.62	0.84	9.8	8.2	1.47	0.14
35.92	21.1	0.61	2.88	190.5	5	114.6	2.09	1.44	0.65	0.83	10.1	8.4	1.52	0.14
36.91	22.3	0.60	2.68	201.1	5	114.6	2.15	1.47	0.68	0.83	10.7	8.8	1.61	0.15
37.89	19.0	0.57	3.00	164.7	5	114.6	2.21	1.49	0.71	0.82	9.1	7.4	1.34	0.12
38.88	18.9	0.57	3.03	162.2	5	114.6	2.26	1.52	0.75	0.81	9.0	7.3	1.33	0.12
39.86	20.1	0.61	3.03	163.8	5	114.6	2.32	1.54	0.78	0.80	9.6	7.8	1.43	0.13
40.85	47.5	1.67	3.51	146.6	5	114.6	2.38	1.57	0.81	0.80	22.7	18.2	3.61	0.00
41.83	36.6	1.65	4.51	129.7	4	114.6	2.43	1.60	0.84	0.79	23.4	18.5	2.73	0.00
42.81	53.0	1.57	2.97	120.8	6	114.6	2.49	1.62	0.87	0.79	20.3	15.9	4.04	0.00
43.80	21.5	0.29	1.35	286.5	6	114.6	2.55	1.65	0.90	0.78	8.2	6.4	1.51	0.13
44.78	24.2	0.59	2.45	229.0	6	114.6	2.60	1.67	0.93	0.77	9.3	7.2	1.73	0.15
45.77	23.0	0.90	3.90	127.8	4	114.6	2.66	1.70	0.96	0.77	14.7	11.3	1.63	0.00
46.75	22.6	0.76	3.35	164.0	5	114.6	2.72	1.72	0.99	0.76	10.8	8.3	1.59	0.00
47.74	32.0	0.95	2.96	208.7	5	114.6	2.77	1.75	1.02	0.76	15.3	11.6	2.34	0.23
48.72	69.5	2.57	3.70	83.2	5	114.6	2.83	1.78	1.05	0.75	33.3	25.0	5.33	0.00
49.70	28.9	0.74	2.55	216.6	6	114.6	2.88	1.80	1.08	0.75	11.1	8.2	2.08	0.19
50.69	28.4	0.69	2.44	190.5	6	114.6	2.94	1.83	1.11	0.74	10.9	8.1	2.04	0.18
51.67	27.6	0.90	3.27	94.5	5	114.6	3.00	1.85	1.15	0.73	13.2	9.7	1.97	0.00
52.66	35.4	1.06	3.00	197.5	5	114.6	3.05	1.88	1.18	0.73	16.9	12.4	2.58	0.27
53.64	83.0	3.73	4.49	120.8	11	130.5	3.11	1.91	1.21	0.72	79.5	57.6	UnDef	0.00
54.63	115.8	4.53	3.91	118.4	5	114.6	3.17	1.94	1.24	0.72	55.4	39.8	9.01	0.00
55.61	262.4	5.44	2.07	-7.8	8	120.9	3.23	1.96	1.27	0.71	62.8	44.8	UnDef	0.00
56.59	379.4	2.76	0.73	-0.6	9	124.1	3.29	1.99	1.30	0.71	72.7	51.5	UnDef	0.00
57.58	334.3	2.43	0.73	14.6	9	124.1	3.35	2.02	1.33	0.70	64.0	45.0	UnDef	0.00
58.56	29.9	0.82	2.73	219.7	5	114.6	3.41	2.05	1.36	0.70	14.3	10.0	2.12	0.18
59.55	26.1	0.44	1.70	262.6	6	114.6	3.47	2.08	1.39	0.69	10.0	6.9	1.81	0.14
60.53	31.9	0.44	1.38	339.5	6	114.6	3.52	2.10	1.42	0.69	12.2	8.4	2.27	0.20
61.52	34.1	0.83	2.44	225.8	6	114.6	3.58	2.13	1.45	0.69	13.1	9.0	2.44	0.22
62.42	32.1	0.83	2.60	200.6	6	114.6	3.63	2.15	1.48	0.68	12.3	8.4	2.27	0.19
63.32	30.0	0.74	2.45	235.0	6	114.6	3.68	2.18	1.51	0.68	11.5	7.8	2.10	0.17
64.30	32.6	0.82	2.52	254.3	6	114.6	3.74	2.20	1.54	0.67	12.5	8.4	2.31	0.20
65.29	34.5	0.80	2.32	263.9	6	114.6	3.80	2.23	1.57	0.67	13.2	8.9	2.46	0.21
66.27	32.6	0.64	1.97	355.3	6	114.6	3.85	2.25	1.60	0.67	12.5	8.3	2.30	0.19
67.26	83.7	3.19	3.81	224.5	5	114.6	3.91	2.28	1.63	0.66	40.1	26.6	6.39	0.00
68.24	135.9	6.32	4.65	-12.0	11	130.5	3.97	2.31	1.66	0.66	130.1	85.7	UnDef	0.00
69.22	62.2	3.26	5.24	62.5	11	130.5	4.03	2.34	1.69	0.65	59.6	38.9	UnDef	0.00
70.21	41.1	1.29	3.14	206.5	5	114.6	4.10	2.37	1.72	0.65	19.7	12.8	2.96	0.29
71.19	39.6	1.03	2.61	232.3	6	114.6	4.15	2.40	1.75	0.65	15.2	9.8	2.83	0.26
72.18	34.4	0.70	2.02	263.7	6	114.6	4.21	2.42	1.79	0.64	13.2	8.5	2.41	0.20
73.16	37.5	0.94	2.51	235.8	6	114.6	4.26	2.45	1.82	0.64	14.4	9.2	2.66	0.23
74.15	36.2	1.20	3.31	229.8	5	114.6	4.32	2.47	1.85	0.64	17.3	11.0	2.55	0.00
75.13	38.2	1.14	2.97	264.3	5	114.6	4.38	2.50	1.88	0.63	18.3	11.6	2.71	0.23
76.11	44.5	1.40	3.13	213.4	5	114.6	4.43	2.53	1.91	0.63	21.3	13.4	3.21	0.32
77.10	54.9	2.23	4.07	283.7	5	114.6	4.49	2.55	1.94	0.63	26.3	16.4	4.03	0.00
78.08	77.6	4.39	5.66	128.1	11	130.5	4.55	2.58	1.97	0.62	74.3	46.3	UnDef	0.00
79.07	57.6	2.59	4.50	137.9	5	114.6	4.61	2.61	2.00	0.62	27.6	17.1	4.24	0.00
80.05	29.5	0.72	2.44	218.0	6	114.6	4.67	2.64	2.03	0.62	11.3	7.0	1.99	0.15

Depth (ft)	AvgQt (tsf)	AvgFs (tsf)	AvgRf (%)	AvgUd (ft)	SBT	U.Wt. pcf	TStress (tsf)	EStress (tsf)	Ueq (tsf)	Cn	N60 (blows/ft)	(N1)60	Su (tsf)	CRR
81.04	30.2	0.64	2.11	298.4	6	114.6	4.72	2.66	2.06	0.61	11.6	7.1	2.04	0.15
82.02	53.2	1.58	2.96	329.5	6	114.6	4.78	2.69	2.09	0.61	20.4	12.4	3.88	0.45
83.00	51.2	1.28	2.51	308.6	6	114.6	4.84	2.71	2.12	0.61	19.6	11.9	3.71	0.41
83.99	91.4	3.75	4.11	215.2	5	114.6	4.89	2.74	2.15	0.60	43.8	26.5	6.92	0.00
84.97	152.6	8.36	5.48	14.7	11	130.5	4.95	2.77	2.18	0.60	146.1	87.8	UnDef	0.00
85.96	118.3	7.05	5.96	19.7	11	130.5	5.02	2.80	2.22	0.60	113.3	67.7	UnDef	0.00
86.94	45.4	1.83	4.03	115.2	5	114.6	5.08	2.83	2.25	0.59	21.7	12.9	3.22	0.00
87.93	43.4	0.89	2.06	298.1	6	114.6	5.13	2.86	2.28	0.59	16.6	9.8	3.06	0.26
88.91	124.3	5.60	4.50	195.1	11	130.5	5.19	2.89	2.31	0.59	119.0	70.1	UnDef	0.00
89.89	60.7	3.62	5.96	15.9	11	130.5	5.26	2.92	2.34	0.59	58.1	34.0	UnDef	0.00
90.88	29.4	0.59	1.99	217.7	6	114.6	5.32	2.95	2.37	0.58	11.3	6.6	1.93	0.13
91.86	35.8	0.74	2.07	342.4	6	114.6	5.37	2.97	2.40	0.58	13.7	7.9	2.43	0.18
92.85	42.6	1.18	2.77	355.1	6	114.6	5.43	3.00	2.43	0.58	16.3	9.4	2.97	0.24
93.83	46.8	1.82	3.89	230.8	5	114.6	5.49	3.03	2.46	0.57	22.4	12.9	3.31	0.00
94.82	36.5	1.50	4.13	199.3	4	114.6	5.54	3.05	2.49	0.57	23.3	13.3	2.47	0.00
95.80	28.0	0.81	2.89	271.5	5	114.6	5.60	3.08	2.52	0.57	13.4	7.6	1.79	0.00
96.78	30.4	0.89	2.92	290.3	5	114.6	5.66	3.10	2.55	0.57	14.6	8.3	1.98	0.00
97.77	32.8	0.97	2.95	300.0	5	114.6	5.71	3.13	2.58	0.57	15.7	8.9	2.16	0.00
98.75	33.3	1.01	3.02	264.5	5	114.6	5.77	3.15	2.61	0.56	16.0	9.0	2.20	0.00

Interpretation Output - Release 1.00.19e

Run No: 03-0203-1606-1479
Job No: 97-100
Client: CDM
Project: CPT SITE INVESTIGATION
Site: SHERWIN WILLIAMS
Location: CPT-01
Engineer: H. YOUNG
CPT Date: 03/29/01
CPT Time: 11:54
CPT File: 027C01.COR
Northing (m): 0.000
Easting (m): 0.000
Elevation (m): 0.000

Water Table (m): 4.57 (ft): 15.0
Su Nkt used: 12.50
Averaging Increment (m): 0.30
Phi Method : Robertson and Campanella, 1983
Dr Method : Jamiolkowski - All Sands
State Parameter M: 1.20
Used Unit Weights Assigned to Soil Zones
Values of 1.0E9 or UnDef are printed for parameters that are not valid for the material type (SBT)

Depth (ft)	k (cm/s)	Bq	Qtn	Rfn	SBTn	Qc1N	DeltaQc1N	Qc1Ncs	Fc (%)	Phi (Deg)	Dr (%)	OCR	State Param	Del(n1)60	(N1)60c
0.49	1.0E-15	0.00	2.4	0.10	1	0.2	UnDef	UnDef	100.0	UnDef	UnDef	1.0	UnDef	UnDef	UnDe
1.48	1.0E-15	0.00	0.1	0.10	1	0.2	UnDef	UnDef	100.0	UnDef	UnDef	1.0	UnDef	UnDef	UnDe
2.46	1.0E-15	0.00	0.1	0.10	1	0.2	UnDef	UnDef	100.0	UnDef	UnDef	1.0	UnDef	UnDef	UnDe
3.44	1.0E-15	0.00	0.0	0.10	1	0.2	UnDef	UnDef	100.0	UnDef	UnDef	1.0	UnDef	UnDef	UnDe
4.43	1.0E-15	0.00	0.0	0.10	1	0.2	UnDef	UnDef	100.0	UnDef	UnDef	1.0	UnDef	UnDef	UnDe
5.41	5.0E-06	0.00	43.3	2.40	7	25.0	38.9	63.9	27.8	UnDef	UnDef	6.0	UnDef	7.5	19.
6.40	5.0E-06	0.00	49.7	2.51	7	31.0	41.6	72.6	26.5	UnDef	UnDef	6.0	UnDef	8.5	23.
7.30	5.0E-05	-0.01	69.9	2.44	7	46.1	38.4	84.5	22.0	40	45.1	10.0	-0.25	7.2	25.
8.20	5.0E-07	0.00	48.5	4.29	6	34.0	117.0	151.0	34.0	UnDef	UnDef	6.0	UnDef	20.9	43.
9.19	5.0E-07	0.00	29.8	3.70	6	22.3	89.3	111.6	39.4	UnDef	UnDef	6.0	UnDef	14.6	29.
10.17	5.0E-07	0.05	23.4	3.43	6	18.6	74.5	93.1	42.5	UnDef	UnDef	6.0	UnDef	12.1	24.
11.15	5.0E-08	0.05	19.7	4.20	1	16.5	UnDef	UnDef	100.0	UnDef	UnDef	6.0	UnDef	UnDef	UnDe
12.14	5.0E-04	0.02	64.1	1.17	7	54.0	22.1	76.1	15.9	40	49.6	1.0	-0.16	3.9	21.
13.21	5.0E-02	0.00	168.3	0.65	9	146.5	0.0	146.5	4.6	44	78.2	1.0	-0.20	0.0	28.
14.27	5.0E-04	0.00	37.5	1.26	7	34.7	31.8	66.5	22.9	38	36.9	1.0	-0.11	4.8	16.
15.26	5.0E-06	0.11	6.9	1.76	4	7.3	29.2	36.6	59.4	UnDef	UnDef	3.0	UnDef	3.6	7.
16.24	5.0E-06	0.21	7.4	1.85	4	7.9	31.6	39.5	58.4	UnDef	UnDef	3.0	UnDef	3.9	7.
17.22	5.0E-06	0.19	8.3	2.67	4	8.9	35.6	44.5	61.0	UnDef	UnDef	3.0	UnDef	4.4	8.
18.21	5.0E-06	0.18	7.3	1.94	4	8.1	32.3	40.4	59.4	UnDef	UnDef	3.0	UnDef	4.0	7.
19.19	5.0E-06	0.29	7.1	0.92	6	8.0	32.2	40.2	50.4	UnDef	UnDef	3.0	UnDef	3.9	7.
20.18	5.0E-05	0.11	12.6	1.61	6	13.6	54.4	68.0	44.1	30	30.0	6.0	-0.01	5.3	10.
21.16	5.0E-03	0.00	55.3	0.68	9	56.7	16.8	73.5	13.5	40	51.0	1.0	-0.10	2.3	16.
22.15	5.0E-05	0.02	19.0	1.85	6	20.6	82.3	102.8	37.7	32	30.0	6.0	-0.08	8.1	16.
23.13	5.0E-06	0.30	5.4	1.92	4	6.8	27.4	34.2	67.1	UnDef	UnDef	1.5	UnDef	3.3	6.
24.11	5.0E-07	0.33	5.2	2.68	4	6.8	27.0	33.8	73.5	UnDef	UnDef	1.5	UnDef	4.4	8.
25.10	5.0E-07	0.26	5.5	3.56	1	7.2	UnDef	UnDef	100.0	UnDef	UnDef	1.5	UnDef	UnDef	UnDe
26.08	5.0E-07	0.22	8.8	3.40	1	10.7	UnDef	UnDef	100.0	UnDef	UnDef	3.0	UnDef	UnDef	UnDe
27.07	5.0E-04	0.02	67.0	2.47	7	73.5	65.5	139.0	22.6	40	58.5	1.0	-0.25	10.0	34.
28.05	5.0E-05	-0.01	86.3	2.96	7	95.3	78.5	173.8	21.9	42	65.9	10.0	-0.32	14.7	52.
29.04	5.0E-04	-0.01	64.2	2.31	7	72.1	62.2	134.3	22.3	40	57.9	1.0	-0.24	9.6	33.

Depth (ft)	k (cm/s)	Bq	Qtn	Rfn	SBTn	Qc1N	DeltaQc1N	Qc1Ncs	Fc (%)	Phi (Deg)	Dr (%)	OCR	State Param	Del(n1)60	(N1)60c
30.02	5.0E-04	-0.01	74.5	1.59	7	84.2	39.6	123.9	17.0	40	62.4	1.0	-0.21	6.9	34.
31.00	5.0E-06	0.03	29.7	4.26	6	34.8	139.4	174.2	41.7	UnDef	UnDef	6.0	UnDef	17.1	34.
31.99	5.0E-07	0.06	19.0	4.43	1	23.1	UnDef	UnDef	100.0	UnDef	UnDef	6.0	UnDef	UnDef	UnDe
32.97	5.0E-08	0.11	12.2	4.87	1	15.6	UnDef	UnDef	100.0	UnDef	UnDef	3.0	UnDef	UnDef	UnDe
33.96	5.0E-07	0.21	12.4	3.98	1	16.0	UnDef	UnDef	100.0	UnDef	UnDef	3.0	UnDef	UnDef	UnDe
34.94	5.0E-06	0.25	13.0	3.07	4	16.8	67.2	84.1	52.6	UnDef	UnDef	6.0	UnDef	8.2	16.
35.92	5.0E-06	0.28	13.2	3.20	4	17.2	68.9	86.2	52.9	UnDef	UnDef	6.0	UnDef	8.4	16.
36.91	5.0E-06	0.28	13.8	2.96	4	18.0	72.2	90.2	50.8	UnDef	UnDef	6.0	UnDef	8.8	17.
37.89	5.0E-06	0.26	11.2	3.39	4	15.2	60.9	76.1	57.5	UnDef	UnDef	3.0	UnDef	7.4	14.
38.88	5.0E-06	0.26	10.9	3.44	4	15.0	59.9	74.9	58.4	UnDef	UnDef	3.0	UnDef	7.3	14.
39.86	5.0E-06	0.24	11.5	3.42	4	15.9	63.4	79.3	57.1	UnDef	UnDef	3.0	UnDef	7.8	15.
40.85	5.0E-06	0.08	28.7	3.69	6	37.1	148.4	185.5	40.0	UnDef	UnDef	6.0	UnDef	18.2	36.
41.83	5.0E-07	0.09	21.4	4.83	1	28.3	UnDef	UnDef	100.0	UnDef	UnDef	6.0	UnDef	UnDef	UnDe
42.81	5.0E-05	0.06	31.2	3.11	6	40.7	162.9	203.6	36.1	36	41.5	6.0	-0.19	15.9	31.
43.80	5.0E-05	0.43	11.5	1.53	6	16.4	65.4	81.8	45.4	30	30.0	3.0	0.04	6.4	12.
44.78	5.0E-05	0.29	12.9	2.75	6	18.3	73.2	91.5	51.0	32	30.0	6.0	-0.03	7.2	14.
45.77	5.0E-07	0.15	12.0	4.41	1	17.3	UnDef	UnDef	100.0	UnDef	UnDef	3.0	UnDef	UnDef	UnDe
46.75	5.0E-06	0.21	11.6	3.81	1	16.9	UnDef	UnDef	100.0	UnDef	UnDef	3.0	UnDef	UnDef	UnDe
47.74	5.0E-06	0.19	16.7	3.24	6	23.7	94.8	118.5	48.1	UnDef	UnDef	6.0	UnDef	11.6	23.
48.72	5.0E-06	0.02	37.5	3.86	6	51.0	204.1	255.1	36.3	UnDef	UnDef	6.0	UnDef	25.0	49.
49.70	5.0E-05	0.22	14.4	2.83	6	21.0	84.2	105.2	49.1	32	30.0	6.0	-0.06	8.2	16.
50.69	5.0E-05	0.19	13.9	2.72	6	20.6	82.3	102.8	49.2	32	30.0	6.0	-0.05	8.1	16.
51.67	5.0E-06	0.07	13.3	3.67	1	19.9	UnDef	UnDef	100.0	UnDef	UnDef	6.0	UnDef	UnDef	UnDe
52.66	5.0E-06	0.15	17.2	3.28	6	25.3	101.0	126.3	47.7	UnDef	UnDef	6.0	UnDef	12.4	24.
53.64	1.0E-15	0.03	41.9	4.66	6	58.8	235.3	294.1	37.5	38	52.1	1.0	-0.34	57.6	115.
54.63	5.0E-06	0.02	58.1	4.02	6	81.4	175.2	256.6	30.6	UnDef	UnDef	10.0	UnDef	29.7	69.
55.61	5.0E-03	-0.01	131.9	2.10	7	183.2	60.7	243.9	14.3	44	84.6	1.0	-0.30	8.3	53.
56.59	5.0E-02	0.00	188.7	0.73	9	263.0	0.0	263.0	4.6	44	95.0	1.0	-0.22	0.0	51.
57.58	5.0E-02	0.00	163.5	0.73	9	230.0	2.5	232.4	5.4	44	91.1	1.0	-0.20	0.3	45.
58.56	5.0E-06	0.21	12.9	3.08	4	20.4	81.7	102.1	52.8	UnDef	UnDef	6.0	UnDef	10.0	20.
59.55	5.0E-05	0.30	10.9	1.96	6	17.7	70.9	88.6	49.8	30	30.0	3.0	0.02	6.9	13.
60.53	5.0E-05	0.32	13.5	1.55	6	21.5	86.2	107.7	42.1	32	30.0	6.0	0.01	8.4	16.
61.52	5.0E-05	0.18	14.3	2.72	6	22.9	91.6	114.4	48.6	32	30.0	6.0	-0.06	9.0	17.
62.42	5.0E-05	0.17	13.2	2.93	4	21.4	85.5	106.9	51.5	32	30.0	6.0	-0.05	8.4	16.
63.32	5.0E-05	0.22	12.1	2.80	4	19.9	79.5	99.4	52.7	30	30.0	3.0	-0.03	7.8	15.
64.30	5.0E-05	0.22	13.1	2.85	4	21.5	86.1	107.6	51.2	32	30.0	6.0	-0.04	8.4	16.
65.29	5.0E-05	0.22	13.8	2.61	6	22.6	90.5	113.1	48.8	32	30.0	6.0	-0.04	8.9	17.
66.27	5.0E-05	0.33	12.8	2.23	6	21.3	85.0	106.3	48.2	32	30.0	6.0	-0.01	8.3	16.
67.26	5.0E-06	0.07	35.0	3.99	6	54.3	217.1	271.4	37.9	UnDef	UnDef	6.0	UnDef	26.6	53.
68.24	1.0E-15	-0.02	57.1	4.79	6	87.5	273.1	360.6	33.4	40	63.5	1.0	-0.42	77.1	162.
69.22	1.0E-15	0.00	24.8	5.60	1	39.8	UnDef	UnDef	100.0	34	40.9	1.0	-0.34	UnDef	UnDe
70.21	5.0E-06	0.13	15.6	3.48	4	26.1	104.4	130.5	50.7	UnDef	UnDef	6.0	UnDef	12.8	25.
71.19	5.0E-05	0.16	14.8	2.91	6	25.0	100.0	125.0	49.0	32	30.0	6.0	-0.07	9.8	19.
72.18	5.0E-05	0.21	12.5	2.30	6	21.6	86.5	108.1	49.2	30	30.0	3.0	-0.02	8.5	16.
73.16	5.0E-05	0.17	13.6	2.83	6	23.4	93.8	117.2	50.4	32	30.0	6.0	-0.06	9.2	18.
74.15	5.0E-06	0.17	12.9	3.75	1	22.5	UnDef	UnDef	100.0	UnDef	UnDef	6.0	UnDef	UnDef	UnDe
75.13	5.0E-06	0.19	13.5	3.36	4	23.6	94.6	118.2	53.2	UnDef	UnDef	6.0	UnDef	11.6	23.
76.11	5.0E-06	0.12	15.9	3.48	4	27.4	109.6	137.0	50.3	UnDef	UnDef	6.0	UnDef	13.4	26.
77.10	5.0E-06	0.14	19.7	4.43	1	33.6	UnDef	UnDef	100.0	UnDef	UnDef	6.0	UnDef	UnDef	UnDe
78.08	1.0E-15	0.03	28.3	6.01	1	47.3	UnDef	UnDef	100.0	36	45.8	1.0	-0.42	UnDef	UnDe
79.07	5.0E-06	0.04	20.3	4.89	1	34.9	UnDef	UnDef	100.0	UnDef	UnDef	6.0	UnDef	UnDef	UnDe
80.05	5.0E-05	0.19	9.4	2.89	4	17.8	71.1	88.9	59.1	30	30.0	3.0	-0.01	7.0	13.

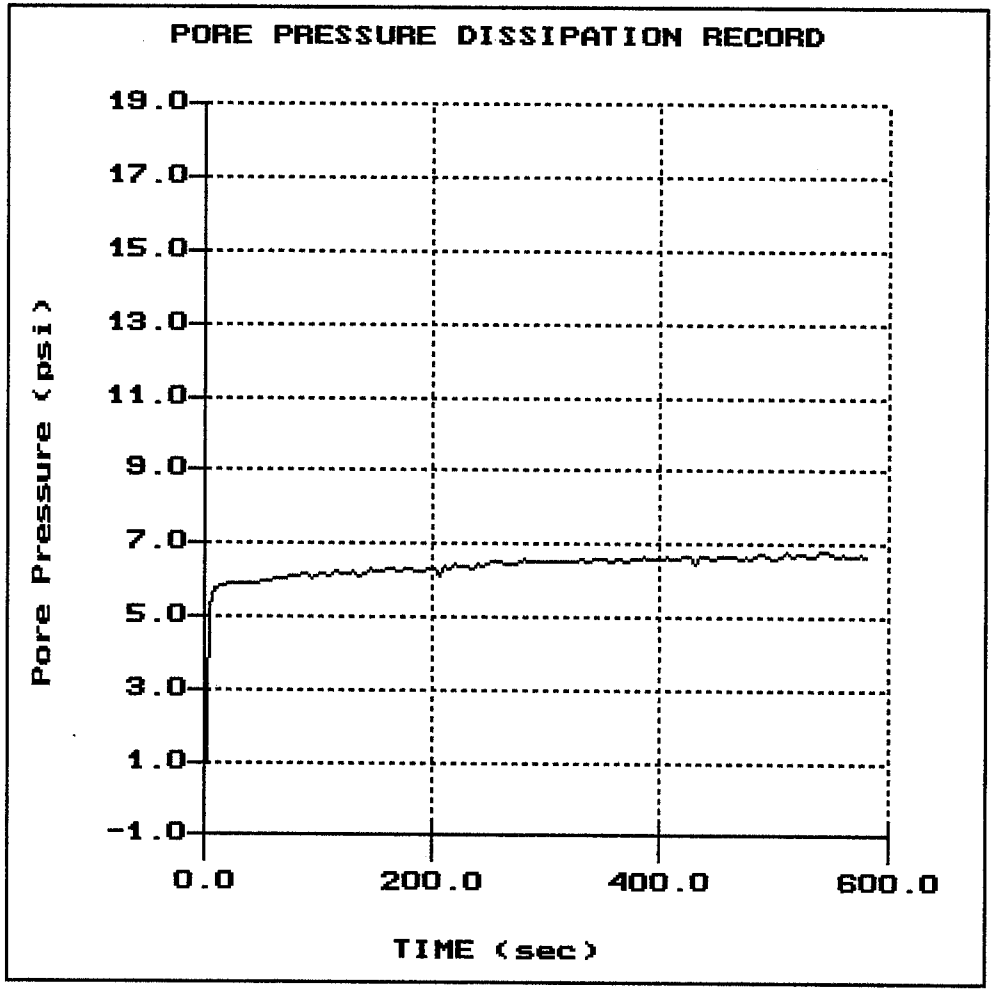
pth (ft)	k (cm/s)	Bq	Qtn	Rfn	SBTn	Qc1N	DeltaQc1N	Qc1Ncs	Fc (%)	Phi (Deg)	Dr (%)	OCR	State Param	Del(n1)60	(N1)60c
81.04	5.0E-05	0.29	9.6	2.50	4	18.1	72.4	90.5	56.4	30	30.0	3.0	0.01	7.1	14.
82.02	5.0E-05	0.17	18.0	3.25	6	31.8	127.1	158.9	46.6	32	34.4	6.0	-0.11	12.4	24.
83.00	5.0E-05	0.16	17.1	2.77	6	30.4	121.8	152.2	45.2	32	33.2	6.0	-0.08	11.9	23.
83.99	5.0E-06	0.05	31.6	4.34	6	54.1	216.3	270.4	40.9	UnDef	UnDef	6.0	UnDef	26.5	52.
84.97	1.0E-15	-0.01	53.3	5.66	1	89.7	UnDef	UnDef	100.0	40	64.2	1.0	-0.53	UnDef	UnDe
85.96	1.0E-15	-0.01	40.4	6.22	1	69.2	UnDef	UnDef	100.0	38	56.7	1.0	-0.57	UnDef	UnDe
86.94	5.0E-06	0.03	14.2	4.54	1	26.4	UnDef	UnDef	100.0	UnDef	UnDef	6.0	UnDef	UnDef	UnDe
87.93	5.0E-05	0.18	13.4	2.34	6	25.1	100.5	125.6	47.8	32	30.0	6.0	-0.04	9.8	19.
88.91	1.0E-15	0.03	41.3	4.70	6	71.6	286.4	358.0	37.8	38	57.7	1.0	-0.34	70.1	140.
89.89	1.0E-15	-0.03	19.0	6.52	1	34.8	UnDef	UnDef	100.0	32	37.0	1.0	-0.41	UnDef	UnDe
90.88	5.0E-05	0.18	8.2	2.43	4	16.8	67.1	83.8	59.8	30	30.0	3.0	0.02	6.6	13.
91.86	5.0E-05	0.27	10.2	2.43	4	20.3	81.2	101.5	54.4	30	30.0	3.0	0.01	7.9	15.
92.85	5.0E-05	0.23	12.4	3.18	4	24.0	96.2	120.2	54.3	30	30.0	3.0	-0.04	9.4	18.
93.83	5.0E-06	0.11	13.7	4.41	1	26.3	UnDef	UnDef	100.0	UnDef	UnDef	6.0	UnDef	UnDef	UnDe
94.82	5.0E-07	0.12	10.1	4.87	1	20.4	UnDef	UnDef	100.0	UnDef	UnDef	3.0	UnDef	UnDef	UnDe
95.80	5.0E-06	0.27	7.3	3.61	1	15.6	UnDef	UnDef	100.0	UnDef	UnDef	3.0	UnDef	UnDef	UnDe
96.78	5.0E-06	0.26	8.0	3.59	1	16.9	UnDef	UnDef	100.0	UnDef	UnDef	3.0	UnDef	UnDef	UnDe
97.77	5.0E-06	0.25	8.6	3.58	1	18.1	UnDef	UnDef	100.0	UnDef	UnDef	3.0	UnDef	UnDef	UnDe
98.75	5.0E-06	0.20	8.7	3.65	1	18.4	UnDef	UnDef	100.0	UnDef	UnDef	3.0	UnDef	UnDef	UnDe

3.3 PORE PRESSURE DISSIPATION PLOTS

CDM

Site: SHERWIN WILLIAMS
Location: CPT-01

Engineer: H. YOUNG
Date:01:29:03 11:54

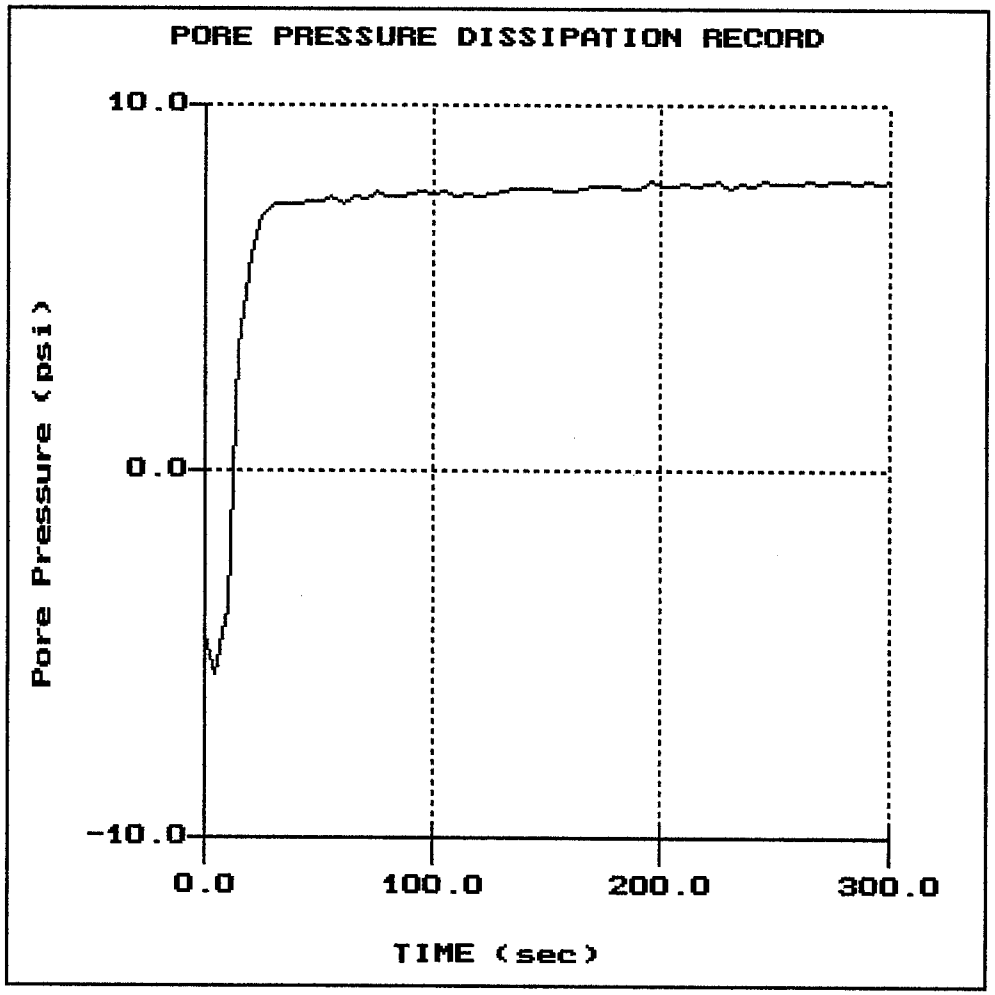


File: 027C01.PPC
Depth (m): 9.30
(ft): 30.51
Duration : 580.0s
U-min: -0.61 0.0s
U-max: 6.77 545.0s

CDM

Site: SHERWIN WILLIAMS
Location: CPT-02

Engineer: H. YOUNG
Date:01:29:03 09:33

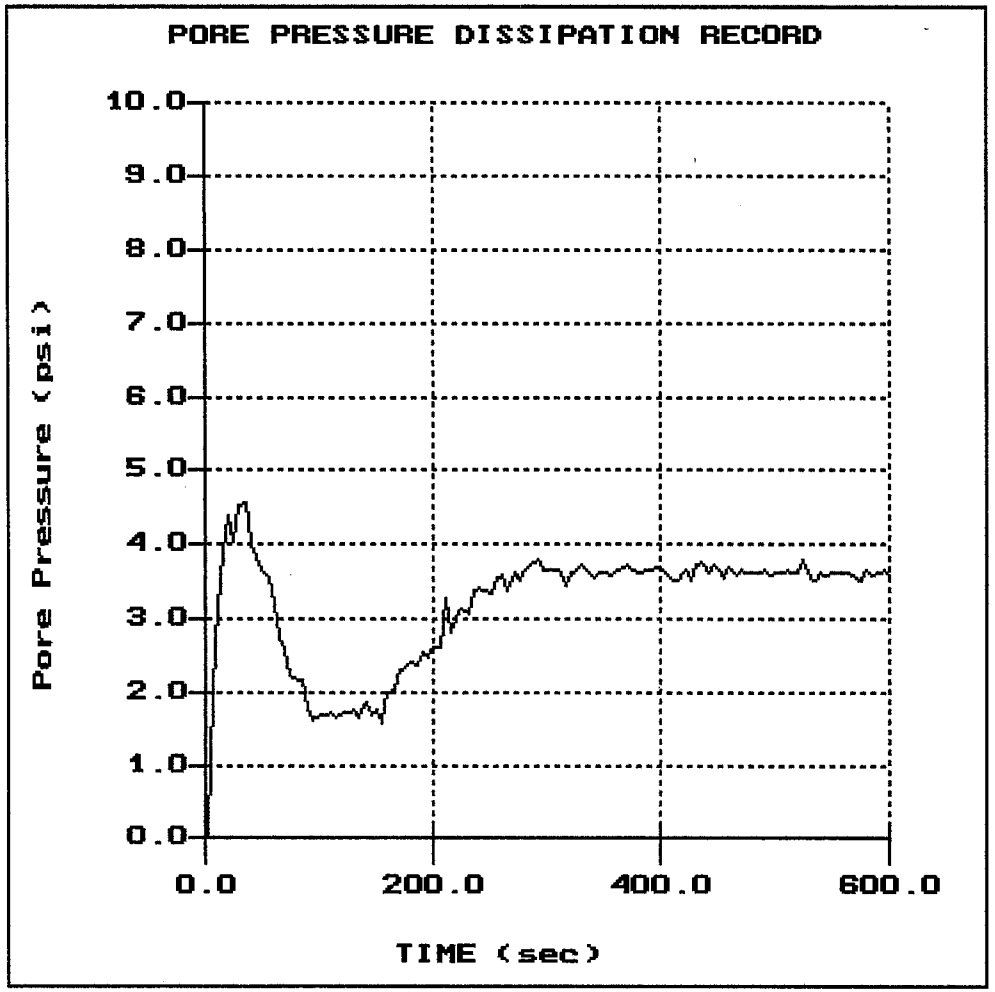


File: 027C02.PPC
Depth (m): 10.30
(ft): 33.79
Duration : 300.0s
U-min: -5.59 5.0s
U-max: 7.93 300.0s

CDM

Site: SHERWIN WILLIAMS
Location: CPT-04

Engineer: H. YOUNG
Date:01:28:03 08:29

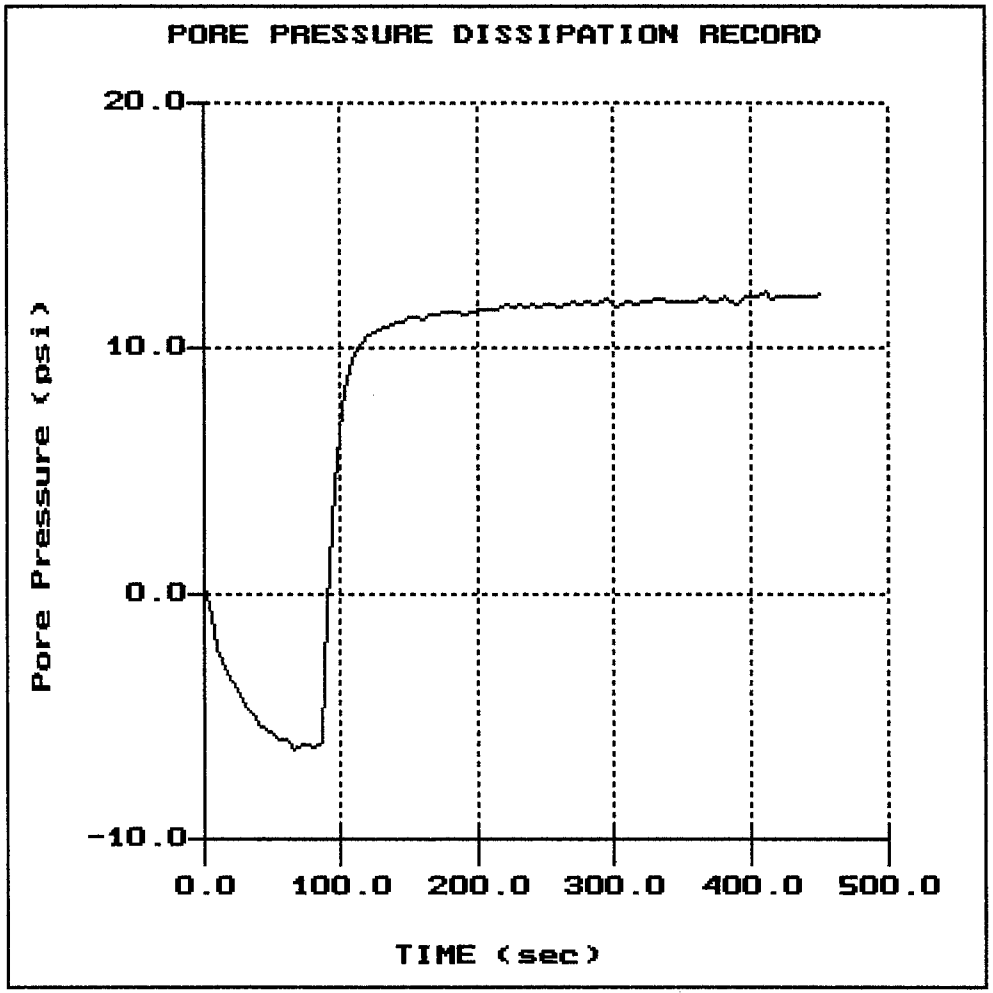


File: 027C04.PPC
Depth (m): 4.85
(ft): 15.91
Duration : 600.0s
U-min: -4.41 0.0s
U-max: 4.54 35.0s

CDM

Site: SHERWIN WILLIAMS
Location: CPT-05

Engineer: H. YOUNG
Date:01:28:03 10:52



File: 027C05.PPC
Depth (m): 10.25
(ft): 33.63
Duration : 450.0s
U-min: -6.35 65.0s
U-max: 12.27 410.0s

GREGG IN SITU CPT Interpretations as of July 31, 2002 (Release 1.20c)

GREGG IN SITU's interpretation routine provides a tabular output of geotechnical parameters based on current published CPT correlations and is subject to change to reflect the current state of practice. The interpreted values are not considered valid for all soil types. The interpretations are presented only as a guide for geotechnical use and should be carefully scrutinized for consideration in any geotechnical design. Reference to current literature is strongly recommended. GREGG IN SITU, Inc. and GREGG DRILLING & TESTING Inc. do not warranty the correctness or the applicability of any of the geotechnical parameters interpreted by the program and can not assume liability for any use of the results in any design or review. Representative hand calculations should be made for any parameter that is critical for design purposes. The end user of the interpreted output should also be fully aware of the techniques and the limitations of any method used in this program. The purpose of this document is to inform the user as to which methods were used and what the appropriate papers and/or publications are for further reference.

The CPT interpretations are based on values of tip, sleeve friction and pore pressure averaged over a user specified interval (e.g. 0.20m). Note that q_t is the recorded tip value, q_c, corrected for pore pressure effects. Since all GREGG IN SITU cones have equal end area friction sleeves, pore pressure corrections to sleeve friction, Fs, are not required.

The tip correction is: $q_t = q_c + (1-a) \bullet u_2$

where: q_t is the corrected tip resistance
q_c is the recorded tip resistance
u_2 is the recorded dynamic pore pressure behind the tip (u_2 position)
a is the Net Area Ratio for the cone (typically 0.85 for GREGG IN SITU cones)

The total stress calculations are based on soil unit weights that have been assigned to the Soil Behavior Type zones, from a user defined unit weight profile or by using a single value throughout the profile. Effective vertical overburden stresses are calculated based on a hydrostatic distribution of equilibrium pore pressures below the water table or from a user defined equilibrium pore pressure profile (this can be obtained from CPT dissipation tests). For over water projects the effects of the column of water have been taken in to account as has the appropriate unit weight of water. How this is done depends on where the instruments were zeroed (i.e. on deck or at mud line).

Details regarding the interpretation methods for all of the interpreted parameters are provided in Table 1. The appropriate references cited in Table 1 are listed in Table 2. Where methods are based on charts or techniques that are too complex to describe in this summary the user should reference to the cited references.

The estimated Soil Behavior Types (normalized and non-normalized) are based on the charts developed by Robertson and Campanella shown in Figures 1 and 2.

Where the results of a calculation/interpretation are declared *'invalid'* the value will be represented by the text strings "-9999" or "-9999.0". Invalid results will occur because of (and not limited to) one or a combination of:

1. Invalid or undefined CPT data (e.g. drilled out section or data gap).

2. Where the interpretation method is inappropriate, for example, drained parameters in an undrained material (and vice versa).

3. Where interpretation input values are beyond the range of the referenced charts or specified limitations of the interpretation method.

4. Where pre-requisite or intermediate interpretation calculations are invalid.

The parameters selected for output from the program are often specific to a particular project. As such, not all of the interpreted parameters listed in Table 1 may be included in the output files delivered with this report.

Table 1
CPT Interpretation Methods

Interpreted Parameter	Description	Equation	Ref
Depth	Mid Layer Depth *(where interpretations are done at each point then Mid Layer Depth = Recorded Depth)*	*Depth (Layer Top) + Depth (Layer Bottom) / 2.0*	
Elevation	Elevation of Mid Layer based on sounding collar elevation supplied by client	Elevation = Collar Elevation - Depth	
Avgqc	Averaged recorded tip value (q_c)	$Avgqc = \frac{1}{n}\sum_{i=1}^{n} q_c$ *n=1 when interpretations are done at each point*	
Avgqt	Averaged corrected tip (q_t) where: $q_t = q_c + (1-a) \bullet u$	$Avgqt = \frac{1}{n}\sum_{i=1}^{n} q_t$ *n=1 when interpretations are done at each point*	
Avgfs	Averaged sleeve friction (f_s)	$Avgfs = \frac{1}{n}\sum_{i=1}^{n} fs$ *n=1 when interpretations are done at each point*	
AvgRf	Averaged friction ratio (Rf) where friction ratio is defined as: $Rf = 100\% \bullet \frac{fs}{qt}$	$AvgRf = 100\% \bullet \frac{Avgfs}{Avgqt}$ *n=1 when interpretations are done at each point*	
Avgu	Averaged dynamic pore pressure *(u)*	$Avgu = \frac{1}{n}\sum_{i=1}^{n} u_i$ *n=1 when interpretations are done at each point*	
AvgRes	Averaged Resistivity (this data is not always available since it is a specialized test requiring an additional module)	$Avgu = \frac{1}{n}\sum_{i=1}^{n} RESISTIVITY_i$ *n=1 when interpretations are done at each point*	
AvgUVIF	Averaged UVIF ultra-violet induced fluorescence (this data is not always available since it is a specialized test requiring an additional module)	$Avgu = \frac{1}{n}\sum_{i=1}^{n} UVIF_i$ *n=1 when interpretations are done at each point*	
AvgTemp	Averaged Temperature (this data is not always available since it is a specialized test)	$Avgu = \frac{1}{n}\sum_{i=1}^{n} TEMPERATURE_i$ *n=1 when interpretations are done at each point*	
AvgGamma	Averaged Gamma Counts (this data is not always available since it is a specialized test requiring an additional module)	$Avgu = \frac{1}{n}\sum_{i=1}^{n} GAMMA_i$ *n=1 when interpretations are done at each point*	
SBT	Soil Behavior Type as defined by Robertson and Campanella	See Figure 1	2, 5
U.Wt.	Unit Weight of soil determined from one of the following user selectable options: 1) uniform value 2) value assigned to each SBT zone 3) user supplied unit weight profile	See references	5
T. Stress σ_v	Total vertical overburden stress at Mid Layer Depth. *A layer is defined as the averaging interval specified by the user. For data interpreted at each point the Mid Layer Depth is the same as the recorded depth.*	$TStress = \sum_{i=1}^{n} \gamma_i h_i$ *where* γ_i is layer unit weight h_i is layer thickness	

CPT Interpretations

Interpreted Parameter	Description	Equation	Ref
E. Stress σ_v'	Effective vertical overburden stress at Mid Layer Depth	$Estress = Tstress - u_{eq}$	
Ueq	Equilibrium pore pressure determined from one of the following user selectable options: 1) hydrostatic from water table depth 2) user supplied profile	For hydrostatic option: $u_{eq} = \gamma_w \bullet (D - D_{wt})$ where u_{eq} is equilibrium pore pressure γ_w is unit weight of water D is the current depth D_{wt} is the depth to the water table	
Cn	SPT N_{60} overburden correction factor	$Cn=(\sigma_v')^{-0.5}$ where σ_v' *is in tsf* $0.5 < C_n < 2.0$	
N_{60}	SPT N value at 60% energy calculated from qt/N ratios assigned to each SBT zone. This method has abrupt N value changes at zone boundaries.	*See Figure 1*	4, 5
N_{60} (Ic)	SPTN Value at 60% energy. This method is a slight modification of the Jefferies and Davies technique whereby the qt/N ratio varies across soil classification zones based on the Ic parameter. This techniques is limited to zones 2 through 7 on the normalized Soil Behavior Type Chart	*See Figure 1*	5, 8
$(N_1)_{60}$	SPT N_{60} value corrected for overburden pressure	$(N_1)_{60} = Cn \bullet N_{60}$	4
$\Delta(N_1)_{60}$	Equivalent Clean Sand Correction to $(N_1)_{60}$	$\Delta(N_1)_{60} = \frac{K_{SPT}}{1 - K_{SPT}} \bullet (N_1)_{60}$ Where: K_{SPT} is defined as: 0.0 for FC < 5% 0.0167 • (FC - 5) for 5% < FC < 35% 0.5 for FC > 35% FC - Fines Content in %	4
$(N_1)_{60cs}$	Equivalent Clean Sand $(N_1)_{60}$	$(N1)_{60cs} = (N1)_{60} + \Delta(N1)_{60}$	4
Su	Undrained shear strength - N_{kt} is user selectable	$Su = \frac{qt - \sigma_v}{N_{kt}}$	1, 5
k	Coefficient of permeability (assigned to each SBT zone)		5
Bq	Pore pressure parameter	$Bq = \frac{\Delta u}{qt - \sigma_v}$ *where:* $\Delta u = u - u_{eq}$ *and u = dynamic pore pressure* *u_{eq} = equilibrium pore pressure*	1, 5
Q_t	Normalized q_t for Soil Behavior Type classification as defined by Robertson, 1990	$Qt = \frac{qt - \sigma_v}{\sigma_v'}$	2, 5
F_r	Normalized Friction Ratio for Soil Behavior Type classification as defined by Robertson, 1990	$Fr = 100\% \bullet \frac{fs}{qt - \sigma_v}$	2, 5
SBTn	Normalized Soil Behavior Type as defined by Robertson and Campanella	See Figure 2	2, 5

CPT Interpretations

Interpreted Parameter	Description	Equation	Ref
q_{c1}	q_t normalized for overburden stress used for seismic analysis	$q_{c1} = q_t \bullet (Pa/\sigma_v')^{0.5}$ where: Pa = atm. Pressure q_t is in MPa	3
q_{c1N}	q_{c1} in dimensionless form used for seismic analysis	$q_{c1N} = q_{c1} / Pa$ where: Pa = atm. pressure	3
K_c	Equivalent clean sand correction for q_{c1N}	*$K_c = 1.0$ for $I_c \leq 1.64$* *$K_c = f(I_c)$ for $I_c > 1.64$ (see reference)* *$K_c = 1.0$ for $1.64 < I_c < 2.36$ and $Fc < 0.5\%$*	3
q_{c1Ncs}	Clean Sand equivalent q_{c1N}	$q_{c1Ncs} = q_{c1N} \bullet K_c$	3
I_c	Soil index for estimating grain characteristics	$Ic = [(3.47 - \log_{10}Q)^2 + (\log_{10} Fr + 1.22)^2]^{0.5}$ *Where:* $Q = \left(\frac{qt - \sigma_v}{P_{a2}}\right)\left(\frac{P_a}{\sigma_v'}\right)^n$ *And* *Fr is in percent* *P_a = atmospheric pressure* *P_{a2} = atmospheric pressure* *n varies from 0.5 to 1.0 and is selected in an iterative manner based on the resulting I_c*	3, 8
FC	Apparent fines content (%)	*$FC=1.75(Ic^{3.25}) - 3.7$* *$FC=100$ for $Ic > 3.5$* *$FC=0$ for $Ic < 1.26$* *$FC = 5\%$ if $1.64 < Ic < 2.6$ AND $F_r<0.5$*	3
Ic Zone	This parameter is the Soil Behavior Type zone based on the Ic parameter (valid for zones 2 through 7 on SBTn chart)	Ic < 1.31 Zone = 7 1.31 < Ic < 2.05 Zone = 6 2.05 < Ic < 2.60 Zone = 5 2.60 < Ic < 2.95 Zone = 4 2.95 < Ic < 3.60 Zone = 3 Ic > 3.60 Zone = 2	3
PHI ϕ	Friction Angle determined from one of the following user selectable options: a) Campanella and Robertson b) Durgunoglu and Mitchel c) Janbu	See reference	5
Dr	Relative Density determined from one of the following user selectable options: a) Ticino Sand b) Hokksund Sand c) Schmertmann 1976 d) Jamiolkowski - All Sands	See reference	5
OCR	Over Consolidation Ratio – 2 methods available	a) Based on Schmertmann's method involving a plot of $S_u/\sigma_v' / (S_u/\sigma_v')_{NC}$ and OCR b) Based on $OCR = K \bullet \left(\frac{qt - \sigma_v}{\sigma_v'}\right)$ where an average value of k=0.3 is used	5
State Parameter	The state parameter is used to describe whether a soil is contractive (SP is positive) or dilative (SP is negative) at large strains based on the work by Been and Jefferies	See reference	9, 7, 5

CPT Interpretations

Interpreted Parameter	Description	Equation	Ref
CRR	Cyclic Resistance Ratio (for M=7.5)	*For* $(q_{c1N})_{cs} < 160$: $CRR = 93 \bullet \left(\frac{(q_{c1N})cs}{1000}\right)^3 + 0.08$ *For* $(q_{c1N})_{cs} < 50$: $CRR = 0.833 \bullet \left(\frac{(q_{c1N})cs}{1000}\right)^3 + 0.05$	5
Youngs Modulus E	Youngs Modulus based on the work by Baldi. There are three types of sands considered in this technique. The user selects the approriate type for the site from: a) OC Sands b) Aged NC Sands c) Recent NC Sands Each sand type has a family of curves that depend on mean normal stress. The program calculates mean normal stress and linearly interpolates between the two extremes provided in Baldi's chart.	Mean normal stress is evaluated from: $\sigma'_m = \frac{1}{3} \bullet (\sigma'_v + \sigma'_h + \sigma'_h)$ where σ_v'= vertical effective stress σ_h'= horizontal effective stress and $\sigma_h = K_o * \sigma_v'$ with Ko assumed to be 0.5	5
K_o	Coefficient of lateral earth pressure at rest.	$K_o = 0.1 \bullet \left(\frac{q_t - \sigma_{v0}}{\sigma'_v}\right)$	5

Savannah River Site Specific Parameters

Interpreted Parameter	Description	Equation	Ref
Ic	Ic based on normalized data at the Savannah River Site; developed by Frank Syms and SGS	$Ic = [(1.95 - \log_{10}Q)^2 + (\log_{10} Fr + 1.78)^2]^{0.5}$ *Where: Q is the normalized tip resistance And Fr is the normalized friction ratio*	10
FC	Fines content based on the normalized Savannah River Site Ic parameter; developed by Frank Syms and SGS	$FC = (5.31 * (I_c)^{2.31}) + 9.61$ For FC > 100 and q_t < 15 tsf the material is flagged as a soft zone	10
FC	Fines Content directly from non-normalized data at the Savannah River Site; developed by Frank Syms and SGS	$FC = [(3.58 - \log_{10}(qtsf))^2 + (1.43 + \log_{10}(Rf))^2]^{1.8}$ For FC > 100 and q_t < 15 tsf the material is flagged as a soft zone *Where: qtsf is the non-normalized tip resistance in tsf Rf is the non-normalized friction ratio*	11

Figure 1
Non-Normalized Behavior Type Classification Chart

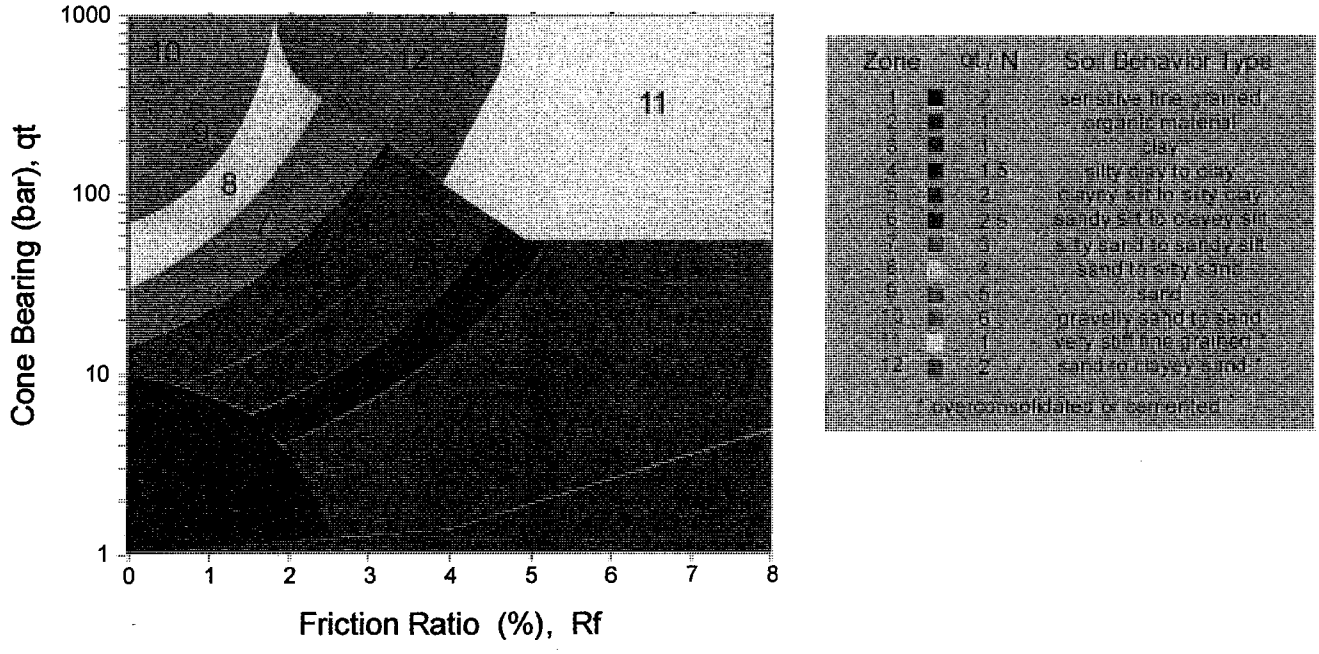
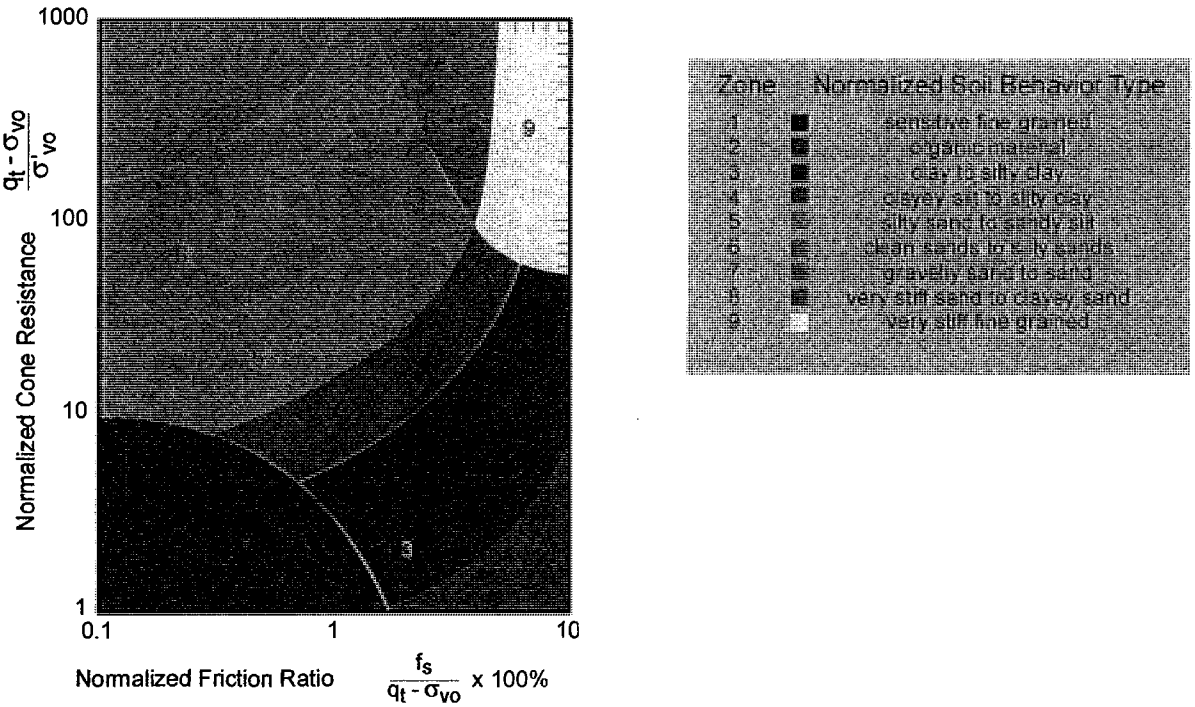


Figure 2
Normalized Behavior Type Classification Chart



GREGG

Table 2
References

No.	References
1	Robertson, P.K., Campanella, R.G., Gillespie, D. and Greig, J., 1986, "Use of Piezometer Cone Data", Proceedings of InSitu 86, ASCE Specialty Conference, Blacksburg, Virginia.
2	Robertson, P.K., 1990, "Soil Classification Using the Cone Penetration Test", Canadian Geotechnical Journal, Volume 27.
3	Robertson, P.K. and Fear, C.E., 1998, "Evaluating cyclic liquefaction potential using the cone penetration test", Canadian Geotechnical Journal, 35: 442-459.
4	Robertson, P.K. and Wride, C.E., 1998, "Cyclic Liquefaction and its Evaluation Based on SPT and CPT", NCEER Workshop Paper, January 22, 1997
5	Lunne, T., Robertson, P.K. and Powell, J. J. M., 1997, " Cone Penetration Testing in Geotechnical Practice," Blackie Academic and Professional.
6	GREGG IN SITU Internal Report
7	Plewes, H.D., Davies, M.P. and Jefferies, M.G., 1992, "CPT Based Screening Procedure for Evaluating Liquefaction Susceptibility", 45th Canadian Geotechnical Conference, Toronto, Ontario, October 1992.
8	Jefferies, M.G. and Davies, M.P., 1993. "Use of CPTu to Estimate equivalent N_{60}", Geotechnical Testing Journal, 16(4): 458-467.
9	Been, K. and Jefferies, M.P., 1985, "A state parameter for sands", Geotechnique, 35(2), 99-112.
10	Frank Syms, Bechtel Corp (Savannah River Site), 2001, "CPTU Fines Content Determination", Calculation No. K-CIC-G-00065 Revision 0.
11	Frank Syms, Bechtel Corp (Savannah River Site) – personal communication

Appendix C
Geotechnical Laboratory Test Results

SMITH-EMERY COMPANY
The Full Service Independent Testing Laboratory, Established 1904

Hunters Point Shipyard, Bldg. 114
P. O. Box 880550
San Francisco, California 94188
(415) 330-3000 Fax (415) 330-3030

791 East Washington Blvd.
Los Angeles, California 90021-3043
(213) 749-3411
Fax (213) 746-7228

GEOSERVICES DIVISION
MAR 1 3 2003

March 11, 2003

SECo File No. 2058
SECo Report No. 03-135

One Walnut Creek Center
100 Pringle Avenue, Sulte 300
Walnut Creek, California 94596

Attn: Mr. Michael Gray

Re: CDM Project No. 13452-35952-TK16.Design
Sherwin-Williams SB-11 and SB-12

SUBJECT: REPORT OF TESTS

TEST STANDARDS: ASTM D2216 (Moisture Content), ASTM D2937 (Dry Unit Weight), ASTM D4318 (Atterberg Limits), ASTM D422 (Sieve Analysis), ASTM D3080 (Direct Shear Test), and ASTM D2435 (Consolidation Test)

SOURCE: Soil boring samples from the Sherwin-Williams Geotechnical Investigation were submitted to our laboratory by your representative on February 6, 2003.

REPORT OF TESTS

In compliance with the request of your authorized representative, we have conducted the subject tests, as per your requirements for the above referenced project. Test results for the moisture content, dry unit weight, and Atterberg Limits are presented on the following table. The Sieve Analysis, Atterberg Limits, Direct Shear, and Consolidation test results/graphs are attached.

Respectfully submitted,
SMITH-EMERY COMPANY

Patrick Morrison

PATRICK MORRISON, R.G. #7174
Registered Geologist
Geoservices Division Manager, SF

Attachments: Sieve Analysis, Atterberg Limits, Direct Shear, and Consolidation test results/graphs

Cc: 2-Addressee

ALL REPORTS ARE SUBMITTED AS THE CONFIDENTIAL PROPERTY OF CLIENTS. AUTHORIZATION FOR PUBLICATION OF OUR REPORT, CONCLUSIONS, OR EXTRACTS FROM OR REGARDING THEM IS RESERVED PENDING OUR WRITTEN APPROVAL AS A MUTUAL PROTECTION TO CLIENTS, THE PUBLIC AND OURSELVES.

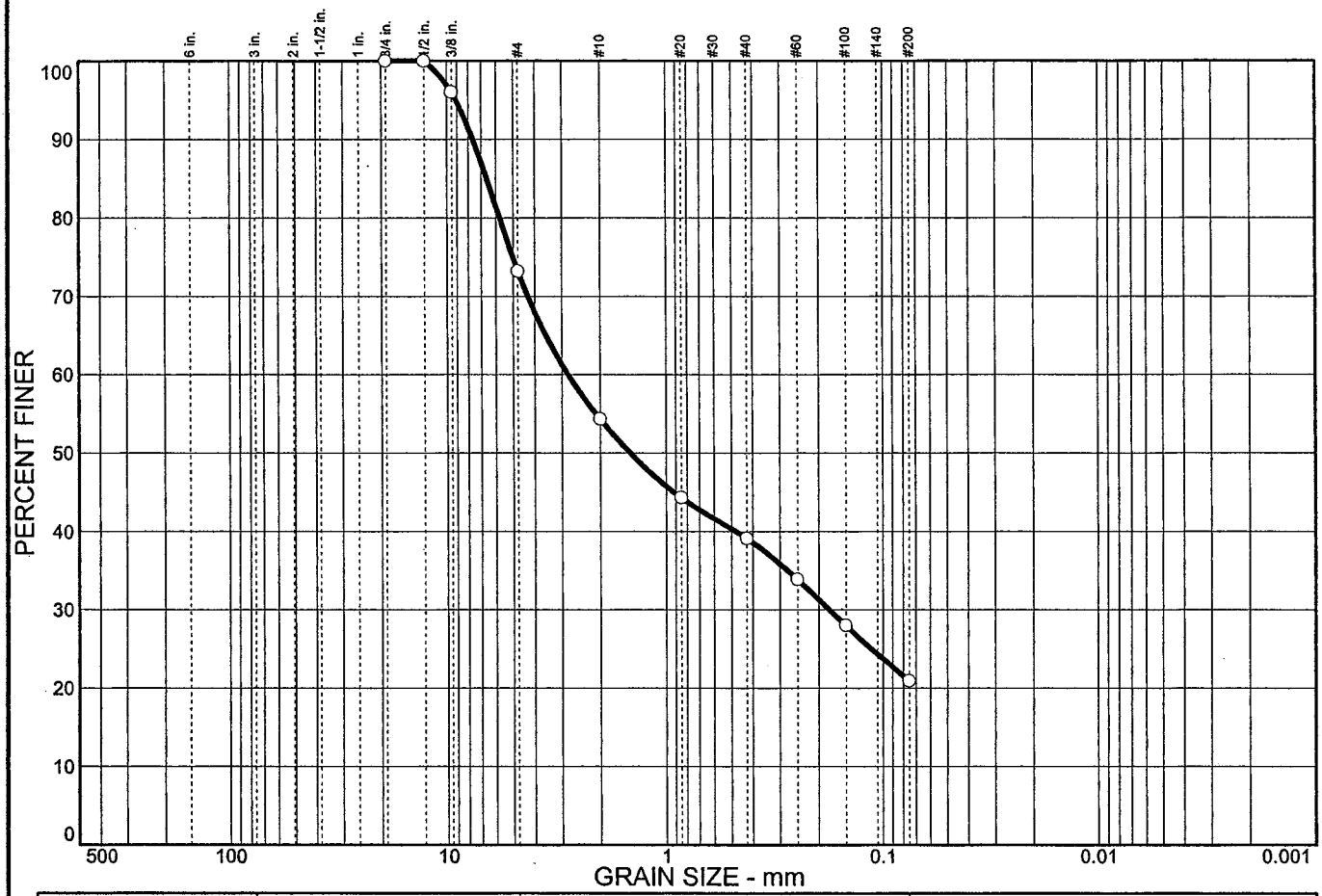
Re: CDM Project No. 13452-35952-TK16.Design
Sherwin Williams SB-11 and SB-12

REPORT OF TESTS

Boring No.	Depth (ft)	Dry Unit Weight (pcf)	Moisture Content (%)	Liquid Limit	Plastic Limit	Plasticity Index	Reports/Graphs Attached
SB-11	18.5	--	--	34	15	19	Plasticity Chart, Direct Shear
SB-11	21	--	--	--	--	--	Sieve Analysis
SB-11	25	97.6	25.0	--	--	--	--
SB-11	27	--	--	30	14	16	Plasticity Chart, Direct Shear
SB-11	30	--	--	--	--	--	Sieve Analysis
SB-11	35	102.6	24.2	--	--	--	Consolidation
SB-11	40			36	16	20	Plasticity Chart
SB-11	45	113.3	18.0	33	15	18	Plasticity Chart, Direct Shear
SB-11	55	118.9	16.2	--	--	--	--
SB-11	65	--	--	39	20	19	Plasticity Chart, Consolidation
SB-12	15	--	--	31	15	16	Plasticity Chart, Direct Shear
SB-12	25	--	--	46	13	33	Plasticity Chart, Consolidation
SB-12	30	--	--	49	22	27	Plasticity Chart, Direct Shear
SB-12	35	--	--	--	--	--	Sieve Analysis
SB-12	40	111.0	18.5	--	--	--	Consolidation
SB-12	45	--	--	33	15	18	Plasticity Chart
SB-12	60	99.8	25.8	70	16	54	Plasticity Chart
SB-12	65	--	--	47	16	31	Plasticity Chart
SB-12	70	114.3	17.5	--	--	--	--

SIEVE ANALYSIS RESULTS / GRAPHS

Particle Size Distribution Report



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	26.8	18.9	15.2	18.2	20.9	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
.75 in.	100.0		
.50 in.	100.0		
.375 in.	96.0		
#4	73.2		
#10	54.3		
#20	44.3		
#40	39.1		
#60	33.9		
#100	28.0		
#200	20.9		

* (no specification provided)

Soil Description

Gray clayey gravelly Sand

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 6.60 D_{60}= 2.82 D_{50}= 1.46
D_{30}= 0.179 D_{15}= D_{10}=
C_u= C_c=

Classification

USCS= SM AASHTO=

Remarks

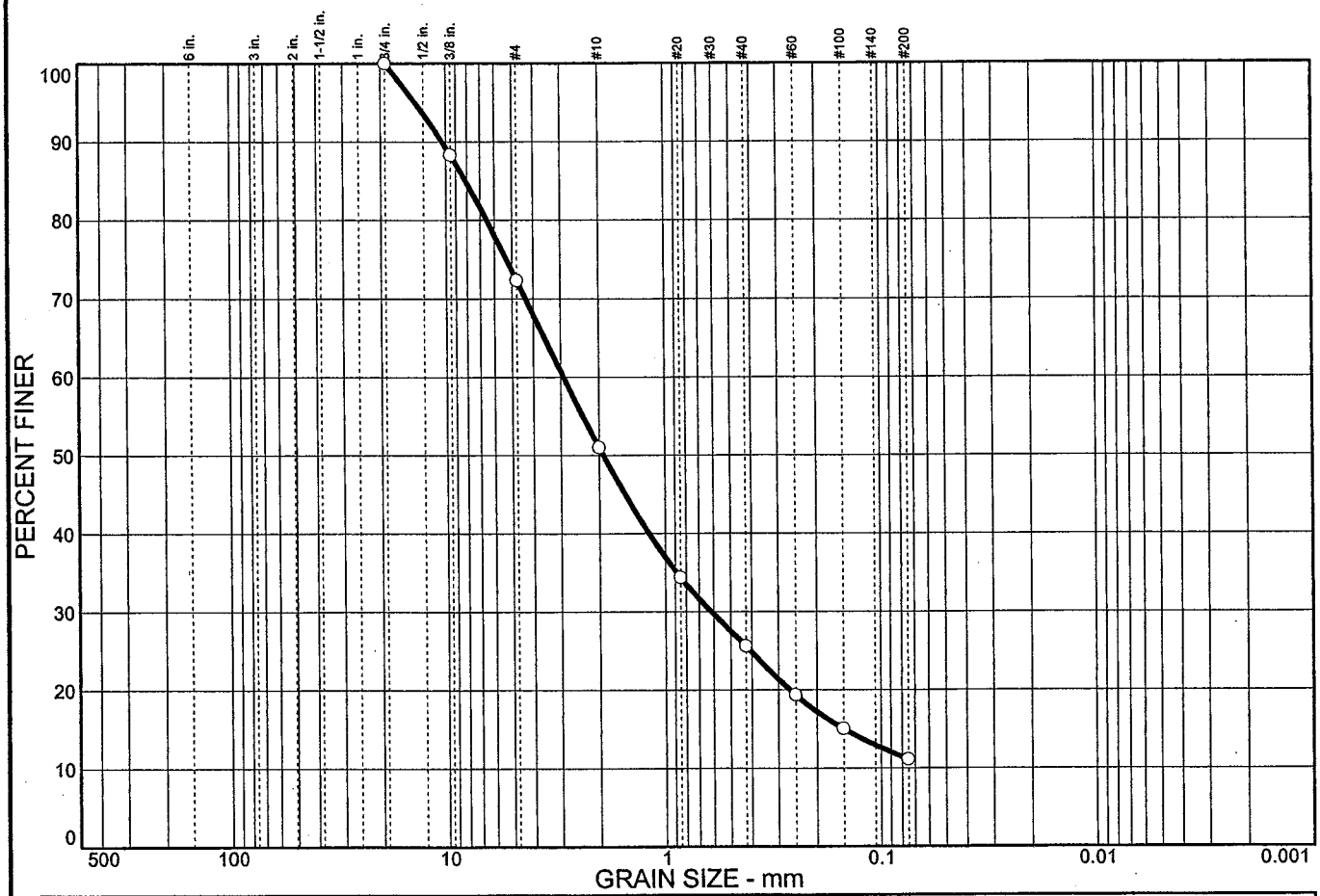
Sample No.: SB-11 **Source of Sample:** CDM-Sherwin Williams **Date:** 2-24-03
Location: **Elev./Depth:** 21

Smith-Emery Company

Client: CDM Inc.
Project: Sherwin Williams (CDM Project No. 13452-35952-TK16.Design)

Project No: 2058-2 **Plate** 1

Particle Size Distribution Report



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	27.7	21.3	25.4	14.5	11.1	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
.75 in.	100.0		
.375 in.	88.3		
#4	72.3		
#10	51.0		
#20	34.4		
#40	25.6		
#60	19.3		
#100	15.0		
#200	11.1		

* (no specification provided)

Soil Description

Brown gravelly Sand with silt

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 8.12 D_{60}= 2.91 D_{50}= 1.91
D_{30}= 0.614 D_{15}= 0.150 D_{10}=
C_u= C_c=

Classification

USCS= SP-SM AASHTO=

Remarks

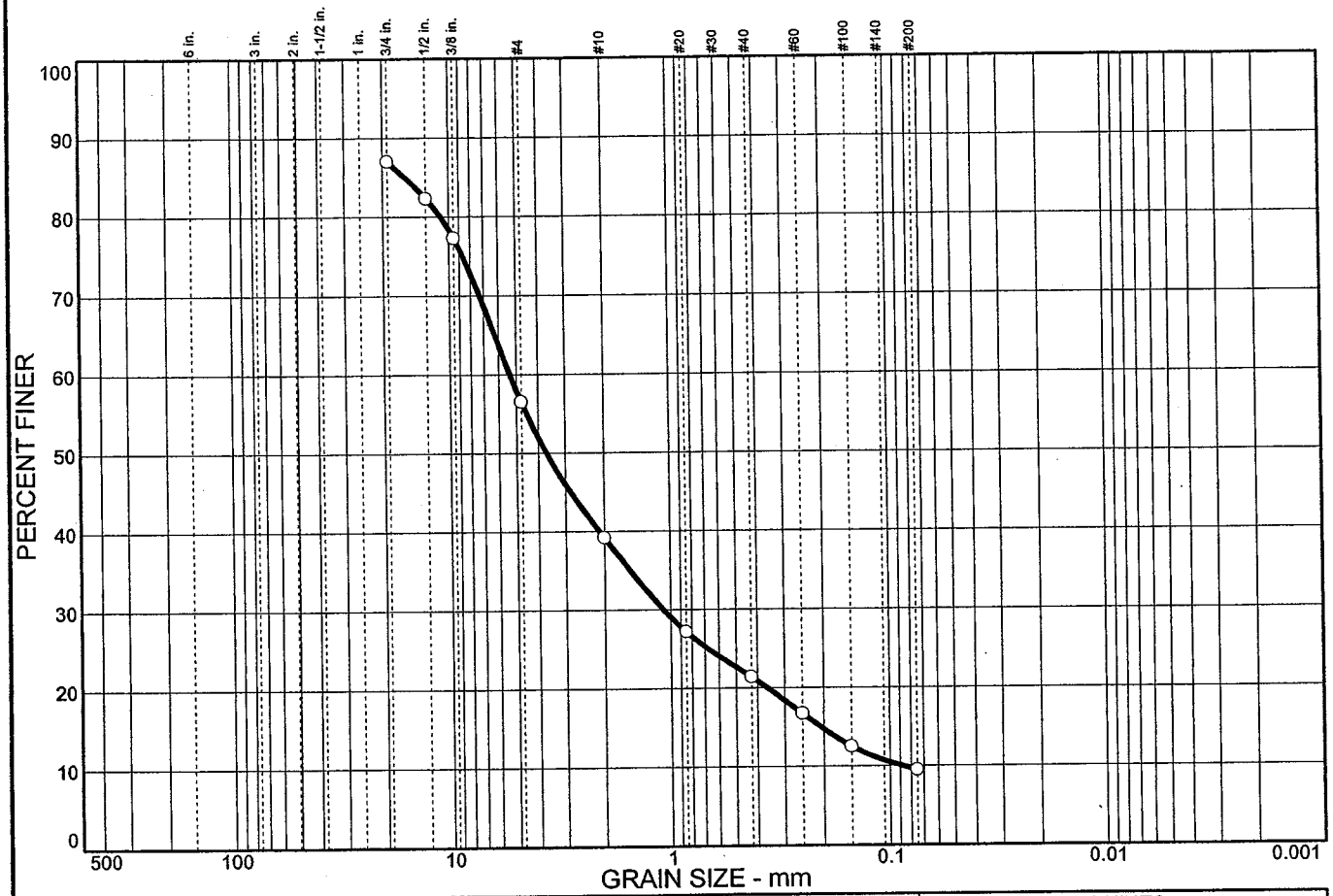
Sample No.: SB-11 **Source of Sample:** CDM-Sherwin Williams **Date:** 2-24-03
Location: **Elev./Depth:** 30

Smith-Emery Company

Client: CDM Inc.
Project: Sherwin Williams (CDM Project No. 13452-35952-TK16.Design)

Project No: 2058-2 **Plate** 2

Particle Size Distribution Report



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
		30.5	17.3	17.8	11.9	9.5	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
.75 in.	87.0		
.50 in.	82.3		
.375 in.	77.3		
#4	56.5		
#10	39.2		
#20	27.2		
#40	21.4		
#60	16.7		
#100	12.5		
#200	9.5		

* (no specification provided)

Soil Description

Brown gravelly Sand with silt

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 15.8 D_{60}= 5.34 D_{50}= 3.66
D_{30}= 1.08 D_{15}= 0.207 D_{10}= 0.0874
C_u= 61.12 C_c= 2.48

Classification

USCS= SW-SM AASHTO=

Remarks

Sample No.: SB-12 **Source of Sample:** CDM-Sherwin Williams **Date:** 2-24-03
Location: **Elev./Depth:** 35

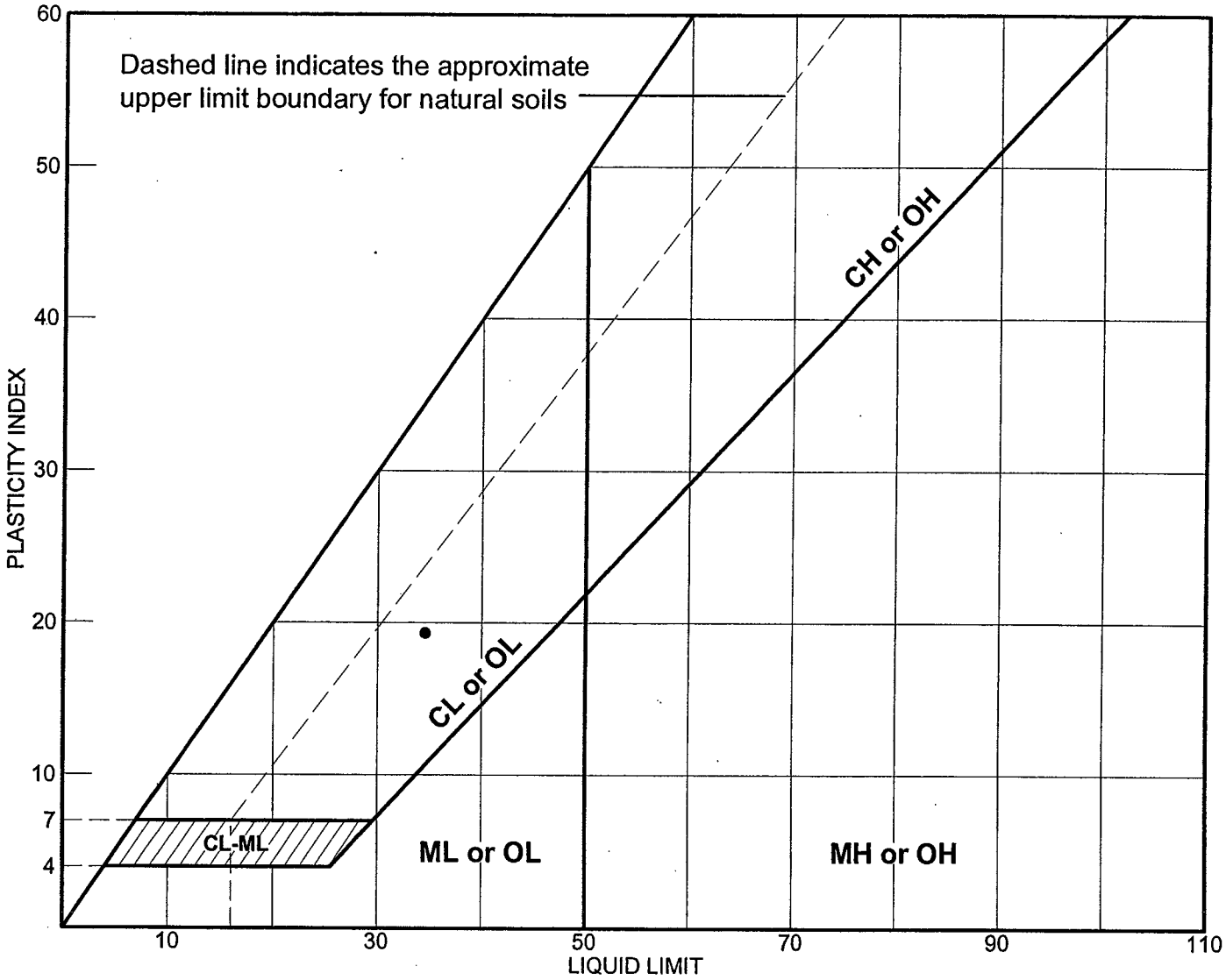
Smith-Emery Company

Client: CDM Inc.
Project: Sherwin Williams (CDM Project No. 13452-35952-TK16.Design)

Project No: 2058-2 **Plate** 3

ATTERBERG LIMITS PLASTICITY CHARTS

LIQUID AND PLASTIC LIMITS TEST REPORT



SOIL DATA								
SYMBOL	SOURCE	SAMPLE NO.	DEPTH (ft.)	NATURAL WATER CONTENT (%)	PLASTIC LIMIT (%)	LIQUID LIMIT (%)	PLASTICITY INDEX (%)	USCS
●	CDM-Sherwin Williams	SB-11	18.5		15.3	34.6	19.3	

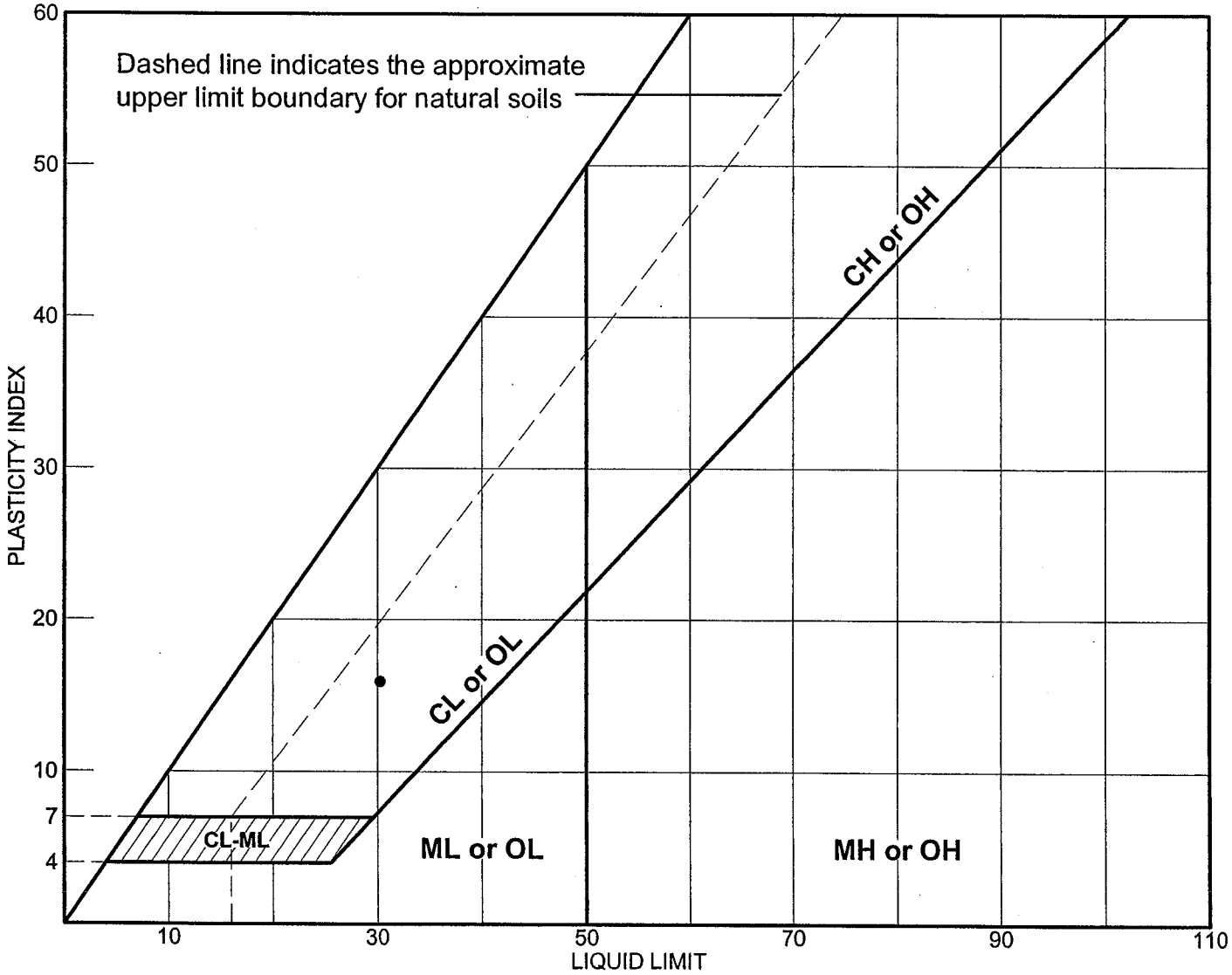
Smith-Emery Company

Client: CDM Inc.

Project: Sherwin Williams (CDM Project No. 13452-35952-TK16.Design)

Project No.: 2058-2 **Plate** 4

LIQUID AND PLASTIC LIMITS TEST REPORT



SOIL DATA								
SYMBOL	SOURCE	SAMPLE NO.	DEPTH (ft.)	NATURAL WATER CONTENT (%)	PLASTIC LIMIT (%)	LIQUID LIMIT (%)	PLASTICITY INDEX (%)	USCS
●	CDM-Sherwin Williams	SB-11	27		14.4	30.3	15.9	

Smith-Emery Company

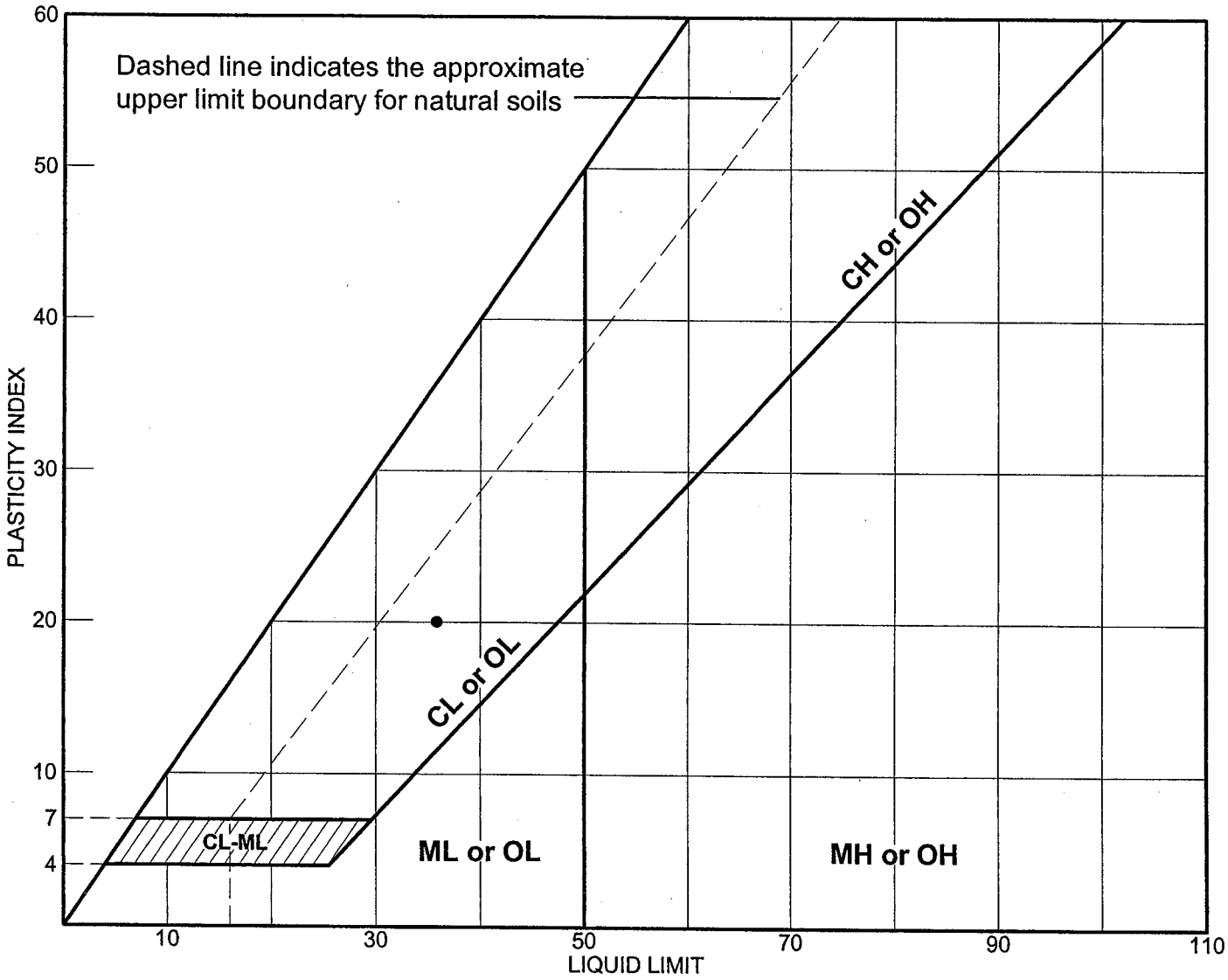
Client: CDM Inc.

Project: Sherwin Williams (CDM Project No. 13452-35952-TK16.Design)

Project No.: 2058-2

Plate 5

LIQUID AND PLASTIC LIMITS TEST REPORT



SOIL DATA								
SYMBOL	SOURCE	SAMPLE NO.	DEPTH (ft.)	NATURAL WATER CONTENT (%)	PLASTIC LIMIT (%)	LIQUID LIMIT (%)	PLASTICITY INDEX (%)	USCS
●	CDM-Sherwin Williams	SB-11	40		15.9	35.9	20.0	

Smith-Emery Company

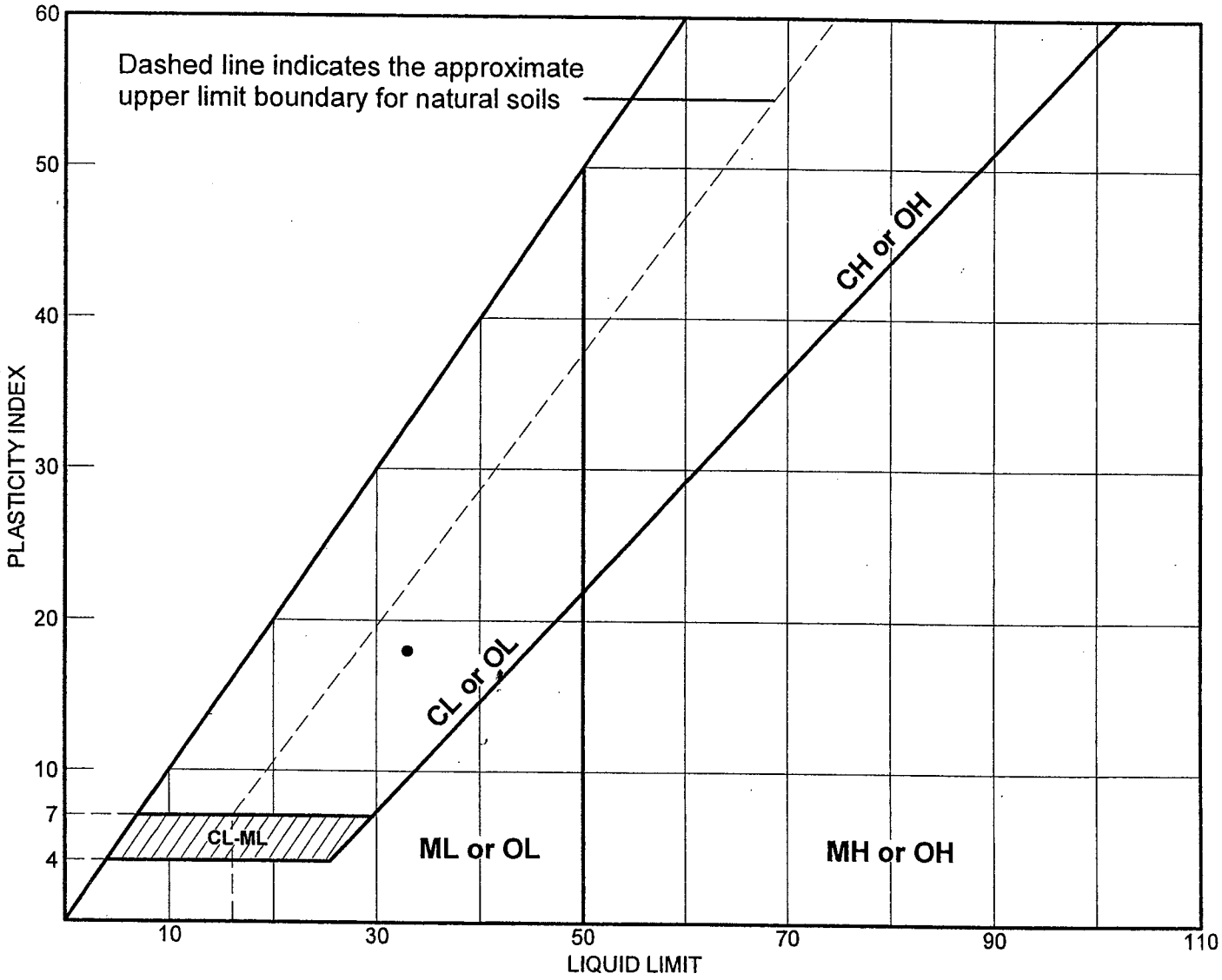
Client: CDM Inc.

Project: Sherwin Williams (CDM Project No. 13452-35952-TK16.Design)

Project No.: 2058-2

Plate 6

LIQUID AND PLASTIC LIMITS TEST REPORT



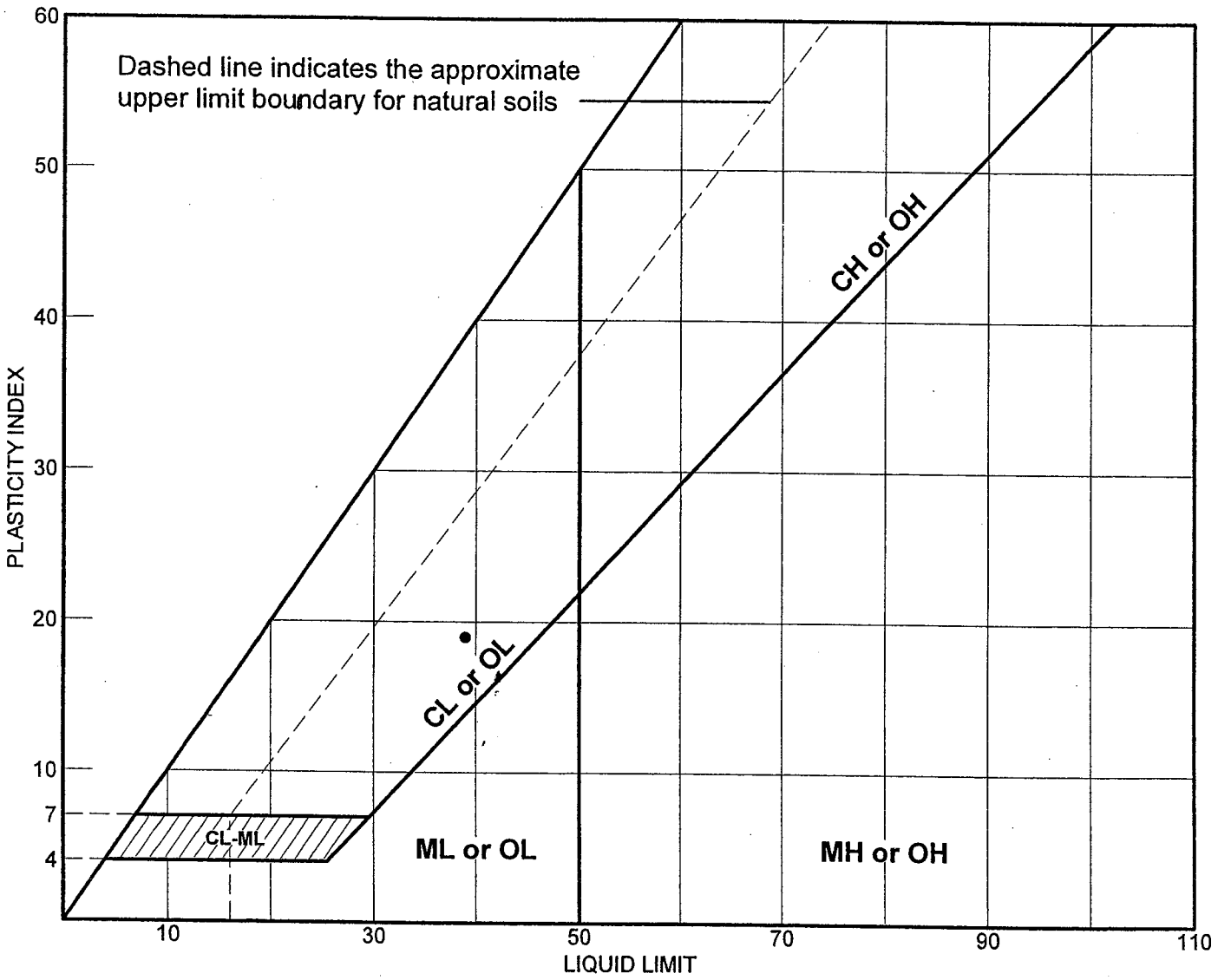
SOIL DATA								
SYMBOL	SOURCE	SAMPLE NO.	DEPTH (ft.)	NATURAL WATER CONTENT (%)	PLASTIC LIMIT (%)	LIQUID LIMIT (%)	PLASTICITY INDEX (%)	USCS
●	Sherwin	SB11-45	45 ft.		15	33	18	CL

Smith-Emery Company

Client: SHERWIN WILLIAMS
Project: 13452-35952-TK16.DESIGN
Project No.: 2058-2

Plate 7

LIQUID AND PLASTIC LIMITS TEST REPORT

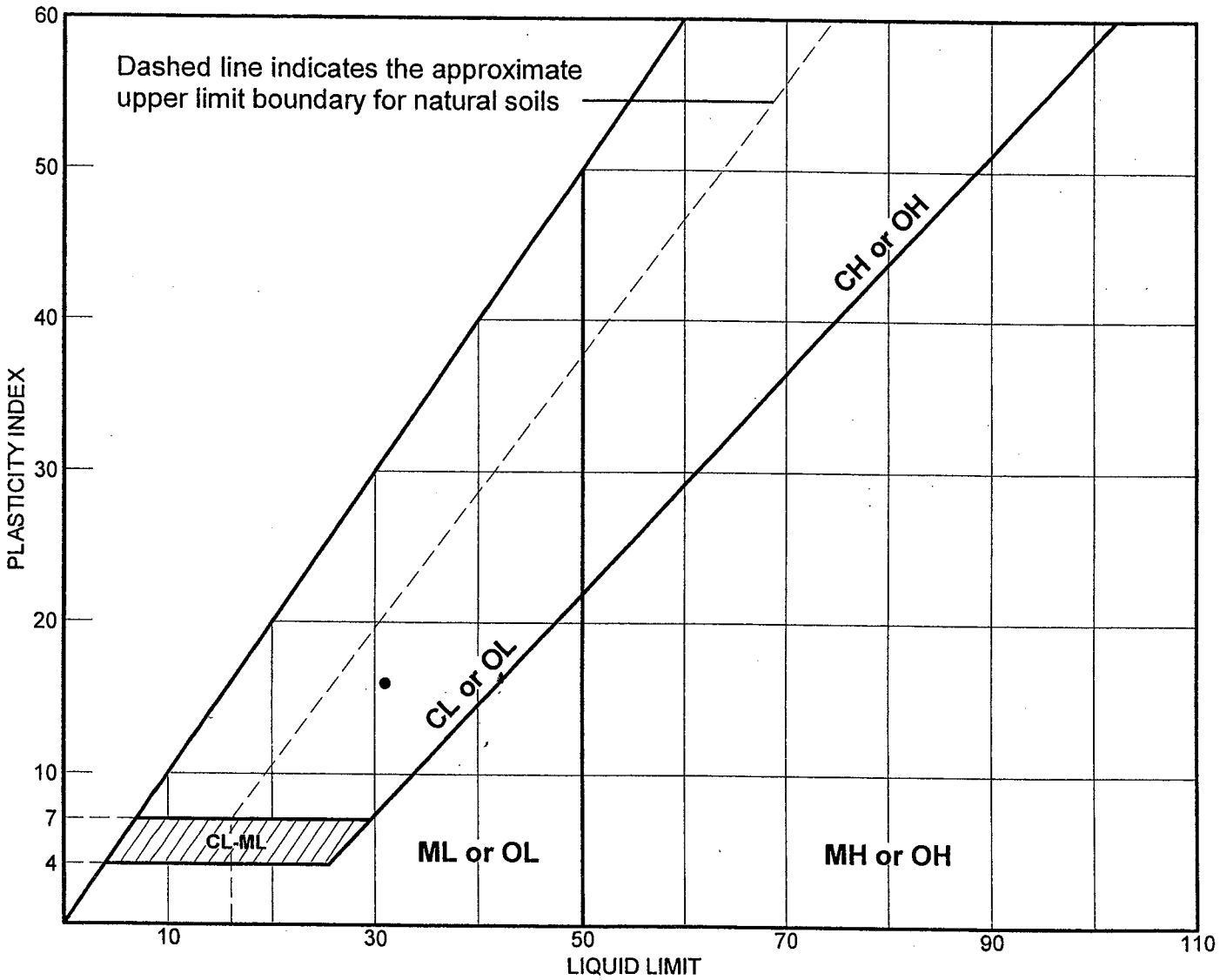


SOIL DATA								
SYMBOL	SOURCE	SAMPLE NO.	DEPTH (ft.)	NATURAL WATER CONTENT (%)	PLASTIC LIMIT (%)	LIQUID LIMIT (%)	PLASTICITY INDEX (%)	USCS
●	Sherwin	SB11-65	65 ft.		20	39	19	CL

Smith-Emery Company

Client: SHERWIN WILLIAMS
Project: 13452-35952-TK16.DESIGN
Project No.: 2058-2
Plate 8

LIQUID AND PLASTIC LIMITS TEST REPORT

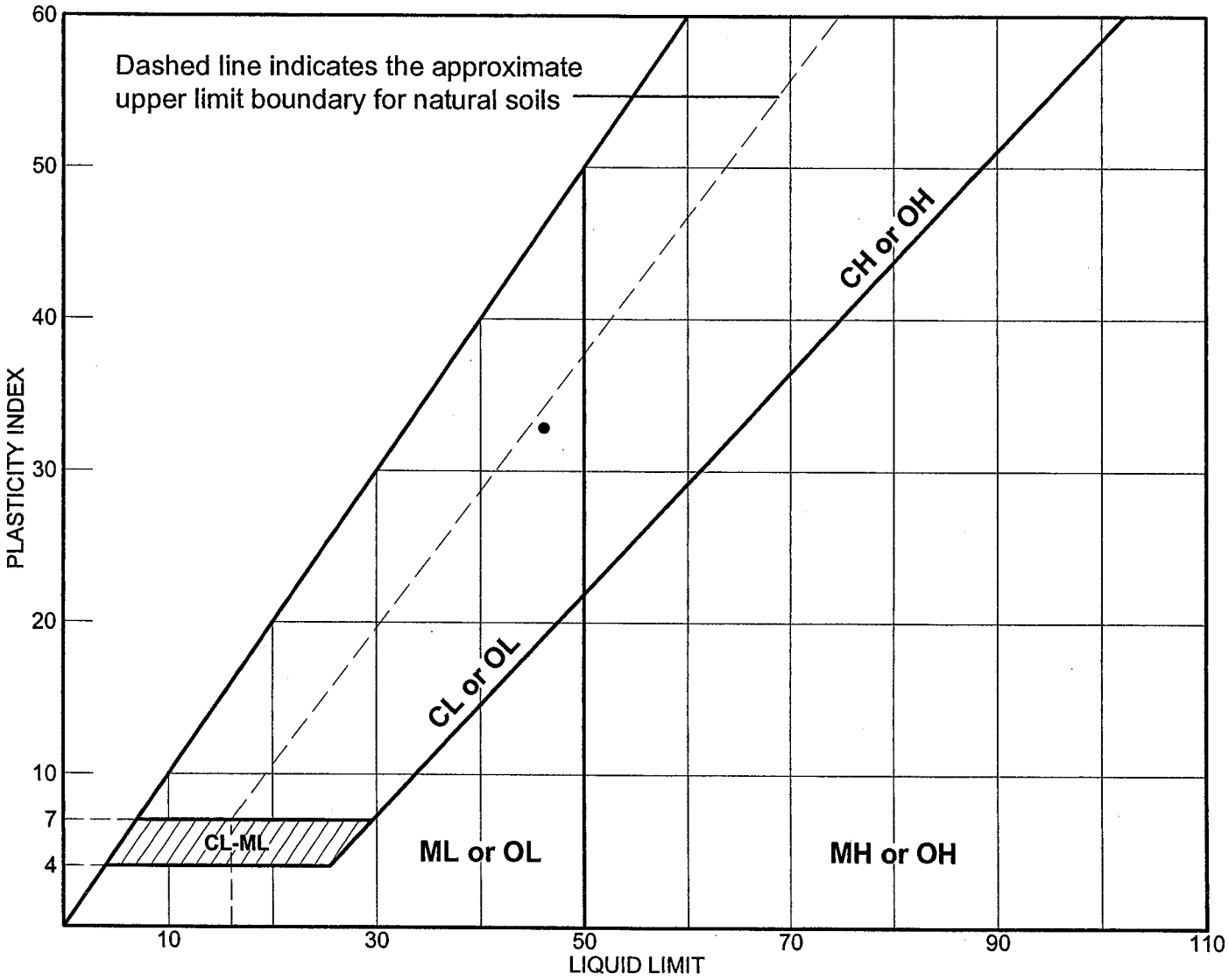


SOIL DATA								
SYMBOL	SOURCE	SAMPLE NO.	DEPTH (ft.)	NATURAL WATER CONTENT (%)	PLASTIC LIMIT (%)	LIQUID LIMIT (%)	PLASTICITY INDEX (%)	USCS
●	Sherwin	SB12-15	15 ft.		15	31	16	CL

Smith-Emery Company

Client: SHERWIN WILLIAMS
Project: 13452-35952-TK16.DESIGN
Project No.: 2058-2

LIQUID AND PLASTIC LIMITS TEST REPORT



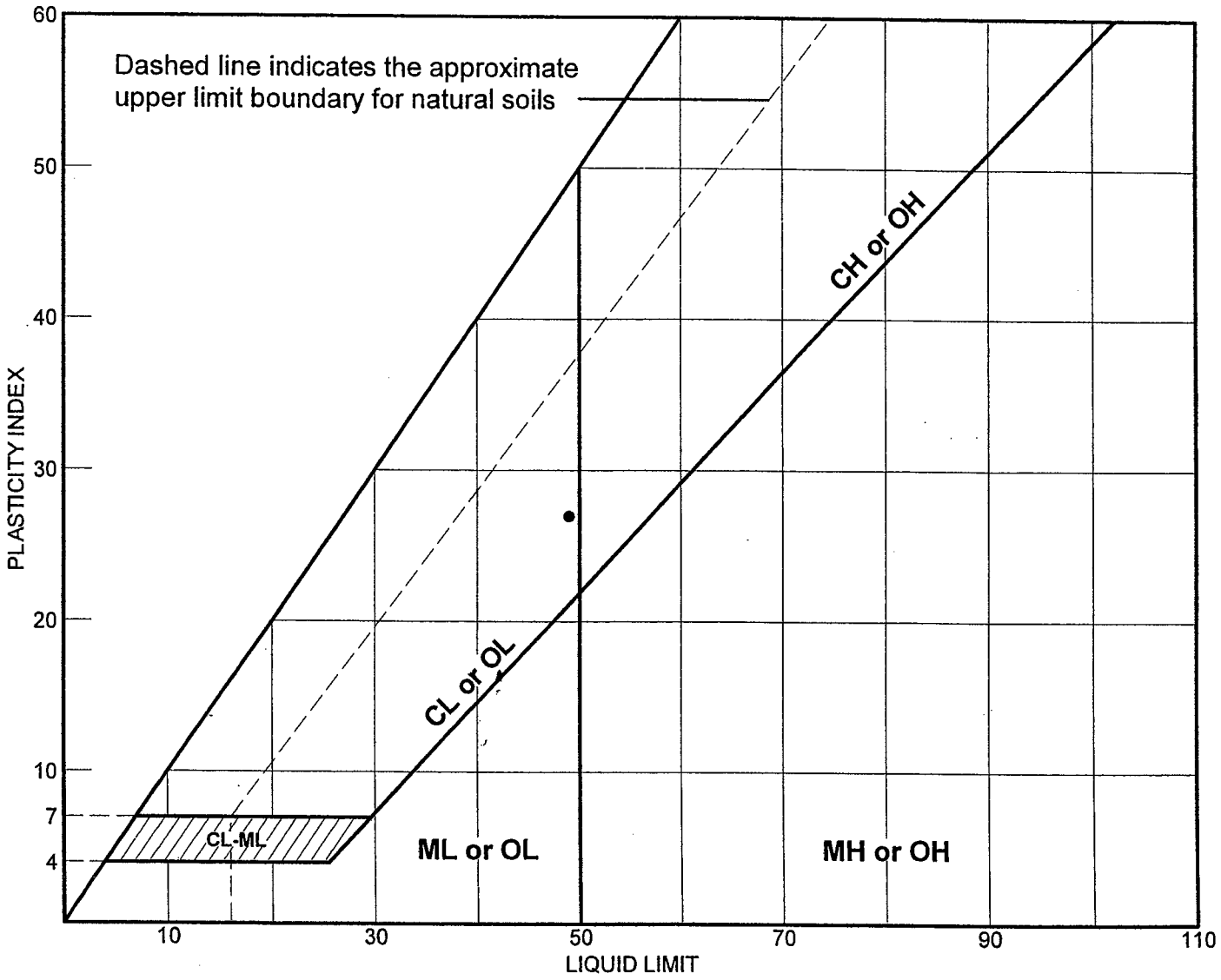
SOIL DATA								
SYMBOL	SOURCE	SAMPLE NO.	DEPTH (ft.)	NATURAL WATER CONTENT (%)	PLASTIC LIMIT (%)	LIQUID LIMIT (%)	PLASTICITY INDEX (%)	USCS
●	CDM-Sherwin Williams	SB-12	25		13.4	46.2	32.8	

Smith-Emery Company

Client: CDM Inc.
Project: Sherwin Williams (CDM Project No. 13452-35952-TK16.Design)

Project No.: 2058-2 **Plate** 10

LIQUID AND PLASTIC LIMITS TEST REPORT



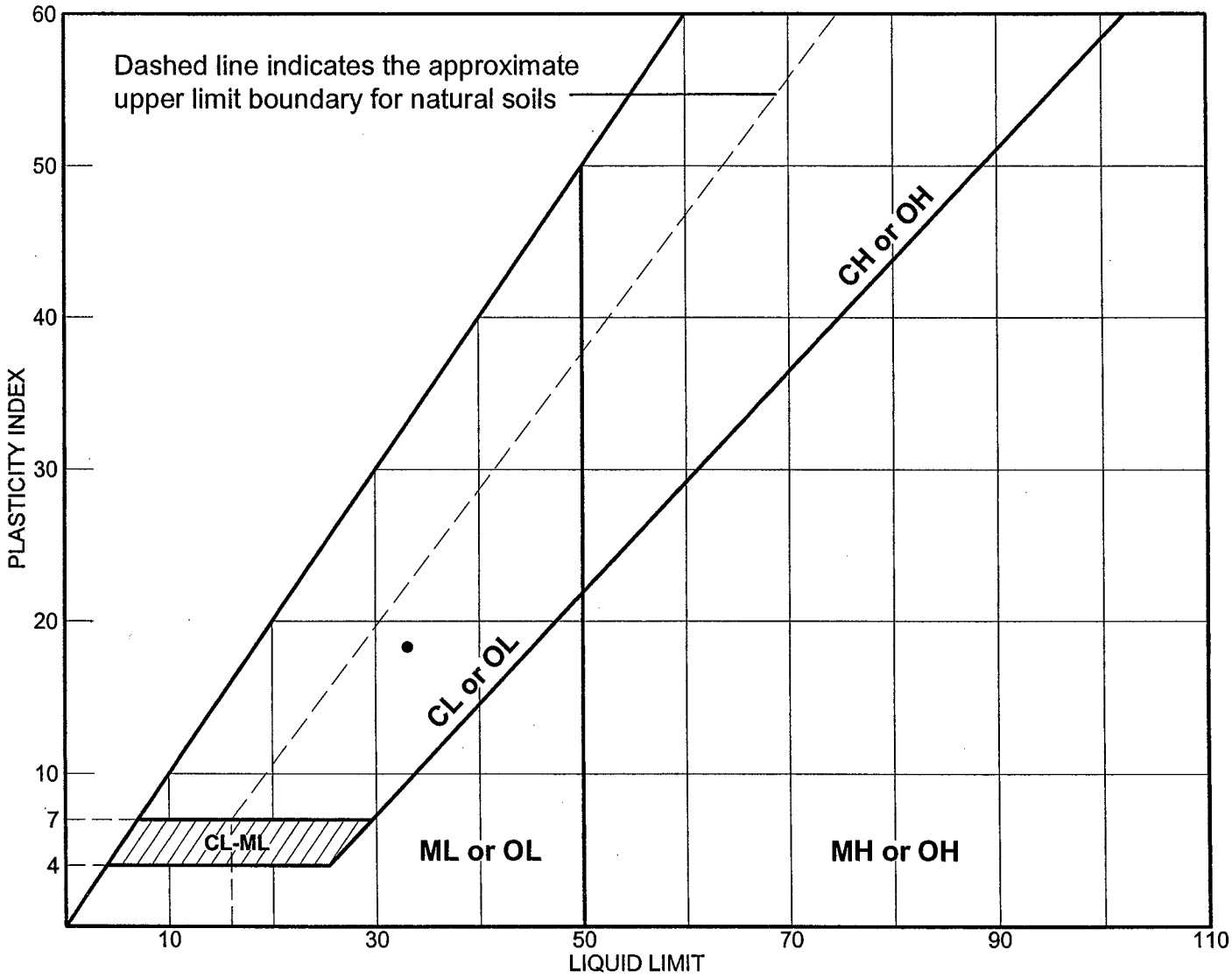
SOIL DATA								
SYMBOL	SOURCE	SAMPLE NO.	DEPTH (ft.)	NATURAL WATER CONTENT (%)	PLASTIC LIMIT (%)	LIQUID LIMIT (%)	PLASTICITY INDEX (%)	USCS
●	Sherwin	SB12-30	30 ft.		22	49	27	CL

Smith-Emery Company

Client: SHERWIN WILLIAMS
Project: 13452-35952-TK16.DESIGN

Project No.: 2058-2 **Plate** 11

LIQUID AND PLASTIC LIMITS TEST REPORT



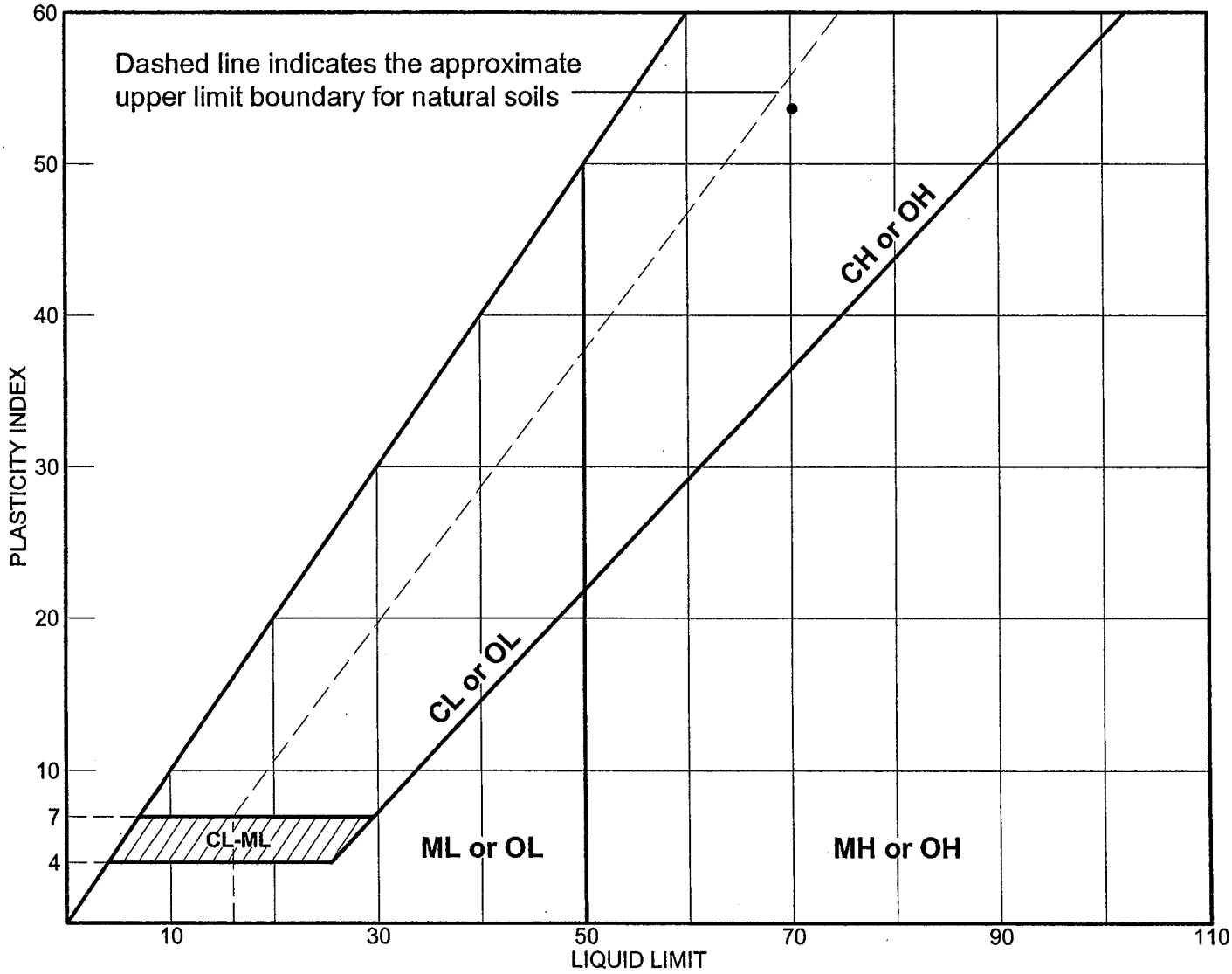
SOIL DATA								
SYMBOL	SOURCE	SAMPLE NO.	DEPTH (ft.)	NATURAL WATER CONTENT (%)	PLASTIC LIMIT (%)	LIQUID LIMIT (%)	PLASTICITY INDEX (%)	USCS
●	CDM-Sherwin Williams	SB-12	45		14.8	33.1	18.3	

Smith-Emery Company

Client: CDM Inc.
Project: Sherwin Williams (CDM Project No. 13452-35952-TK16.Design)

Project No.: 2058-2 **Plate** 12

LIQUID AND PLASTIC LIMITS TEST REPORT



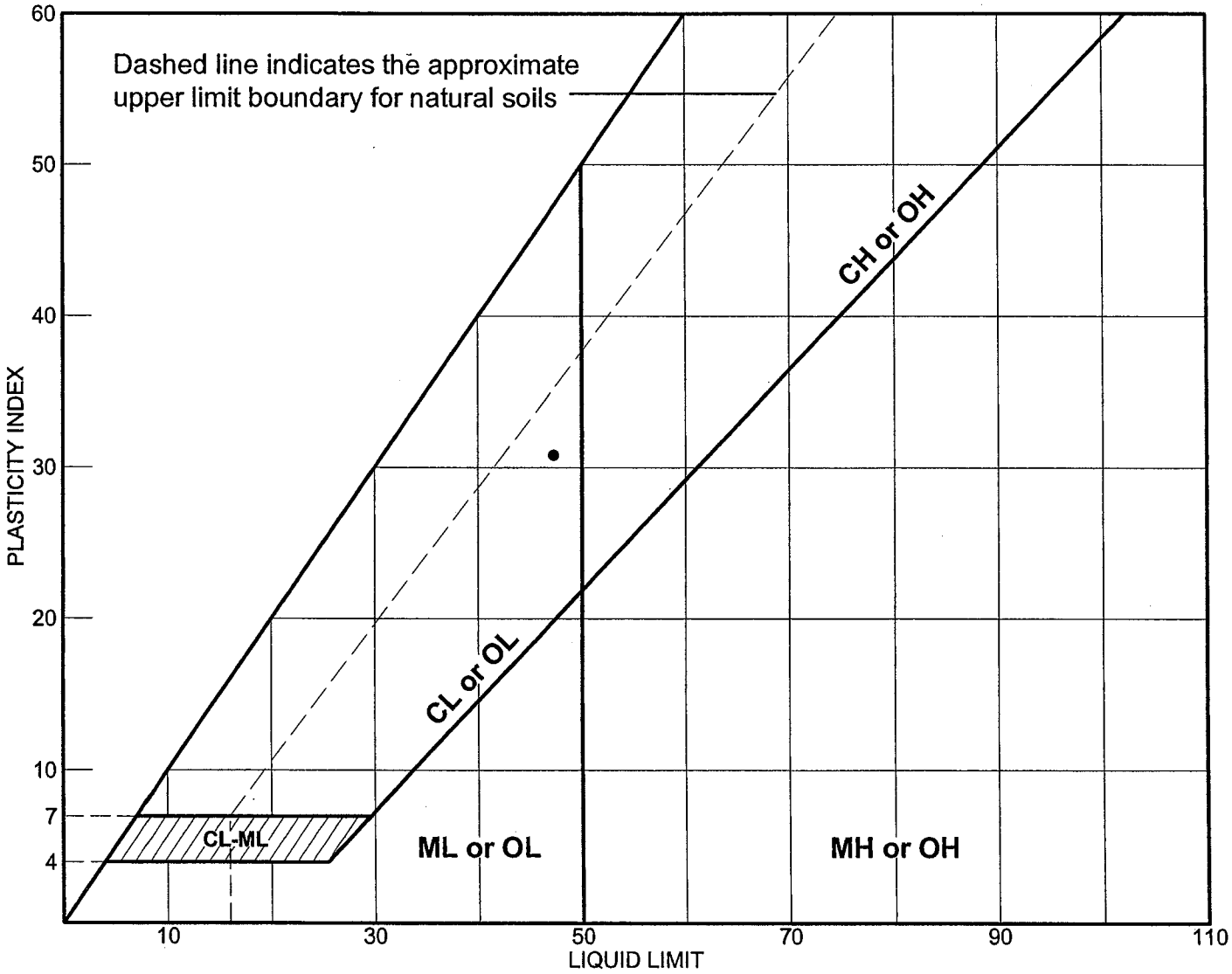
SOIL DATA								
SYMBOL	SOURCE	SAMPLE NO.	DEPTH (ft.)	NATURAL WATER CONTENT (%)	PLASTIC LIMIT (%)	LIQUID LIMIT (%)	PLASTICITY INDEX (%)	USCS
●	CDM-Sherwin Williams	SB-12	60		16.6	70.2	53.6	

Smith-Emery Company

Client: CDM Inc.
Project: Sherwin Williams (CDM Project No. 13452-35952-TK16.Design)

Project No.: 2058-2 **Plate** 13

LIQUID AND PLASTIC LIMITS TEST REPORT



SOIL DATA								
SYMBOL	SOURCE	SAMPLE NO.	DEPTH (ft.)	NATURAL WATER CONTENT (%)	PLASTIC LIMIT (%)	LIQUID LIMIT (%)	PLASTICITY INDEX (%)	USCS
●	CDM-Sherwin Williams	SB-12	65		16.5	47.3	30.8	

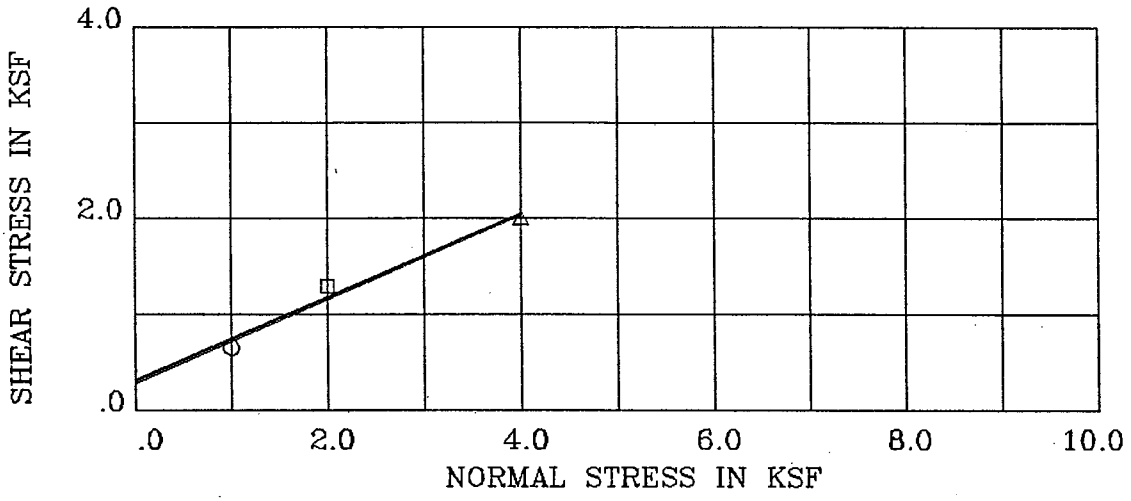
Smith-Emery Company

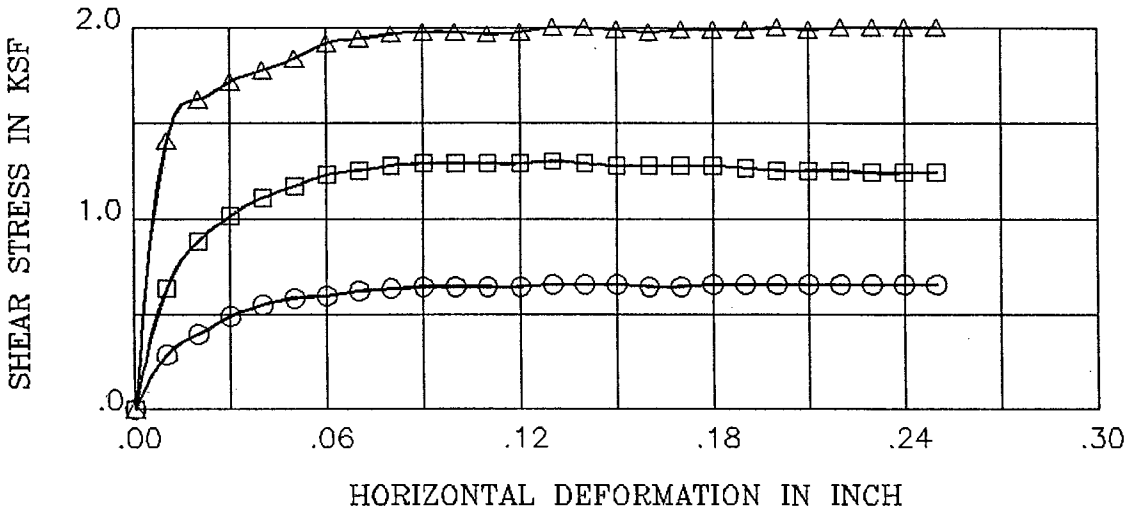
Client: CDM Inc.

Project: Sherwin Williams (CDM Project No. 13452-35952-TK16.Design)

Project No.: 2058-2 **Plate** 14

DIRECT SHEAR TESTS



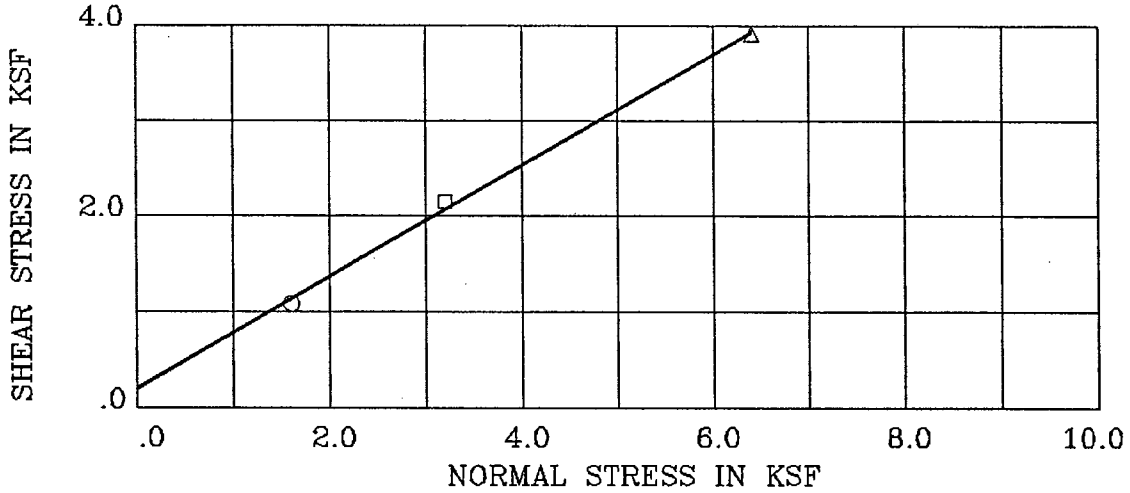


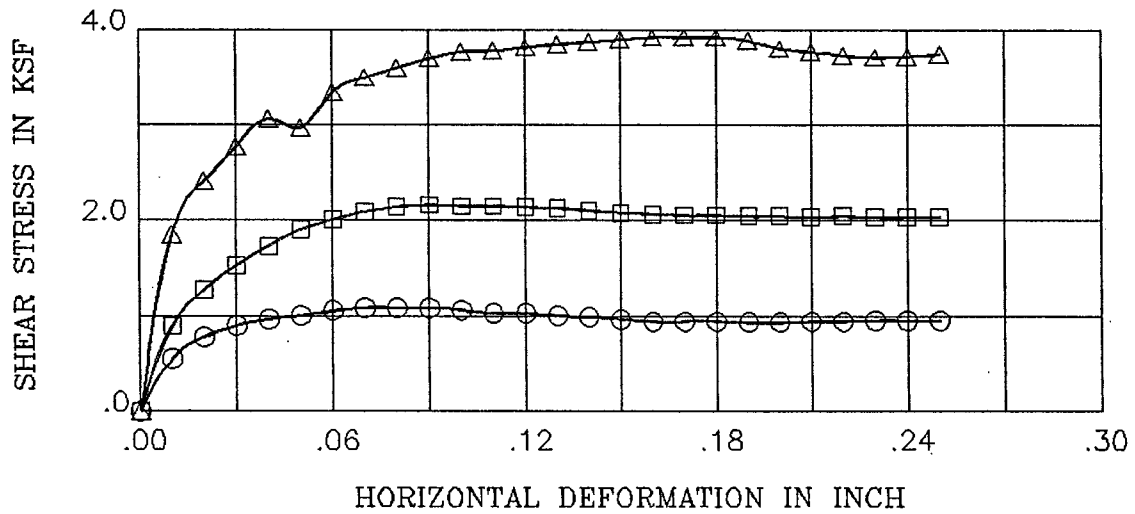
BORING/SAMPLE : SB11-18.5/ DEPTH (ft) : 18.5
DESCRIPTION : GRAY CLAYEY SILT
STRENGTH INTERCEPT (C) : .303 KSF
FRICTION ANGLE (PHI) : 23.5 DEG
(PEAK STRENGTH)

SYMBOL	MOISTURE CONTENT (%)	DRY DENSITY (pcf)	VOID RATIO	NORMAL STRESS (ksf)	PEAK SHEAR (ksf)	RESIDUAL SHEAR (ksf)
○	25.8	102.5	.644	1.00	.66	.65
□	25.0	103.8	.623	2.00	1.30	1.24
△	27.3	100.7	.673	4.00	2.00	1.98

Remark : INUNDATED

Project No.2058-2	Project Name:S.WILLIAMS 13452-35952-TK16.DESIGN
Smith-Emery Company	DIRECT SHEAR TEST Plate No.: 15



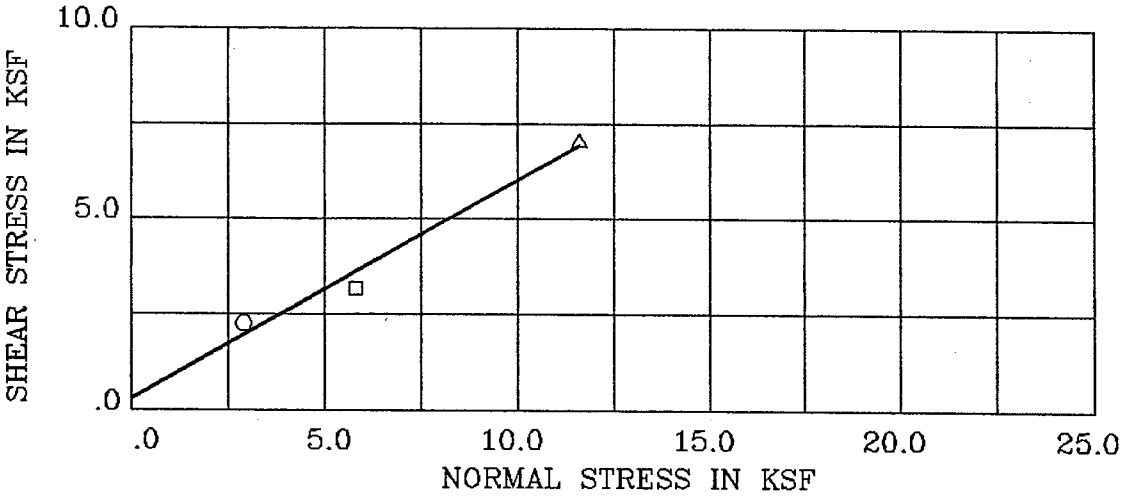


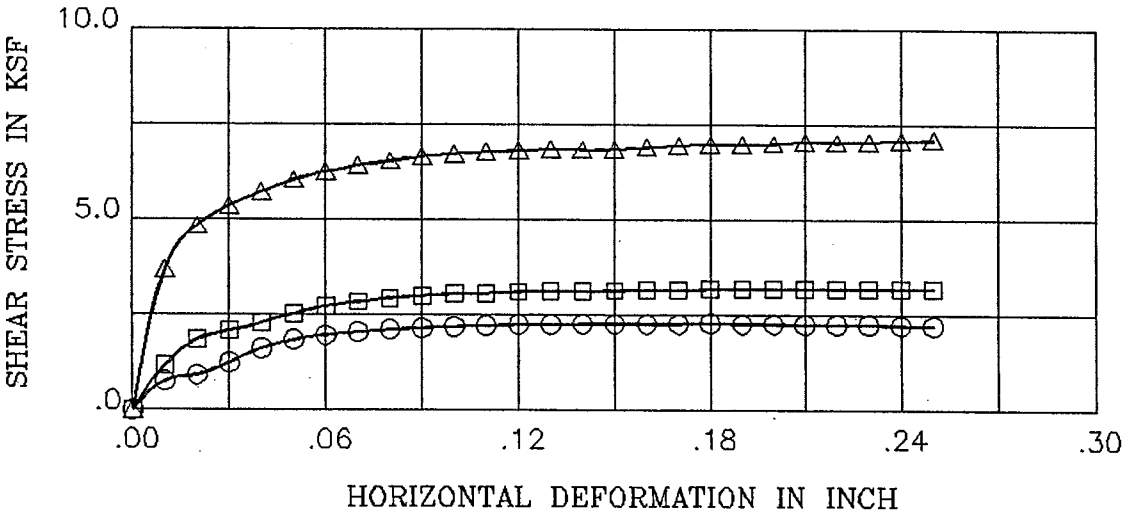
BORING/SAMPLE : SB11-27 / DEPTH (ft) : 27.0
DESCRIPTION : BROWN CLAYEY SAND
STRENGTH INTERCEPT (C) : .204 KSF
FRICTION ANGLE (PHI) : 30.3 DEG
(PEAK STRENGTH)

SYMBOL	MOISTURE CONTENT (%)	DRY DENSITY (pcf)	VOID RATIO	NORMAL STRESS (ksf)	PEAK SHEAR (ksf)	RESIDUAL SHEAR (ksf)
○	19.8	103.6	.626	1.60	1.09	.93
□	19.9	103.8	.623	3.20	2.15	2.02
△	20.8	104.5	.612	6.40	3.92	3.70

Remark : INUNDATED

Project No.2058-2	Project Name:S.WILLIAMS 13452-35952-TK16.DESIGN
Smith-Emery Company	DIRECT SHEAR TEST Plate No.: 16



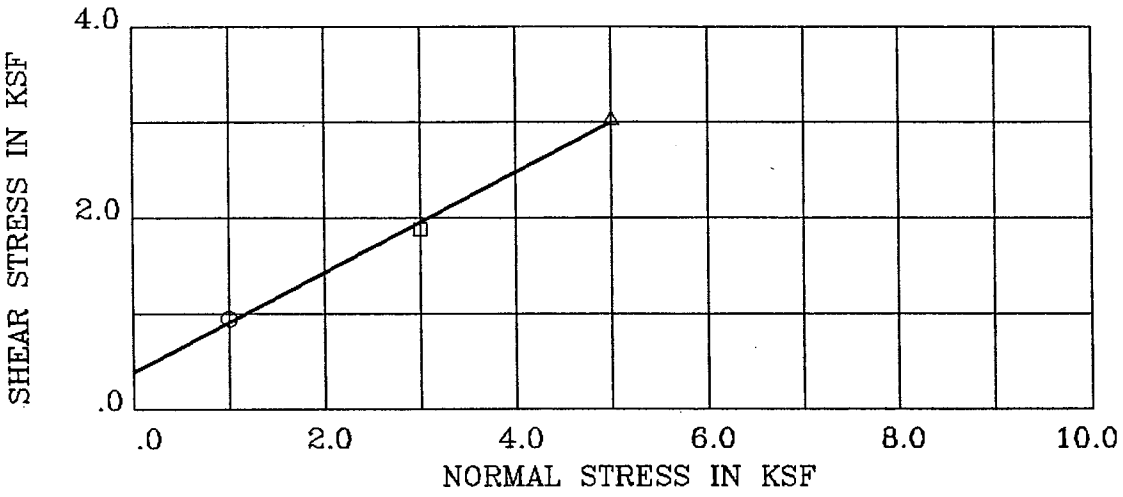


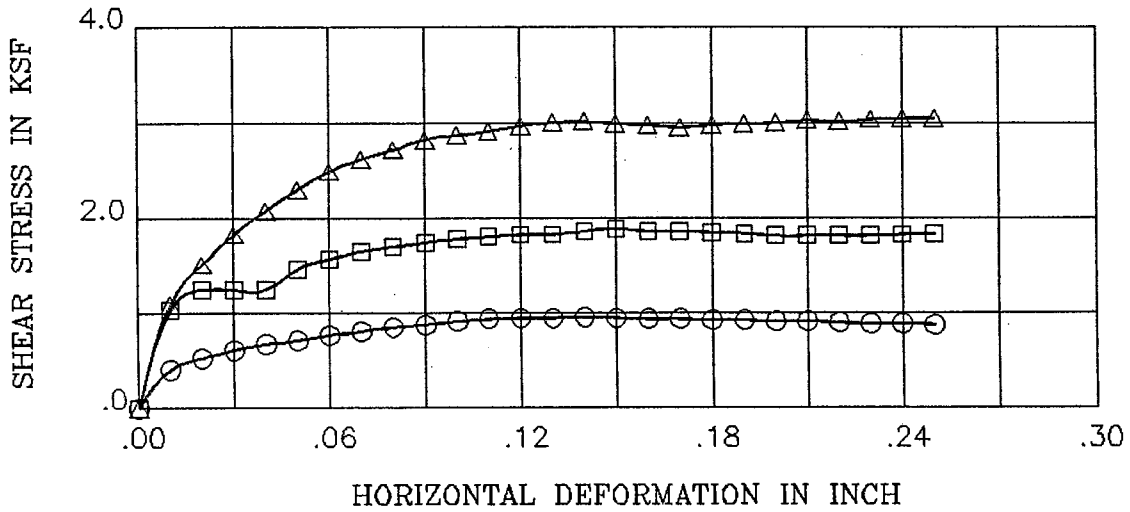
BORING/SAMPLE : SB11-45 / DEPTH (ft) : 45.0
DESCRIPTION : BROWN SILTY CLAY WITH GRAVEL
STRENGTH INTERCEPT (C) : .298 KSF
FRICTION ANGLE (PHI) : 29.8 DEG
(PEAK STRENGTH)

SYMBOL	MOISTURE CONTENT (%)	DRY DENSITY (pcf)	VOID RATIO	NORMAL STRESS (ksf)	PEAK SHEAR (ksf)	RESIDUAL SHEAR (ksf)
○	20.2	108.7	.550	2.90	2.26	2.20
□	19.8	110.0	.532	5.80	3.17	3.15
△	14.2	121.1	.391	11.60	7.09	7.09

Remark : INUNDATED

Project No.2058-2	Project Name:S.WILLIAMS 13452-35952-TK16.DESIGN
Smith-Emery Company	DIRECT SHEAR TEST Plate No.: 17



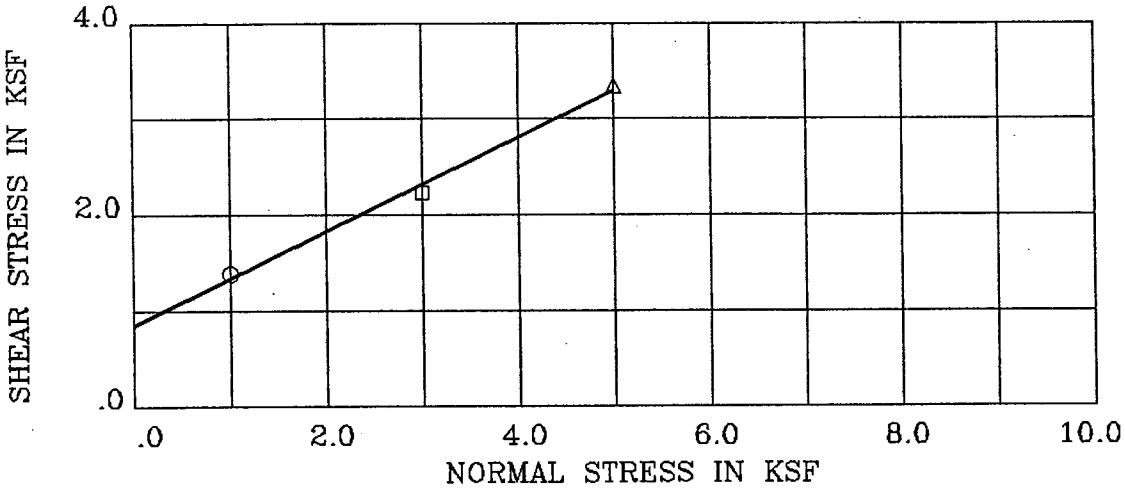


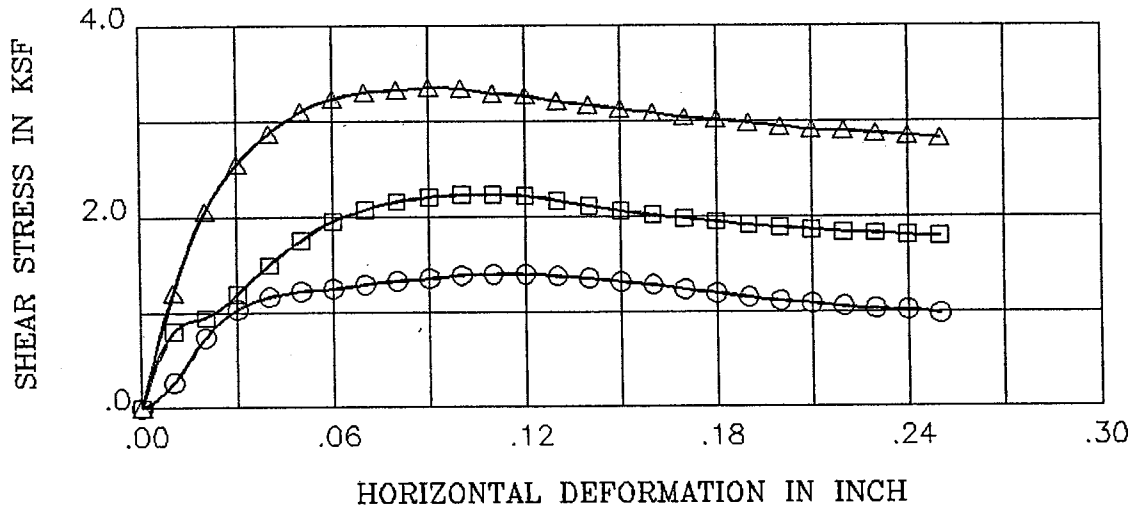
BORING/SAMPLE : SB12-15 / DEPTH (ft) : 15.0
DESCRIPTION : BROWN SILTY CLAY
STRENGTH INTERCEPT (C) : .388 KSF
FRICTION ANGLE (PHI) : 27.7 DEG
(PEAK STRENGTH)

SYMBOL	MOISTURE CONTENT (%)	DRY DENSITY (pcf)	VOID RATIO	NORMAL STRESS (ksf)	PEAK SHEAR (ksf)	RESIDUAL SHEAR (ksf)
○	20.9	107.2	.572	1.00	.95	.87
□	21.7	106.7	.579	3.00	1.88	1.81
△	20.9	107.7	.565	5.00	3.05	3.05

Remark : INUNDATED

Project No.2058-2	Project Name:S.WILLIAMS 13452-35952-TK16.DESIGN
Smith-Emery Company	DIRECT SHEAR TEST Plate No.: 18





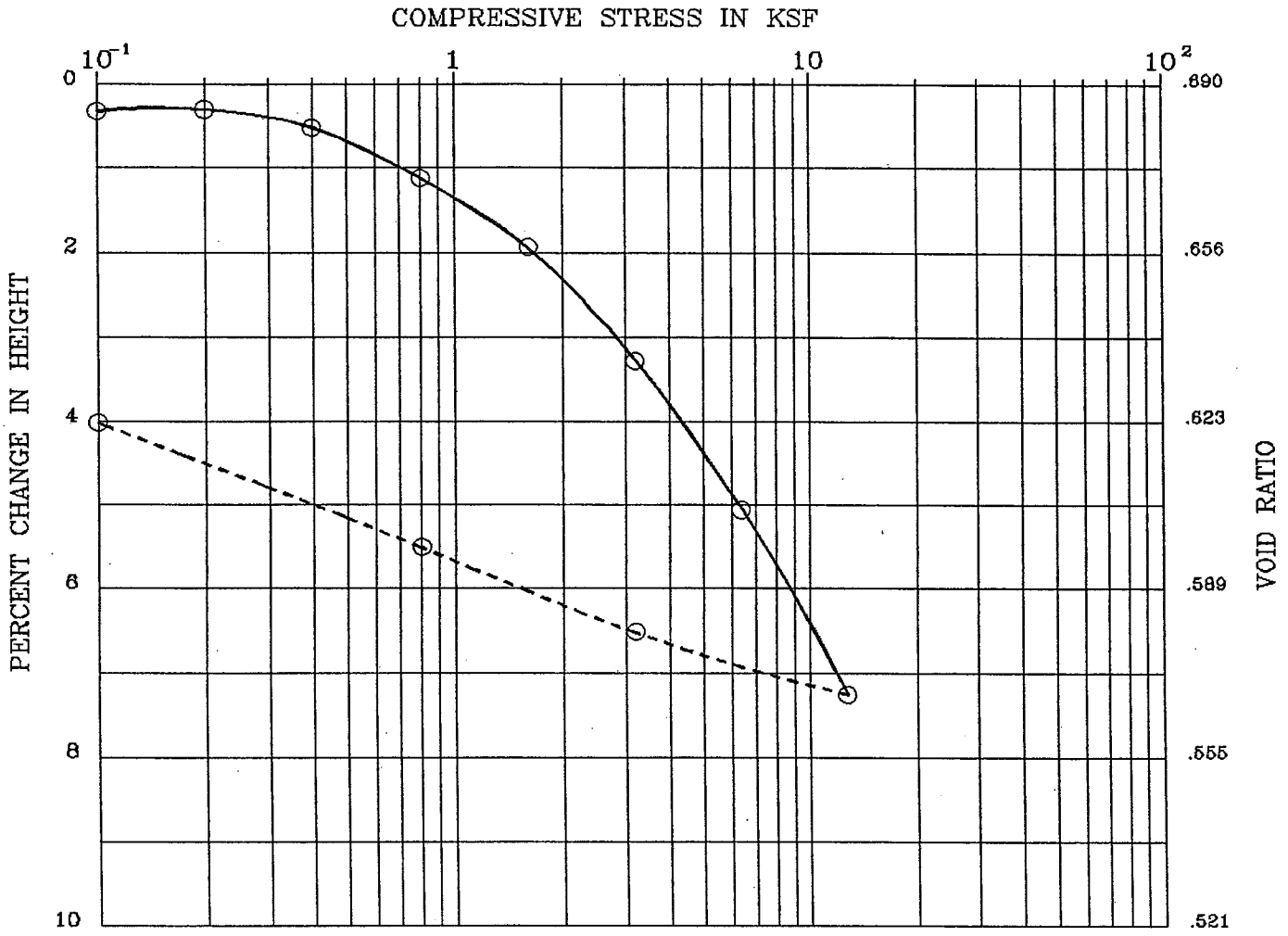
BORING/SAMPLE : SB12-30 / DEPTH (ft) : 30.0
DESCRIPTION : BROWN SILTY CLAY
STRENGTH INTERCEPT (C) : .859 KSF
FRICTION ANGLE (PHI) : 26.0 DEG
(PEAK STRENGTH)

SYMBOL	MOISTURE CONTENT (%)	DRY DENSITY (pcf)	VOID RATIO	NORMAL STRESS (ksf)	PEAK SHEAR (ksf)	RESIDUAL SHEAR (ksf)
○	24.8	102.0	.651	1.00	1.39	.98
□	22.9	104.3	.616	3.00	2.23	1.79
△	22.5	105.1	.603	5.00	3.35	2.82

Remark : INUNDATED

Project No.2058-2	Project Name:S.WILLIAMS 13452-35952-TK16.DESIGN
Smith-Emery Company	DIRECT SHEAR TEST Plate No.: 19

CONSOLIDATION TESTS

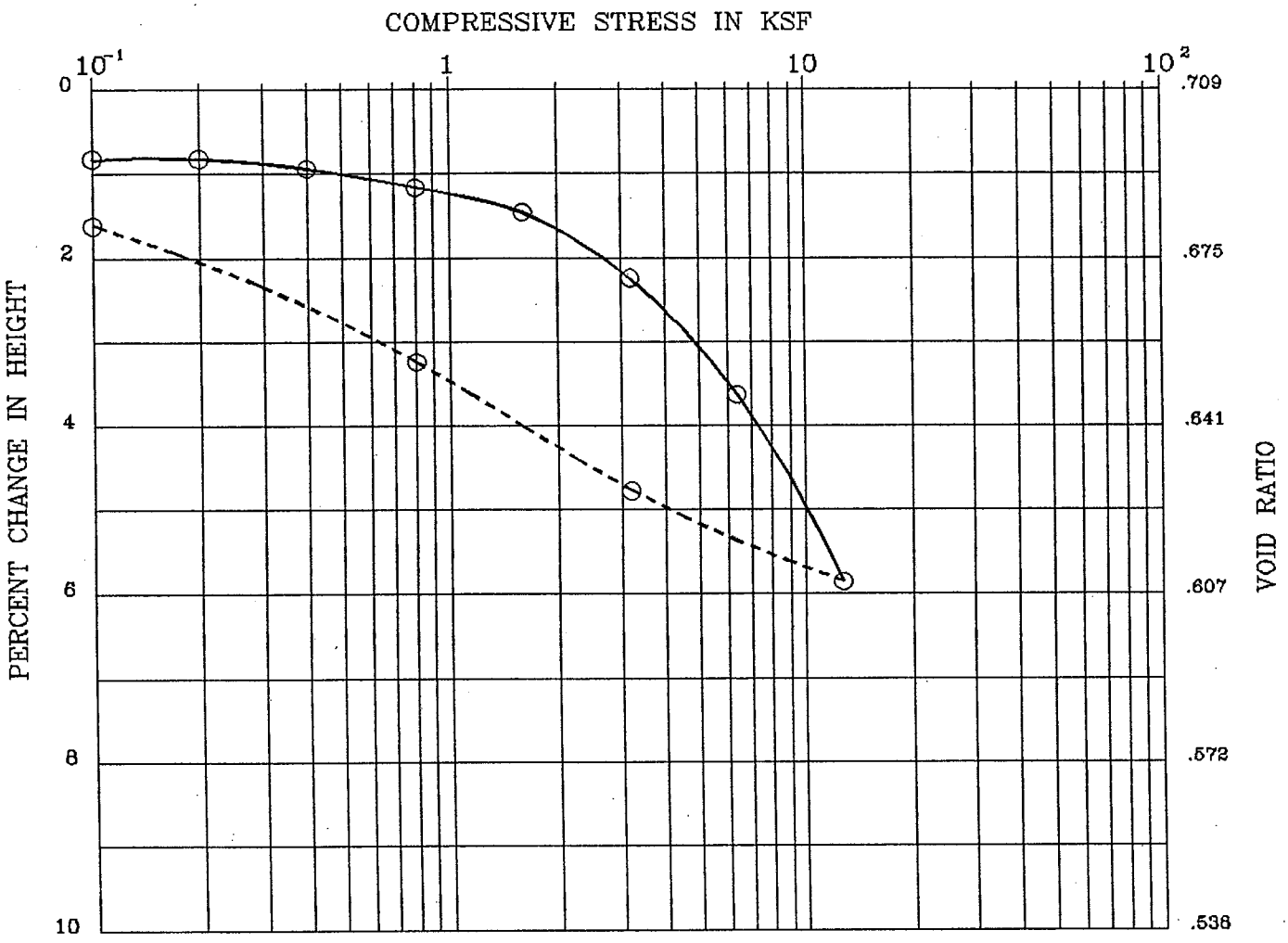


BORING	: SB11-35 /	DESCRIPTION	: BROWN CLAYEY SILT
DEPTH (ft)	: 35.0	LIQUID LIMIT	:
SPEC. GRAVITY	: 2.78	PLASTIC LIMIT	:

	MOISTURE CONTENT (%)	DRY DENSITY (pcf)	PERCENT SATURATION	VOID RATIO
INITIAL	24.2	102.6	98	.690
FINAL	22.4	106.9	100	.623

Remark : INUNDATED AT 0.1 KSF

Project No.2058-2	S.WILLIAMS 13452-35952-TK16.DESN
SMITH EMERY	CONSOLIDATION TEST Plate No. 20



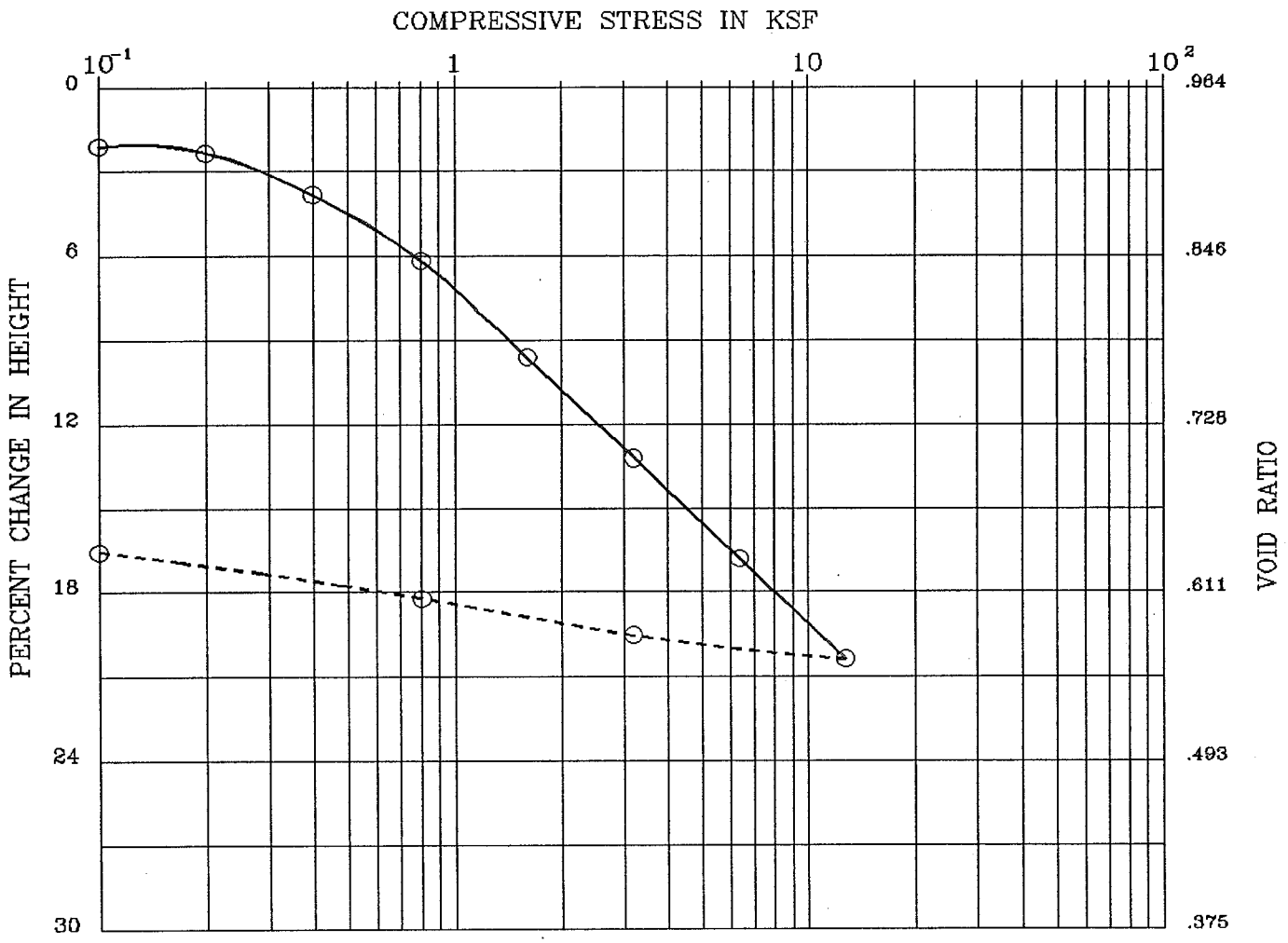
BORING : SB11-65 /
DEPTH (ft) : 65.0
SPEC. GRAVITY : 2.81

DESCRIPTION : BRN SILTY CLAY
LIQUID LIMIT :
PLASTIC LIMIT :

	MOISTURE CONTENT (%)	DRY DENSITY (pcf)	PERCENT SATURATION	VOID RATIO
INITIAL	24.0	102.7	95	.709
FINAL	24.2	104.4	100	.682

Remark : INUNDATED AT 0.1 KSF

Project No.2058-2	S.WILLIAMS 13452-35952-TK16.DESN
SMITH EMERY	CONSOLIDATION TEST Plate No. 21



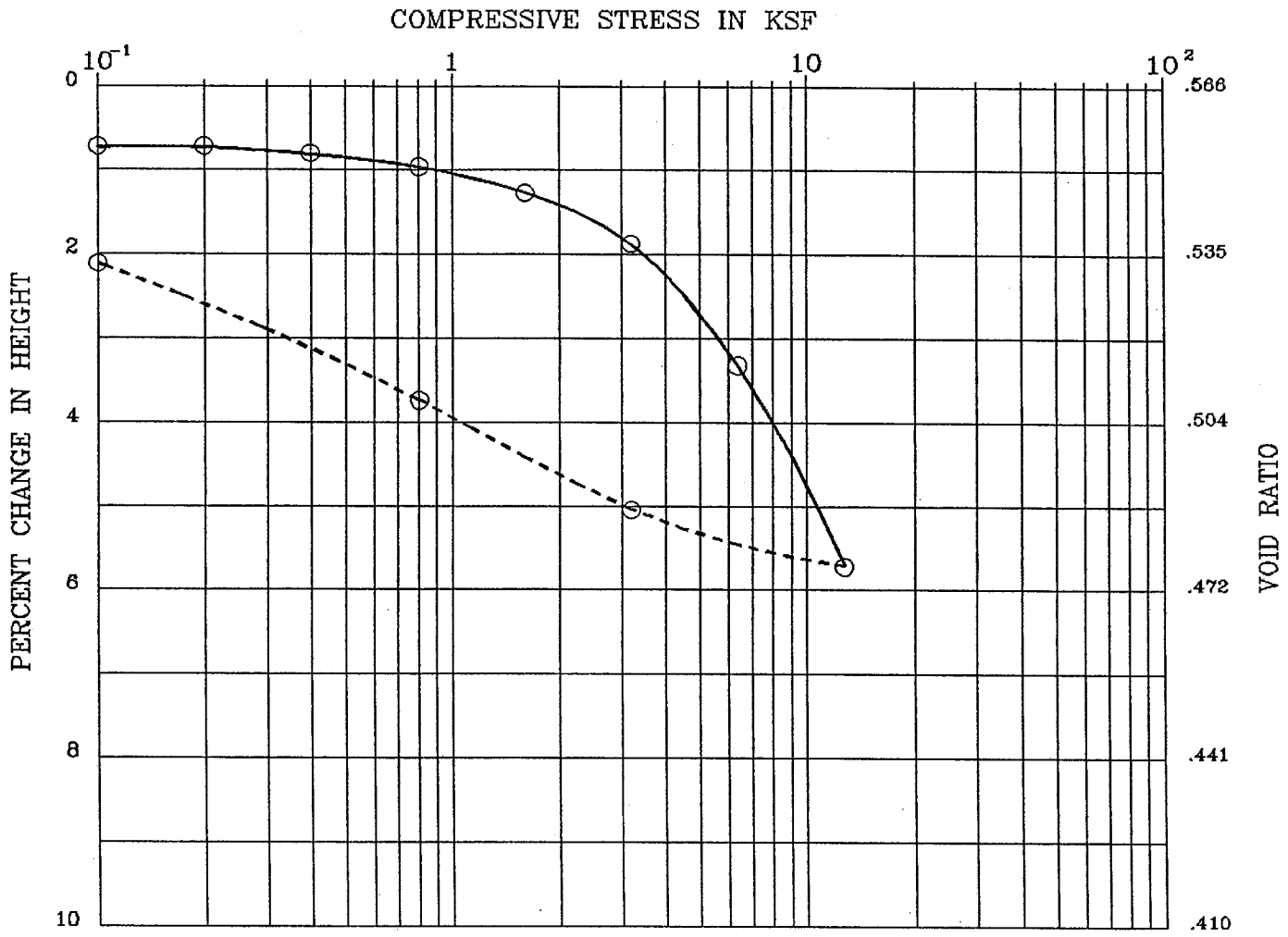
BORING : SB12-25 /
DEPTH (ft) : 25.0
SPEC. GRAVITY : 2.70

DESCRIPTION : BROWN SILTY CLAY
LIQUID LIMIT :
PLASTIC LIMIT :

	MOISTURE CONTENT (%)	DRY DENSITY (pcf)	PERCENT SATURATION	VOID RATIO
INITIAL	34.3	85.9	96	.964
FINAL	23.1	102.9	98	.640

Remark : INUNDATED AT 0.8 KSF

Project No.2058-2	SHERWIN WILLIAMS .
SMITH EMERY	CONSOLIDATION TEST Plate No. 22



BORING : SB12-40 /
DEPTH (ft) : 40.0
SPEC. GRAVITY : 2.77

DESCRIPTION : BRN SILTY CLAY
LIQUID LIMIT :
PLASTIC LIMIT :

	MOISTURE CONTENT (%)	DRY DENSITY (pcf)	PERCENT SATURATION	VOID RATIO
INITIAL	18.7	110.3	92	.566
FINAL	19.2	112.7	100	.533

Remark : INUNDATED AT 0.1 KSF

Project No.	S.WILLIAMS 13452-35952-TK16.DESN
SMITH EMERY	CONSOLIDATION TEST Plate No. 23

Appendix D
EQFAULT Summary

****
*   *
* E Q F A U L T *
*   *
* Version 3.00 *
*   *
****

DETERMINISTIC ESTIMATION OF
PEAK ACCELERATION FROM DIGITIZED FAULTS

JOB NUMBER: 13452

DATE: 04-17-2003

JOB NAME: s-w

CALCULATION NAME: Preliminary Sample Run Analysis

FAULT-DATA-FILE NAME: CDMGFLTE.DAT

SITE COORDINATES:
SITE LATITUDE: 37.8343
SITE LONGITUDE: 122.2872

SEARCH RADIUS: 70 mi

ATTENUATION RELATION: 23) Abrahamson & Silva (1995b/1997) Horiz.- Soil
UNCERTAINTY (M=Median, S=Sigma): M Number of Sigmas: 0.0
DISTANCE MEASURE: clodis
SCOND: 0
Basement Depth: 5.00 km Campbell SSR: Campbell SHR:
COMPUTE PEAK HORIZONTAL ACCELERATION

FAULT-DATA FILE USED: CDMGFLTE.DAT

MINIMUM DEPTH VALUE (km): 0.0

EQFAULT SUMMARY

DETERMINISTIC SITE PARAMETERS

ABBREVIATED FAULT NAME	APPROXIMATE DISTANCE mi (km)	ESTIMATED MAX. EARTHQUAKE EVENT: MAXIMUM EARTHQUAKE MAG.(Mw)	PEAK SITE ACCEL. g	EST. SITE INTENSITY MOD.MERC.
HAYWARD (Total Length)	3.1(5.0)	7.1	0.434	X
HAYWARD (North)	3.1(5.0)	6.9	0.420	X
HAYWARD (South)	11.0(17.7)	6.9	0.197	VIII
CALAVERAS (No.of Calaveras Res)	14.0(22.5)	6.8	0.158	VIII
SAN ANDREAS (Peninsula)	15.4(24.8)	7.1	0.161	VIII
SAN ANDREAS (1906)	15.4(24.8)	7.9	0.209	VIII
CONCORD - GREEN VALLEY	16.8(27.0)	6.9	0.141	VIII
SAN ANDREAS (North Coast)	16.8(27.0)	7.6	0.178	VIII
RODGERS CREEK	17.8(28.6)	7.0	0.139	VIII
SAN GREGORIO	18.4(29.6)	7.3	0.150	VIII
GREENVILLE	21.2(34.1)	6.9	0.116	VII
WEST NAPA	22.9(36.9)	6.5	0.093	VII
GREAT VALLEY 6	25.7(41.3)	6.7	0.112	VII
MONTE VISTA - SHANNON	27.5(44.2)	6.8	0.110	VII
GREAT VALLEY 5	28.6(46.0)	6.5	0.094	VII
POINT REYES	30.8(49.5)	6.8	0.100	VII
HAYWARD (SE Extension)	33.2(53.4)	6.4	0.063	VI
GREAT VALLEY 4	34.4(55.3)	6.6	0.083	VII
CALAVERAS (So.of Calaveras Res)	38.6(62.2)	6.2	0.044	VI
GREAT VALLEY 7	39.5(63.6)	6.7	0.076	VII
HUNTING CREEK - BERRYESSA	43.1(69.3)	6.9	0.062	VI
SAN ANDREAS (Santa Cruz Mtn.)	48.0(77.2)	7.0	0.060	VI
SARGENT	51.6(83.1)	6.8	0.050	VI
ZAYANTE-VERGELES	54.3(87.4)	6.8	0.048	VI
MAACAMA (South)	55.8(89.8)	6.9	0.049	VI
GREAT VALLEY 3	56.5(91.0)	6.8	0.058	VI
MONTEREY BAY - TULARCITOS	63.8(102.6)	7.1	0.061	VI
GREAT VALLEY 8	63.8(102.6)	6.6	0.046	VI
ORTIGALITA	67.2(108.1)	6.9	0.042	VI
COLLAYOMI	68.7(110.6)	6.5	0.032	V
SAN ANDREAS (Pajaro)	68.8(110.8)	6.8	0.038	V

-END OF SEARCH- 31 FAULTS FOUND WITHIN THE SPECIFIED SEARCH RADIUS.

LARGEST MAXIMUM-EARTHQUAKE SITE ACCELERATION: 0.4335 g

SPECIAL PUBLICATION 117A

GUIDELINES FOR EVALUATING AND MITIGATING SEISMIC HAZARDS IN CALIFORNIA

2008

THE RESOURCES AGENCY
MIKE CHRISMAN
SECRETARY FOR RESOURCES

STATE OF CALIFORNIA
ARNOLD SCHWARZENEGGER
GOVERNOR

DEPARTMENT OF CONSERVATION
BRIDGETT LUTHER
DIRECTOR

CALIFORNIA GEOLOGICAL SURVEY
JOHN G. PARRISH, PH.D, *STATE GEOLOGIST*

Copyright © 2008 by the California Department of Conservation, California Geological Survey. All rights reserved. No part of this publication may be reproduced without written consent of the California Geological Survey.

"The Department of Conservation makes no warranties as to the suitability of this product for any particular purpose."

Cover photograph is of a storm-induced landslide in Laguna Beach, California. Earthquakes can also trigger landslides.

SPECIAL PUBLICATION 117A

GUIDELINES FOR EVALUATING AND MITIGATING SEISMIC HAZARDS IN CALIFORNIA

Originally adopted March 13, 1997 by the State Mining and Geology Board in Accordance with the Seismic Hazards Mapping Act of 1990.
Revised and Re-adopted September 11, 2008 by the State Mining and Geology Board in Accordance with the Seismic Hazards Mapping Act of 1990

Copies of these Guidelines, California's Seismic Hazards Mapping Act, and other related information are available on the World Wide Web at:
http://www.conservation.ca.gov/cgs/shzp/Pages/Index.aspx
Copies also are available for purchase from the Public Information Offices of the California Geological Survey.

CALIFORNIA GEOLOGICAL SURVEY'S PUBLIC INFORMATION OFFICES:

Southern California Regional Office
888 S. Figueroa Street, Suite #475
Los Angeles, CA 90017
(213) 239-0878

Publications and Information Office
801 K Street, MS 14-33
Sacramento, CA 95814-3532
(916) 445-5716

Bay Area Regional Office
Earth Science Information Center / Map Sales
Building 3, Room 3-121
345 Middlefield Road, MS 520
Menlo Park, CA 94025
(650) 688-6327

PREFACE

This document contains several important revisions to the 1997 edition of Special Publication 117, "Guidelines for Evaluating and Mitigating Seismic Hazards in California", and supersedes that version. This release also supersedes a previous 2008 update of Special Publication 117 that was released electronically in portable document format. Changes in ground motion requirements for foundation design, and, for assessments of liquefaction and slope stability hazards in the latest edition of the California Building Code, have necessitated additional changes for consistency. To avoid confusion with the previous 2008 release, this document carries the designation "Special Publication 117A."

More than ten years have passed since these Guidelines were first published, during which time there have been significant changes in practice as a result of continuing research in geotechnical earthquake engineering and soil mechanics, and from investigations of several significant earthquakes such as the 1999 Chi-Chi Earthquake in Taiwan and the 1999 Kocali Earthquake in Turkey. This has prompted the need to revise these Guidelines in several areas.

New tools for the screening and evaluation of slope stability and liquefaction hazards have been developed, and new and improved attenuation relations for the estimation of future ground motions have emerged from analysis of numerous new near-field strong motion recordings of recent large earthquakes. These advancements are already finding their way from the professional literature into practice, and the revised Special Publication 117A includes references to them. In addition, mitigation of ground failure hazards has been consolidated into a new chapter that includes the role of grading in hazard mitigation. These changes will improve the utility of these Guidelines in the evaluation of seismic hazards for proposed development within California's regulatory "zones of required investigation" pursuant to the Seismic Hazards Mapping Act of 1990. Future revisions to the Guidelines may be more frequent because of rapid developments in this field, and for efficiency the revisions will be downloadable from the following web site: http://www.conservation.ca.gov/cgs/shzp/Pages/shmppgminfo.aspx.

CONTENTS

CHAPTER 1 1
INTRODUCTION 1
Objectives 2
CHAPTER 2 3
DEFINITIONS, CAVEATS, AND GENERAL CONSIDERATIONS 3
Definitions 3
Minimum Statewide Safety Standard 4
Areal Extent of Hazard 4
Off-Site Origin of Hazard 6
Relationship of these Guidelines to Local General Plans and Permitting Ordinances 6
Relationship of these Guidelines to the CEQA Process and Other Site Investigation Requirements 6
Criteria for Project Approval 7
Engineers or Geologists - Who Does What? 8
CHAPTER 3 9
OVERVIEW OF INVESTIGATIONS FOR ASSESSING SEISMIC HAZARDS 9
Introduction 9
Items to Consider in the Site Investigation Study 9
Screening Investigation 10
Quantitative Evaluation of Hazard Potential 11
Detailed Field Investigations – General Information Needs 11
Content of Reports 11
CHAPTER 4 15
ESTIMATION OF EARTHQUAKE GROUND-MOTION PARAMETERS 15
Introduction 15
California Building Code 15
Probabilistic Seismic Hazard Analysis (PSHA) 16
Deterministic Seismic Hazard Analysis (DSHA) 16
Selection of a Site-Specific Design Strong-Motion Record 17
CHAPTER 5 19
ANALYSIS OF EARTHQUAKE-INDUCED LANDSLIDE HAZARDS 19
Screening Investigations for Earthquake-Induced Landslide Potential 19
Additional Considerations 21
Quantitative Evaluation of Earthquake-Induced Landslide Potential 21
Detailed Field Investigation 22
Geotechnical Laboratory Testing 25
Slope Stability Analysis 27
Evaluation of Potential Earthquake-Induced Landslide Hazards 33
Pseudo-Static Analysis 33
Newmark Displacement Analysis 33
CHAPTER 6 35
ANALYSIS OF LIQUEFACTION HAZARDS 35

Screening Investigations for Liquefaction Potential 35
Quantitative Evaluation of Liquefaction Resistance 38
Detailed Field Investigation 38
Geotechnical Laboratory Testing 40
Evaluation of Potential Liquefaction Hazards 40
Lateral Spreading and Site Displacement Hazards 41
Localized Liquefaction Hazards 42
CHAPTER 7 45
GUIDELINES FOR MITIGATING SEISMIC HAZARDS 45
Introduction 45
Basic Considerations 46
Mitigation of Landslide Hazards 47
Rotational Landslides 47
Fill Displacements 49
Soil Flows 51
Rock Falls & Topples 52
Mitigation of Liquefaction Hazards 54
Large-Scale Displacements 54
Localized Failures 55
Concluding Remarks 61
CHAPTER 8 63
GUIDELINES FOR REVIEWING SITE-INVESTIGATION REPORTS 63
The Reviewer 63
Qualifications 63
Conflict of Interest 64
Reviewing Reports 64
The Report 64
Report Guidelines and Standards 65
Review of Submitted Reports 65
Report Filing Requirements 66
Waivers 66
Waiver Filing Requirements 67
Appeals 67
REFERENCES CITED 69
RELATED REFERENCES 77
APPENDIX A 83
SEISMIC HAZARDS MAPPING ACT 83
APPENDIX B 89
SEISMIC HAZARDS MAPPING 89
REGULATIONS 89
APPENDIX C 93
TECHNICAL TERMS AND DEFINITIONS 93
APPENDIX D 95
SOURCES FOR STRONG-MOTION RECORDS 95
APPENDIX E 97

GEOLOGIC ENVIRONMENTS LIKELY TO PRODUCE EARTHQUAKE-INDUCED LANDSLIDES 97

ILLUSTRATIONS

Figure 1. Values of f_{eq} as a Function of MHA_r, Magnitude and Distance for Threshold Displacements of (a) 5 cm and (b) 15 cm (Modified from Blake and others, 2002). 30
Figure 2. Minimum Setbacks established by the California Building Code. 49
Figure 3. The typical mitigation for a Cut-and-Fill lot is to construct a gradual "stepped" transition between bedrock and fill, overexcavating unstable soils and recompacting suitable fill beneath the footprint (Stewart and others, 2001). 50
Figure 4. Gradation chart showing the range for some of the preferred soil treatment methods based on different soil contents (Hayward Baker, 1997). 58

ACKNOWLEDGEMENTS

Many people contributed their time and effort to the creation of this document. Listed below are those with their affiliation at the time that they currently serve, or have previously served, on various boards, committees and working groups that provided advice during implementation of the Seismic Hazards Mapping Act, and were contributors to this publication.

State Mining and Geology Board:

Current Members (2008):

Cheryl Bly-Chester, Vice Chair
Erin Garner
Kathy Lund
Seena Hoose
Julian C. Isham
Allen M. Jones, Chairman
Robert Tepel
Stephen M. Testa, Executive Officer

Past Members:

Sands Figuers
Robert Grunwald
DeWayne Holmdahl, Chairman
Raymond Krauss
Julie Mann, Vice Chairwoman
Robert Munro
Sheila M. Murphy
Lee Thibadeau
Alvin Franks
I.M. Idriss
John G. Parrish, Former Executive Officer

Seismic Hazards Mapping Act Advisory Committee (1997):

Edward Baum, AAA of Southern California
Kenneth Blackman, City of Santa Rosa
John Buzas, County of Orange Governments
Bruce R. Clark, Leighton and Associates, Chair
Richard Clinton, Fireman's Fund
Robert D. Darragh, Dames & Moore
Sands Figuers, Norfleet Consultants
Paul Flores, Office of Emergency Services
Alvin Franks, Consultant
Diane Guzman, County of Santa Cruz
Sheila M. Murphy, City of Los Angeles
Jeanne Perkins, Association of Bay Area
Allan Porush, Dames & Moore
Richard Roth, Department of Insurance
William U. Savage, Pacific Gas and Electric
J. Carl Stepp, Electric Power Research Institute

Ground Motion Working Group (1997):

Norm Abrahamson, Consultant
Roger Borcherdt, U.S. Geological Survey
Kevin Coppersmith, Geomatrix
C. Allin Cornell, Stanford University
William Holmes, Rutherford and Chekene
I.M. Idriss, University of California-Davis
William Joyner, U.S. Geological Survey
Yoshiharu Moriwaki, Woodward Clyde Consultants
Jeanne Perkins, Association of Bay Area Governments
Allan Porush, Dames & Moore
Edward Rinne, Kleinfelder, Inc.
William U. Savage, Pacific Gas and Electric, Chair
J.P. Singh, GeoSpectra
Paul Somerville, Woodward Clyde Consultants
J. Carl Stepp, Electric Power Research Institute, Former Chair

Liquefaction Hazards Working Group (1997):

Robert D. Darragh, Dames & Moore, Chair
Robert Hawk, City of San Diego
I.M. Idriss, University of California-Davis
William Lettis, William Lettis and Associates
Maurice Power, Geomatrix Consultants
Ray Seed, University of California
John Tinsley, U.S. Geological Survey
T. Leslie Youd, Brigham Young University

Earthquake-Induced Landslides Working Group (1997):

Bruce R. Clark, Leighton and Associates, Chair
William Cotton, Cotton and Associates
Diane Guzman, County of Santa Cruz
Thomas Holzer, U.S. Geological Survey
Randall Jibson, U.S. Geological Survey
David Keefer, U.S. Geological Survey
Robert Larson, County of Los Angeles Department of Public Works
Scott Lindvall, Harza/LRB
J. David Rogers, Rogers/Pacific

Planning and Implementation Working Group (1997):

Kenneth Blackman, City of Santa Rosa, Chair
Edward Baum, AAA of Southern California Governments
John Buzas, County of Orange
Richard Eisner, Office of Emergency Services
Jeanne Perkins, Association of Bay Area
Richard Roth, Department of Insurance
Thomas Tobin, California Seismic Safety Commission
Diane Guzman, County of Santa Cruz
George Mader, William Spangle and Associates
Ken Topping, Consultant

California Geological Survey Staff (1997; *1997 & 2008 revision):

Allan Barrows, Senior Engineering Geologist, RG 3172
David J. Beeby, Principal Geologist, RG 3456
James Davis, State Geologist, RG 3468
Mark DeLisle, Associate Engineering Geologist, RG 126, GP 585
Earl Hart, Senior Geologist, RG 462, EG 935
*Timothy McCrink, Senior Engineering Geologist, RG 4466, EG 1549
Bea McKamey, Land and Water Use Analyst
*Jack McMillan, Senior Engineering Geologist, RG 4683, EG 1831
Mark Petersen, Associate Seismologist, RG 6754, EG 2129
*Charles Real, Supervising Engineering Geologist, GP 968
Michael Reichle, Supervising Geologist, GP 943
Theodore Smith, Senior Engineering Geologist, RG 3445, EG 1029
Robert Sydnor, Senior Engineering Geologist, RG 3267, EG 968, HG 6

External Review Group for This Revision (2008):

Thomas Blake, Fugro West, Inc.
Jonathan Bray, University of California, Berkeley
Alan Kropp, Alan Kropp & Associates, Inc.
Ellen Rathje, University of Texas, Austin
Ted Sayer, Cotton, Shires & Associates, Inc.
Jonathan Stewart, University of California, Los Angeles
Mike Shimamoto, City of San Jose

CHAPTER 1

INTRODUCTION

Prompted by damaging earthquakes in northern and southern California, in 1990 the State Legislature passed the Seismic Hazards Mapping Act. The Governor signed the Act, codified in the Public Resources Code as Division 2, Chapter 7.8 (see Appendix A), which became operative on April 1, 1991.

The purpose of the Act is to protect public safety from the effects of strong ground shaking, liquefaction, landslides, or other ground failure, and other hazards caused by earthquakes. The program and actions mandated by the Seismic Hazards Mapping Act closely resemble those of the Alquist-Priolo Earthquake Fault Zoning Act (which addresses only surface fault-rupture hazards) and are outlined below:

1. **The State Geologist** is required to delineate the various "seismic hazard zones."

2. **Cities and Counties**, or other local permitting authority, must regulate certain development "projects" within the zones. They must withhold the development permits for a site within a zone until the geologic and soil conditions of the project site are investigated and appropriate mitigation measures, if any, are incorporated into development plans.

3. **The State Mining and Geology Board** provides additional regulations, policies, and criteria, to guide cities and counties in their implementation of the law (see Appendix B). The Board also provides guidelines for preparation of the Seismic Hazard Zone Maps (available at: http://www.conservation.ca.gov/cgs/shzp/Pages/shmppgminfo.aspx) and for evaluating and mitigating seismic hazards (this document).

4. **Sellers (and their agents)** of real property within a mapped hazard zone must disclose that the property lies within such a zone at the time of sale.

This document constitutes the guidelines for evaluating seismic hazards other than surface fault-rupture, and for recommending mitigation measures as required by Public Resources Code Section 2695(a). Nothing in these Guidelines is intended to conflict with or supersede any requirement, definition, or other provision of Chapter 7.8 of the Public Resources Code; California Code of Regulations, Title 14, Division 2, Chapter 8, Article 10; the Business and Professions Code; or any other state law or regulation.

Objectives

The objectives of these Guidelines are twofold:

1. To assist in the evaluation and mitigation of earthquake-related hazards for projects within designated zones of required investigations; and

2. To promote uniform and effective statewide implementation of the evaluation and mitigation elements of the Seismic Hazards Mapping Act.

The Guidelines will be helpful to the owner/developer seeking approval of specific development projects within zones of required investigation and to the engineering geologist and/or civil engineer who must investigate the site and recommend mitigation of identified hazards. They will also be helpful to the lead agency engineering geologist and/or civil engineer who must complete the technical review, and other lead agency officials involved in the planning and development approval process. Effective evaluation and mitigation ultimately depends on the combined professional judgment and expertise of the evaluating and reviewing professionals.

The methods, procedures, and references contained herein are those that the State Mining and Geology Board, the Seismic Hazards Mapping Act Advisory Committee, and its Working Groups believe are currently representative of quality practice. Seismic hazard assessment and mitigation is a rapidly evolving field and it is recognized that additional approaches and methods will be developed. If other methods are used, they should be justified with appropriate data and documentation.

For a general description of the Department's Seismic Hazards Zonation Program, its products and their uses, refer to the CGS website:
http://www.conservation.ca.gov/cgs/shzp/Pages/Index.aspx

CHAPTER 2

DEFINITIONS, CAVEATS, AND GENERAL CONSIDERATIONS

Definitions

Key terms that will be used throughout the Guidelines are defined in the Act and related regulations. These are:

- **"Acceptable level"** of risk means that level that provides reasonable protection of the public safety, though it does not necessarily ensure continued structural integrity and functionality of the project [CCR Title 14, Section 3721(a)].

- **"Certified Engineering Geologist"** means an engineering geologist who is certified in the State of California [CCR Title 14, Section 3721(c); Business and Professions Code (BPC) Sections 7804 and 7822] and practicing in his or her area of expertise. These professionals will be referred to throughout these Guidelines as "engineering geologists." See page 8 (*Engineers or Geologists— Who Does What?*) for a discussion of scope of involvement in site-investigation reports and related reviews.

- **"Lead agency"** means the state agency, city, or county with the authority to approve projects [CCR Title 14, Section 3721(b)].

- **"Mitigation"** means those measures that are consistent with established practice and reduce seismic risk to "acceptable levels" [Public Resources Code (PRC) Section 2693(c)].

- **"Owner/Developer"** is defined as the party seeking permits to undertake a "project", as defined below.

- **"Project"** is defined by the Seismic Hazards Mapping Act as any structures for human occupancy, or any subdivision of land that contemplates the eventual construction of structures for human occupancy. Unless lead agencies impose more stringent requirements, single-family frame dwellings are exempt unless part of a development of four or more dwellings. (The definition is complex; see Table 1 for specific language.)

- **"Registered Civil Engineer"** means a civil engineer who is registered in the State of California [CCR Title 14, Section 3721(c); BPC Sections 6701-6704] and practicing in his or her area of expertise. These professionals will be referred to throughout these Guidelines as

"civil engineers." See page 8 (*Engineers or Geologists—Who Does What?*) for a discussion of scope of involvement in site-investigation reports and related reviews.

- **"Seismic Hazard Evaluation Reports"** document the data and methods used by the State Geologist to develop the "**Seismic Hazard Zone Maps**."

- **"Seismic Hazards Mapping Act"**— California Public Resources Code Sections 2690 and following, included as Appendix A.

- **"Seismic Hazards Mapping Regulations"**— California Code of Regulations (CCR), Title 14, Division 2, Chapter 8, Article 10, included as Appendix B.

- **"Seismic Hazard Zone Maps"** are maps issued by the State Geologist under PRC Section 2696 that show zones of required investigation.

- **"Site-Investigation Report"** means a report prepared by a certified engineering geologist and/or a civil engineer practicing within the area of his or her competence, which documents the results of an investigation of the site for seismic hazards and recommends mitigation measures to reduce the risk of identified seismic hazards to acceptable levels. In PRC Section 2693(b) and elsewhere, this report is referred to as a "geotechnical report."

- **"Zones of Required Investigation"** referred to as "**Seismic Hazard Zones**" in CCR Section 3722, are areas shown on Seismic Hazard Zone Maps where site investigations are required to determine the need for mitigation of potential liquefaction and/or earthquake-induced landslide ground displacements.

Definitions of technical terms appear in Appendix C.

Minimum Statewide Safety Standard

Based on the above definitions of "mitigation" and "acceptable risk," the Seismic Hazards Mapping Act and related regulations establish a statewide minimum public safety standard for mitigation of earthquake hazards. This means that the minimum level of mitigation for a project should reduce the risk of ground failure during an earthquake to a level that does not cause the collapse of buildings for human occupancy, but in most cases, **not** to a level of no ground failure at all. However, nothing in the Act, the regulations, or these Guidelines precludes lead agencies from enacting more stringent requirements, requiring a higher level of performance, or applying these requirements to developments other than those that meet the Act's definition of "project."

Areal Extent of Hazard

The Seismic Hazard Zone Maps are developed using a combination of historic records, field observations, and computer-mapping technology. The maps may not identify all areas that have potential for liquefaction, earthquake-induced landsliding, strong ground shaking, and other earthquake and geologic hazards. Although past earthquakes have caused ground failures in only

a small percentage of the total area zoned, a worst-case scenario of a major earthquake during or shortly after a period of heavy rainfall is something that has not occurred in northern California

Table 1. Definition of "Project"

Public Resources Code Section 2693.

As used in [Chapter 7.8, the Seismic Hazards Mapping Act]:

d) "Project" has the same meaning as in Chapter 7.5 (commencing with Section 2621), except as follows:

(1) A single-family dwelling otherwise qualifying as a project may be exempted by the city or county having jurisdiction of the project.

(2) "Project" does not include alterations or additions to any structure within a seismic hazard zone which do not exceed either 50 percent of the value of the structure or 50 percent of the existing floor area of the structure.

Public Resources Code Section 2621.6.

(a) As used in (Chapter 7.5, the Alquist-Priolo Earthquake Fault Zoning Hazard Act), "project" means either of the following:

(1) Any subdivision of land which is subject to the Subdivision Map Act (Division 2 (commencing with Section 66410) of Title 7 of the Government Code), and which contemplates the eventual construction of structures for human occupancy.

(2) Structures for human occupancy, with the exception of either of the following:

(A) Single-family wood-frame or steel-frame dwellings to be built on parcels of land for which geologic reports have been approved pursuant to paragraph (1).

(B) A single-family wood-frame or steel-frame dwelling not exceeding two stories when that dwelling is not part of a development of four or more dwellings.

(b) For the purposes of this chapter, a mobile home whose body width exceeds eight feet shall be considered to be a single-family wood-frame dwelling not exceeding two stories.

California Code of Regulations Section 3601 (Policies and Criteria of the State Mining and Geology Board, With Reference to the Alquist-Priolo Earthquake Fault Zoning Act).

The following definitions as used within the Act and herein shall apply:

(e) A "structure for human occupancy" is any structure used or intended for supporting or sheltering any use of occupancy, which is expected to have a human occupancy rate of more than 2,000 person-hours per year.

(f) Story "is that portion of a building included between the upper surface of any floor and the upper surface of the floor next above, except that the topmost story shall be that portion of the building included between the upper surface of the topmost floor and the ceiling or roof above. For the purpose of the Act and this subchapter, the number of stories in a building is equal to the number of distinct floor levels, provided that any levels that differ from each other by less than two feet shall be considered as one distinct level."

since 1906, and has not been witnessed in historic times in southern California. The damage from such an event in a heavily populated area is likely to be more widespread than that experienced in the 1971 San Fernando earthquake, the 1989 Loma Prieta earthquake, or the 1994 Northridge earthquake.

Off-Site Origin of Hazard

The fact that a site lies outside a zone of required investigation does not necessarily mean that the site is free from seismic or other geologic hazards, regardless of the information shown on the Seismic Hazard Zone Maps. The zones do not always include landslide or lateral spread run-out areas. Project sites that are outside of any zone may be affected by ground failure runout from adjacent or nearby sites.

Finally, neither the information on the Seismic Hazard Zone Maps, nor in any technical reports that describe how the maps were prepared nor what data were used is sufficient to serve as a substitute for the required site-investigation reports called for in the Act.

Relationship of these Guidelines to Local General Plans and Permitting Ordinances

Public Resources Code Section 2699 directs cities and counties to "take into account the information provided in available seismic hazard maps" when it adopts or revises the safety element of the general plan and any land-use planning or permitting ordinances. Cities and counties should consider the information presented in these Guidelines when adopting or revising these plans and ordinances.

Relationship of these Guidelines to the CEQA Process and Other Site Investigation Requirements

Nothing in these Guidelines is intended to negate, supersede, or duplicate any requirements of the California Environmental Quality Act (CEQA) or other state laws and regulations. At the discretion of the lead agency, some or all of the investigations required by the Seismic Hazards Mapping Act may occur either before, concurrent with, or after the CEQA process or other processes that require site investigations.

Some of the potential mitigation measures described herein (e.g., strengthening of foundations) will have little or no adverse impact on the environment. However, other mitigation measures (e.g., draining of subsurface water, driving of piles, densification, extensive grading, or removal of liquefiable material) may have significant impacts. If the CEQA process is completed prior to the site-specific investigation, it may be desirable to discuss a broad range of potential mitigation measures (any that might be proposed as part of the project) and related impacts. If, however, part or all of the site-specific investigation is conducted prior to completion of the CEQA process, it may be possible to narrow the discussion of mitigation alternatives to only those that would provide reasonable protection of the public safety given site-specific conditions.

More stringent requirements are prescribed by the California Building Code (CCR Title 24) for hospitals, public schools, and essential service buildings. For such structures, the requirements of the Seismic Hazards Mapping Act are intended to complement the CCR Title 24 requirements.

Criteria for Project Approval

The State's minimum criteria required for project approval within zones of required investigation are defined in CCR Title 14, Section 3724, from which the following has been excerpted:

> *"The following specific criteria for project approval shall apply within seismic hazard zones and shall be used by affected lead agencies in complying with the provisions of the Act:*
>
> *(a) A project shall be approved only when the nature and severity of the seismic hazards at the site have been evaluated in a geotechnical report and appropriate mitigation measures have been proposed.*
>
> *(b) The geotechnical report shall be prepared by a registered civil engineer or certified engineering geologist, having competence in the field of seismic hazard evaluation and mitigation. The geotechnical report shall contain site-specific evaluations of the seismic hazard affecting the project, and shall identify portions of the project site containing seismic hazards. The report shall also identify any known off-site seismic hazards that could adversely affect the site in the event of an earthquake. The contents of the geotechnical report shall include, but shall not be limited to, the following:*
>
> *(1) Project description.*
>
> *(2) A description of the geologic and geotechnical conditions at the site, including an appropriate site location map.*
>
> *(3) Evaluation of site-specific seismic hazards based on geological and geotechnical conditions, in accordance with current standards of practice.*
>
> *(4) Recommendations for appropriate mitigation measures as required in Section 3724(a), above.*
>
> *(5) Name of report preparer(s), and signature(s) of a certified engineering geologist and/or registered civil engineer, having competence in the field of seismic hazard evaluation and mitigation.*
>
> *(c) Prior to approving the project, the lead agency shall independently review the geotechnical report to determine the adequacy of the hazard evaluation and proposed mitigation measures and to determine the requirements of Section 3724(a), above, are satisfied. Such reviews shall be conducted by a certified engineering geologist or registered civil engineer, having competence in the field of seismic hazard evaluation and mitigation."*

Lead agencies can have other, more stringent criteria for project approval. The State Mining and Geology Board recommends that the official professional Registration or Certification Number and license expiration date of each report preparer be included in the signature block of the

report. In addition, Chapter 3 provides a list of topics that should be addressed in site-investigation reports prepared for liquefaction and/or earthquake-induced landslides.

Engineers or Geologists - Who Does What?

The Act and Regulations state that the site-investigation reports must be prepared by a certified engineering geologist or registered civil engineer, who must have competence in the field of seismic hazard evaluation and mitigation, and be *reviewed* by a certified engineering geologist or registered civil engineer, also competent in the field of seismic hazard evaluation and mitigation. *Although the Seismic Hazards Mapping Act does not distinguish between the types of licensed professionals who may prepare and review the report, the current Business and Professions Code (Geologist and Geophysicist Act, Section 7832; and Professional Engineers Act, Section 6704) restricts the practice of these two professions. Because of the differing expertise and abilities of engineering geologists and civil engineers, the scope of the site-investigation report for the project may require that* ***both*** *types of professionals prepare and review the report, each practicing in the area of his or her expertise*. Involvement of both engineering geologists and civil engineers will generally provide greater assurance that the hazards are properly identified, assessed, and mitigated.

The State Mining and Geology Board recommends that engineering geologists and civil engineers conduct the assessment of the surface and subsurface geological/geotechnical conditions at the site, including off-site conditions, to identify potential hazards to the project. It is appropriate for the civil engineer to design and recommend mitigation measures. It also is appropriate for both engineering geologists and civil engineers to be involved in the implementation of the mitigation measures– engineering geologists to confirm the geological conditions and civil engineers to oversee the implementation of the approved mitigation measures.

CHAPTER 3

OVERVIEW OF INVESTIGATIONS FOR ASSESSING SEISMIC HAZARDS

Introduction

Investigation of potential seismic hazards at a site can be performed in two steps or stages: (1) a preliminary **screening investigation**, and (2) a **quantitative evaluation** of the seismic hazard potential and its consequences. As noted below, it is possible to successfully complete the investigation by skipping one or the other stage. For example, a consultant's screening investigation may find that a previous site-specific investigation, on or adjacent to the project site, has shown that no seismic hazards exist, and that a quantitative evaluation is not necessary. Conversely, a consultant may know from experience that a project site is susceptible to a given hazard, and may opt to forego the screening investigation and start with a quantitative evaluation of the hazard.

Some lead agency reviewers recommend that for large projects the developer's consultant(s) meet with the lead agency technical reviewer prior to the start of the site investigation. This allows the consultant and technical reviewer to discuss the scope of the investigation. Topics of this discussion may include the area to be investigated for various hazards, the acceptability of investigative techniques to be used, on-site inspection requirements, or other local requirements.

Items to Consider in the Site Investigation Study

The following concepts are provided to help focus the site-investigation report:

1. When conducting a site-specific ground response study, consultants are encouraged to utilize, if possible, the latest seismic ground-motion and active fault parameter data. This information is available at the following URL: http://earthquake.usgs.gov/research/hazmaps/.

2. The fact that a site lies within a mapped zone of required investigation does not necessarily indicate that a hazard requiring mitigation is present. Instead, it indicates that regional (that is, not site-specific) information suggests that the probability of a hazard requiring mitigation is great enough to warrant a site-specific investigation. However, the working premise for the planning and execution of a site investigation within Seismic Hazard Zones is that ***the suitability of the site should be demonstrated***. This premise will persist until either: (a) the site investigation satisfactorily demonstrates the absence of liquefaction or landslide hazard,

or (b) the site investigation satisfactorily defines the liquefaction or landslide hazard and provides a suitable recommendation for its mitigation.

3. The fact that a site lies outside a mapped zone of required investigation does not necessarily mean that the site is free from seismic or other geologic hazards, nor does it preclude lead agencies from adopting regulations or procedures that require site-specific soil and/or geologic investigations and mitigation of seismic or other geologic hazards. It is possible that development proposals may involve alterations (for example, cuts, fills, and/or modifications that would significantly raise the water table) that could cause a site outside the zone to become susceptible to earthquake-induced ground failure.

4. Lead agencies have the right to approve (and the obligation to reject) a proposed project based on the findings contained in the site-investigation report and the lead agency's technical review. The task of the developer's consulting engineering geologist and/or civil engineer is to demonstrate, to the satisfaction of the lead agency's technical reviewer, that:

   - The site-specific investigation is sufficiently thorough;
   - The findings regarding identified hazards are valid; and,
   - The proposed mitigation measures achieve an acceptable level of risk, as defined by the lead agency and CCR Title 14, Section 3721(a).

Screening Investigation

The purpose of screening investigations for sites within zones of required investigation is to evaluate the severity of potential seismic hazards, or to screen out sites included in these zones that have a low potential for seismic hazards. If a screening investigation can **clearly** demonstrate the absence of seismic hazards at a project site, and if the lead agency technical reviewer concurs with this finding, the screening investigation will satisfy the site-investigation report requirement and no further investigation will be required. If the findings of the screening investigation cannot demonstrate the absence of seismic hazards, then the more-comprehensive quantitative evaluation needs to be conducted.

The documents reviewed should be both regional and, if information is available, site-specific in scope. The types of information reviewed during a screening investigation often includes topographic maps, geologic and soil engineering maps and reports, aerial photographs, water well logs, agricultural soil survey reports, and other published and unpublished references. The references used should focus on current journals, maps, reports, and methods. Seismic Hazard Evaluation Reports, which summarize the findings and data on which CGS's Seismic Hazard Zone Maps are based, can provide much of the regional geologic and seismic information needed for a screening investigation. Aerial photographs can be useful to identify existing and potential landslide and/or liquefaction features (headwall scarps, debris chutes, fissures, grabens, sand boils, etc.) that suggest or preclude the existence of ground failure hazards that might affect the site. Several sets of stereoscopic aerial photographs that pre-date project site area development, and taken during different seasons of the year are particularly useful for identifying subtle

geomorphic features. A field reconnaissance of the area is highly recommended to verify the information developed in the earlier steps to fill in information in questionable areas and to observe the surface features and details that could not be determined from other data sources.

Quantitative Evaluation of Hazard Potential

Detailed Field Investigations – General Information Needs

Within the zone of required investigations, the objective of the detailed field investigation is to obtain sufficient information on which the engineering geologist and/or civil engineer can evaluate the nature and severity of the risk and develop a set of recommendations for mitigation. In the case of projects where the property is to be subdivided and sold to others undeveloped, the aim of the investigation is to determine which parcels contain buildable sites that meet the previously defined acceptable level of risk. The work should be based upon a detailed, accurate topographic base map prepared by a registered civil engineer or land surveyor. The map should be of suitable scale, and should cover the area to be developed as part of the project, as well as adjacent areas: which affect or may be affected by the project.

The detailed field investigation commonly involves the collection of subsurface information from trenches or borings, on or adjacent to the site. The subsurface exploration should extend to depths sufficient to expose geologic and subsurface water conditions that could affect slope stability or liquefaction potential. A sufficient quantity of subsurface information is needed to permit the engineering geologist and/or civil engineer to extrapolate with confidence the subsurface conditions that might affect the project, so that the seismic hazard can be properly evaluated, and an appropriate mitigation measure can be designed by the civil.

The preparation of engineering geologic maps and geologic cross sections is often an important step to developing an understanding of the significance and extent of potential seismic hazards. These maps and/or cross sections should extend far enough beyond the site to identify off-site hazards and features that might affect the site.

Content of Reports

The site investigation report should contain sufficient information to allow the lead agency's technical reviewer to satisfactorily evaluate the potential for seismic hazards and the proposed mitigation. No attempt is made here to define the limits of what constitutes a complete screening investigation or quantitative evaluation report. Site-specific conditions and circumstances, as well as lead agency requirements, will dictate which issues and what level of detail are required to adequately define and mitigate the hazard(s). The following list (Table 2) is provided to assist investigators and reviewers in identifying seismic hazard-related factors significant to the project. Not all of the information in the list will be relevant or required, and some investigations may require additional types of data or analyses.

Table 2. Recommended content for site-investigation reports within zones of required investigations.

Reports that address liquefaction and/or earthquake-induced landslides should include, but not necessarily be limited to, the following data:
1. Description of the proposed project's location, topographic relief, drainage, geologic and soil materials, and any proposed grading.
2. Site plan map of project site showing the locations of all explorations, including test pits, borings, penetration test locations, and soil or rock samples.
3. Description of seismic setting, historic seismicity, nearest pertinent strong-motion records, and methods used to estimate (or source of) earthquake ground-motion parameters used in liquefaction and landslide analyses.
4. 1:24,000 or larger-scale geologic map showing bedrock, alluvium, colluvium, soil material, faults, shears, joint systems, lithologic contacts, seeps or springs, soil or bedrock slumps, and other pertinent geologic and soil features existing on and adjacent to the project site.
5. Logs of borings, test pits, or other subsurface data obtained.
6. Geologic cross sections depicting the most critical (least stable) slopes, geologic structure, stratigraphy, and subsurface water conditions, supported by boring and/or trench logs at appropriate locations.
7. Laboratory test results; soil classification, shear strength, and other pertinent geotechnical data.
8. Specific recommendations for mitigation alternatives necessary to reduce known and/or anticipated geologic/seismic hazards to an acceptable level of risk.
Reports that address earthquake-induced landslides may also need to include:
1. Description of shear test procedures (ASTM or other) and test specimens.
2. Shear strength plots, including identification of samples tested, whether data points reflect peak or residual values, and moisture conditions at time of testing.
3. Summary table or text describing methods of analysis, shear strength values, assumed groundwater conditions, and other pertinent assumptions used in the stability calculations.
4. Explanation of choice of seismic coefficient and/or design strong-motion record used in slope stability analysis, including site and/or topographic amplification estimates.
5. Slope stability analyses of critical (least-stable) cross sections, which substantiate conclusions and recommendations concerning stability of natural and as-graded slopes.
6. Factors of safety against slope failure and/or calculated displacements for the various anticipated slope configurations (cut, fill, and/or natural slopes).
7. Conclusions regarding the stability of slopes with respect to earthquake-induced landslides and their likely impact on the proposed project.
8. Discussion of proposed mitigation measures, if any, necessary to reduce damage from potential earthquake-initiated landsliding to an acceptable level of risk.
9. Acceptance testing criteria (e.g., pseudo-static factor of safety), if any, that will be used to demonstrate satisfactory remediation.
Reports that address liquefaction hazards may also need to include the following:
1. If methods other than Standard Penetration Test (SPT; ASTM D 1586; ASTM D 6066) and Cone Penetration Test (CPT; ASTM 3441) are used, description of pertinent equipment and procedural details of field measurements of penetration resistance (borehole type, hammer type and drop mechanism, sampler type and dimensions, etc.).
2. Boring logs showing raw (unmodified) N-values if SPT's are performed; CPT probe logs showing raw qc-values and plots of raw sleeve friction if CPT's are performed.
3. Explanation of the basis and methods used to convert raw SPT, CPT, and/or other non-standard data to "corrected" and "standardized" values.
4. Tabulation and/or plots of corrected values used for analyses.
5. Explanation of methods used to develop estimates of field loading equivalent uniform cyclic stress ratios (CSR) used to represent the anticipated field earthquake excitation (cyclic loading).
6. Explanation of the basis for evaluation of the equivalent uniform cyclic stress ratio necessary to cause liquefaction (CRR) within the number of equivalent uniform loading cycles considered representative of the design earthquake.
7. Factors of safety against liquefaction at various depths and/or within various potentially liquefiable soil units.

Table 2. Recommended content for site-investigation reports within zones of required investigations.

8.	Conclusions regarding the potential for liquefaction and its likely impact on the proposed project.
9.	Discussion of proposed mitigation measures, if any, necessary to reduce potential damage caused by liquefaction to an acceptable level of risk.
10.	Criteria for SPT-based, CPT-based, or other types of acceptance testing, if any, that will be used to demonstrate satisfactory remediation.

CHAPTER 4

ESTIMATION OF EARTHQUAKE GROUND-MOTION PARAMETERS

Introduction

Quantitative analyses of in-situ liquefaction resistance and earthquake-induced landslide potential require site-specific assessment of ground shaking levels suitable for those purposes. A simplified Seed-Idriss (1982) liquefaction analysis requires an estimation of peak ground acceleration (PGA) and earthquake magnitude. A pseudo-static slope stability analysis may require estimates of PGA and magnitude for the selection of an appropriate seismic coefficient. If a seismic site response analysis, a Newmark analysis or a more complex dynamic analysis is to be performed, representative strong-motion records will need to be selected on the basis of site-specific ground-motion parameter estimates. The following sections of this Chapter provide guidance on the selection of site-specific ground-motion parameters and representative strong-motion records.

California Building Code

The 2007 California Building Code (CBC) requires analysis of liquefaction and slope-stability for various categories of construction, and prescribes alternative methods to obtain the ground motion inputs used in these analyses (CBC, 2007). These provisions must be adhered to for certain seismic structural design categories specified in the CBC. Ground motions used to evaluate liquefaction or slope stability for "projects" defined under the Seismic Hazards Mapping Act (see Table 1), which include design categories beyond those requiring such analyses by the CBC, should be obtained by the same methods prescribed for ground failure analyses in the CBC. The Simple Prescribed Parameter Values (SPPV) method described in the previous version of these Guidelines should no longer be used for that purpose, and is omitted here. Furthermore, the associated supplemental ground shaking hazard maps are no longer included in Seismic Hazard Zone Reports that accompany Official Seismic Hazard Zone Maps released after the year 2008. Such maps found in previous SHZ reports should no longer be used to estimate ground shaking in the evaluation of ground failure hazards for projects located within the seismic hazard zones.

Provisions in the foundation section of the CBC have evolved toward more detailed analysis of earthquake-induced ground failure potential for construction in seismically active areas of the state, and this trend is likely to continue. It is the intent of the Seismic Hazards Mapping Act to supplement the CBC in areas where more rigorous analysis may be required. Site investigations triggered by the Act should always consult the most current version of the CBC when considering the most appropriate methods of hazard evaluation.

Probabilistic Seismic Hazard Analysis (PSHA)

Evaluation of liquefaction and landslide hazard may include a probabilistic seismic hazard analysis of ground motions. PSHA studies typically include the following:

1. A database consisting of potentially damaging earthquake sources, including known active faults and historic seismic source zones, their activity rates, and distances from the project site. This should include a comparison with the USGS/CGS-developed slip rates for faults in California, used in preparation of the National Seismic Hazard Map. Differences in slip rates should be documented and the reasons for them explained (for example, revised slip rates or new paleoseismic information from recent studies). CGS recommends using the national earthquake source database directly, because it is updated regularly and is readily available online: http://earthquake.usgs.gov/research/hazmaps/.

2. Use of published maximum moment magnitudes for earthquake sources, or estimates that are justified, well-documented, and based on published procedures;

3. Use of published curves for attenuation of PGA with distance from earthquake source, as a function of earthquake magnitude and travel path (e.g., see special issue of Earthquake Spectra, v. 24, n.1, 2008);

4. An evaluation of the likely effects of site-specific response characteristics (e.g., amplification due to soft soils, deep sedimentary basins, topography, near-source effects, etc.); and,

5. Characterization of the ground motion at the site in terms of PGA taking into account historical seismicity, available paleoseismic data, the geological slip rate of regional active faults, and site-specific response characteristics.

   Useful references include Cornell, 1968; Youngs and Coppersmith, 1985; National Research Council, 1988; Reiter, 1990; Okumura and Shinozuka, 1990; Working Group on California Earthquake Probabilities, 1990, 1995, and 2008; Kramer, 1996; and McGuire, 2004.

Deterministic Seismic Hazard Analysis (DSHA)

Site-specific deterministic evaluation of seismic hazard can also be performed, and such studies typically include the following:

1. Evaluation of potentially damaging earthquake sources, and deterministic selection of one or more suitable "controlling" sources and seismic events. The deterministic earthquake event magnitude for any fault should be a ***maximum*** value that is specific to that seismic source. Maximum earthquakes may be assessed by estimating rupture dimensions of the fault (e.g., Wells and Coppersmith, 1994; dePolo and Slemmons, 1990). The USGS/CGS database of earthquake sources in California is readily available (see section on PSHA);

2. Use of published curves for the effects of seismic travel path using the shortest distance from the source(s) to the site (e.g., see special issue of Earthquake Spectra, v. 24, n.1, 2008); and,

3. Evaluation of the effects of site-specific response characteristics on either (a) site accelerations, or (b) cyclic shear stresses within the site soils of interest.

Selection of a Site-Specific Design Strong-Motion Record

Depending on the method used to perform a seismic slope stability or liquefaction analysis, it may be necessary to select design strong-motion records that represent the anticipated earthquake shaking at a project site. For a seismic slope-stability analysis the design strong-motion record will be used to evaluate the site seismic response (site amplification) and/or for the calculation of Newmark displacements. For liquefaction evaluations the design strong-motion record will be used for the site seismic response to determine the appropriate peak ground acceleration to use in a simplified Seed-Idriss-type liquefaction analysis. It could also be used for a detailed finite-element strain-based method of analysis where the magnitude of potential large lateral spread displacements are critical to the proposed project.

The selection process typically involves two steps: (1) estimating magnitude, source distance, spectral character and peak ground acceleration parameters relevant to the project site, and (2) searching for existing strong-motion records that have parameters that closely match the estimated values. The methods described in the preceding sections of this chapter describe the recommended approaches to the parameter estimates. The selection of a representative strong-motion record should consider the following:

1. The selection should be based primarily on matching recordings for equivalent magnitude, source distance, site conditions (including soil type, topography, and potential for basin resonance and directivity effects), and PGA, that have spectral characteristics relevant to the project;

2. It may not always be possible to find a good match between the site parameters and the existing strong-motion records, and it may be necessary to use a record that does not match the site parameter criteria and scale it to fit those parameters, making sure that the duration of the scaled record is appropriate for the anticipated magnitude;

3. If the site to be analyzed is underlain by soils or weakly cemented rock, and a strong-motion recording site with similar characteristics cannot be found, a seismic site response analysis should be performed as mentioned above; and,

4. It is recommended that several strong-motion records be used to account for natural variability of earthquake ground motions. The selection of strong-motion records requires consideration of the controlling earthquake magnitude, distance, site conditions, and other effects such as forward-directivity. Due to the important influence of the characteristics of strong-motion records on the results of dynamic analyses, a suite of at least five records is suggested for most projects.

A database of strong-motion records is available from the National Earthquake Engineering Center at the following URL: http://www.strongmotioncenter.org/ and the Pacific Earthquake Engineering Research Center Strong Ground Motion Database used to derive the next-generation attenuation relations: http://peer.berkeley.edu/products/strong_ground_motion_db.html. This and other sources for acquiring strong-motion records are provided in Appendix D.

CHAPTER 5

ANALYSIS OF EARTHQUAKE-INDUCED LANDSLIDE HAZARDS

Screening Investigations for Earthquake-Induced Landslide Potential

The purpose of screening investigations for sites within zones of required investigation for earthquake-induced landslides is to evaluate the severity of the hazard, or to screen out sites included in these zones that have a low potential for landslide hazards. If a screening investigation can ***clearly*** demonstrate the absence of earthquake-induced landslide hazard at a project site, and if the lead agency technical reviewer concurs with this finding, the screening investigation will satisfy the site-investigation report requirement and no further investigation will be required. If the findings of the screening investigation cannot demonstrate the absence of the hazard, then the more-comprehensive quantitative evaluation needs to be conducted.

An important aspect of evaluating the potential for earthquake-induced landslides is the recognition of the types of slope failures commonly caused by earthquakes. Keefer (1984) studied 40 historical earthquakes and found that different types of landslides occur with different frequencies. Table 3 summarizes Keefer's findings. In addition, Keefer (1984) summarized the geologic environments that are likely to produce earthquake-induced landslides. A table of these environments is provided in Appendix E to assist in the evaluation of project sites for the screening investigations.

The screening investigation should evaluate, and the report should address, the following basic questions:

- **Are existing landslides, active or inactive, present on, or adjacent (either uphill or downhill) to the project site?**

An assessment of the presence of existing landslides on the project site for a screening investigation will typically include a review of published and unpublished geologic and landslide inventory maps of the area and an interpretation of aerial photographs. The distinctive landforms associated with landslides (scarps, troughs, disrupted drainages, etc.) should be noted, if present, and the possibility that they are related to landslides should be assessed.

Table 3. Relative abundance of earthquake-induced landslides from 40 historical earthquakes (Keefer, 1984; Table 4, p. 409).

Relative Abundance of Earthquake-Induced Landslides	Description
Very Abundant (more than 100,000 in the 40 earthquakes)	Rock falls, disrupted soil slides, rock slides
Abundant (10,000 to 100,000 in the 40 earthquakes)	Soil lateral spreads, soil slumps, soil block slides, soil avalanches
Moderately common (1000 to 10,000 in the 40 earthquakes)	Soil falls, rapid soil flows, rock slumps
Uncommon (100 to 1000 in the 40 earthquakes)	Subaqueous landslides, slow earth flows, rock block slides, rock avalanches

- **Are there geologic formations or other earth materials located on or adjacent to the site that are known to be susceptible to landslides?**

Many geologic formations in California, notably late Tertiary and Quaternary siltstones and shales (for example, the Orinda and Modelo formations), are highly susceptible to landsliding. These rock units are generally well known among local engineering geologists. For some areas, susceptible formations have also been noted on the Landslide Hazard Identification Maps published by CGS.

- **Do slope areas show surface manifestations of the presence of subsurface water (springs and seeps), or can potential pathways or sources of concentrated water infiltration be identified on or upslope of the site?**

Subsurface water in slopes can be an important indicator of landslide potential. Water may be forced to the surface along impermeable layers such as landslide rupture surfaces. Springs, seeps, or vegetation (phreatophytes) may result from impermeable layers and near-surface water. Topographic depressions, heavy irrigation, or disrupted surface water channels can cause ponding and increased infiltration of surface water. These features may be visible on pre- and/or post-development aerial photographs taken during certain seasons, or during a field reconnaissance. Presence of shallow subsurface water is significant because pore-water pressure reduces the forces resisting landslide movement.

- **Are susceptible landforms and vulnerable locations present? These include steep slopes, colluvium-filled swales, cliffs or banks being undercut by stream or wave action, areas that have recently slid.**

In addition to existing landslide deposits, certain other slopes are especially susceptible to landsliding. These include very steep slopes, and ones where the support at the base of the slope has been removed or reduced. Removal of support at the base of a slope occurs naturally by stream or wave erosion and the same effect can be produced by grading of cut slopes. Colluvium-filled swales usually develop naturally over thousands of years, and the resulting

thick, deeply weathered soil may be especially susceptible to debris flows. Hazardous slope features can generally be noted on aerial photographs, sufficiently detailed topographic maps, or from a geologic field reconnaissance.

- **Given the proposed development, could anticipated changes in the surface and subsurface hydrology (due to watering of lawns, on-site sewage disposal, concentrated runoff from impervious surfaces, etc.) increase the potential for future landsliding in some areas?**

Misdirected runoff from streets during rainstorms can cause saturation of surficial materials and, in turn, development of catastrophic debris flows. Improperly designed highway culverts and watering of lawns on marine terraces can create unstable gullies, undermined coastal bluffs, or both. It is likely that the proposed development will alter the local groundwater regime in some way. The investigation should describe the likely effects that altered runoff patterns, lawn watering or septic systems will have on slope stability; identify sensitive areas; and, when warranted, recommend mitigation.

Additional Considerations

The Earthquake-Induced Landslides Working Group recommends that the screening investigation should include a site reconnaissance by the project's engineering geologist and/or civil engineer. This will allow for the recognition of potential earthquake hazards that cannot normally be recognized in a purely office-based screening investigation.

Guidance on the preparation of a report for the screening investigation is provided in Chapter 3 of these Guidelines. If the results of the screening investigation show that the potential for earthquake-induced landsliding is low, the report should state the reasons why a quantitative evaluation is not needed for the project site.

In addition to common methods of quantitative seismic slope stability analysis, the next section includes some quantitative screening tools that can further serve to identify when slide displacements are likely to be significant enough to warrant a full quantitative analysis of seismic slope stability.

Quantitative Evaluation of Earthquake-Induced Landslide Potential

If the screening investigation indicates the presence of potentially unstable slopes affecting the proposed project site, a quantitative evaluation of earthquake-induced landslide potential should be conducted. The major phases of such a study typically include a detailed field investigation, drilling and sampling, geotechnical laboratory testing, and slope stability analyses. Reference should be made to Chapter 3 for guidance on what types of information from the following sections should be included in the site-investigation report.

Detailed Field Investigation

Engineering Geologic Investigations

The engineering geologic investigation phase of the project site investigation consists of surface observations and geologic mapping. The overall scope of the engineering geologic investigation for earthquake-induced landslide hazards is fundamentally the same as the work that would be conducted for any project that has potential landslide hazards, regardless of the triggering mechanism. However, the investigator should keep in mind the environments and the relative abundance of landslide types triggered by earthquakes as described by Keefer (1984) and shown in Appendix E and Table 3, respectively. The engineering geologic investigation is significant because it provides the basis for the subsurface investigations, field instrumentation, and geotechnical analyses that follow.

Prior to the site reconnaissance, the area of the project and possible details about the proposed construction (structures and cut/fill locations) should be identified, and available geologic and geotechnical information, stereoscopic aerial photographs, and topographic maps should be collected and reviewed (Keaton and DeGraff, 1996). If a screening investigation has been conducted for the site, much of this information may already have been reviewed. Once the results of the office-based investigation have been completed and understood, on-site engineering geologic mapping can be conducted.

The purpose of the on-site engineering geologic mapping is to document surface conditions, which, in turn, provides a basis for projecting subsurface conditions that may be relevant to the stability of the site. The on-site engineering geologic mapping should identify, classify, and locate on a map the features and characteristics of existing landslides, and surficial and bedrock geologic materials, especially those landslides and geologic materials that may specifically impact the proposed construction activities. Other important aspects of the site to document include: landslide features and estimates of depth to the rupture surface; distribution and thickness of colluvium; rock discontinuities such as bedding, jointing, fracturing and faulting; depth of bedrock weathering; surface water features such as streams, lakes, springs, seeps, marshes, and closed or nearly closed topographic depressions.

Engineering geologic cross sections should be located so as to provide information that will be needed for planning subsurface investigations and stability analyses. The most useful orientation is typically perpendicular to topographic contours and longitudinally down existing landslide deposits. The projected shape of the rupture surface, geologic contacts and orientations, and groundwater surfaces should be shown along with the topographic profile. Estimates of the depth to the landslide rupture surface is an important parameter for planning a subsurface investigation and longitudinal cross sections can be helpful in making these estimates (McGuffey and others, 1996).

The results of the engineering geologic mapping can be presented in many forms, but generally should include a map, cross sections, and proposed construction and subsurface investigation locations and/or field instrumentation sites. Whatever method of presentation is chosen, it should be remembered that the presentation of the surface mapping information needs to be

characterized in terms that are meaningful for, and usable by the design engineer. Doing so will help ensure that key factors that must be accommodated in the construction are understood (Keaton and DeGraff, 1996).

Subsurface Investigation

Planning

Exploratory work by the engineering geologist and civil engineer should be conducted at locations considered most likely to reveal any subsurface conditions which may indicate the potential for earthquake-induced landslide failures, especially those that directly impact the proposed project. In particular, an investigation should locate and define the geometry of bedding and fracture surfaces, contacts, faults, and other discontinuities as well as actual landslide rupture surfaces.

Subsurface exploration methods can be classed as direct methods and indirect methods (Hunt, 1984a). Direct methods, such as test borings and the excavation of test pits or trenches, allow the examination of the earth materials, usually with the removal of samples. Indirect methods, such as geophysical surveys and the use of the cone penetrometer, provide a measure of material properties that allows the estimation of the material type (McGuffey and others, 1996).

Subsurface investigations should be supervised by an experienced engineering geologist and/or civil engineer to ensure that the field activities are properly executed and the desired results are achieved. According to McGuffey and others (1996), the subsurface investigation field supervision should:

1. Ensure that technical and legal contract specifications are followed;

2. Maintain liaison with the designer of the exploration program;

3. Select and approve modifications to the program as new or unanticipated conditions are revealed;

4. Ensure that complete and reliable field reports are developed; and

5. Identify geologic conditions accurately.

The depth to which explorations should extend can be difficult to define in advance of the subsurface investigation. Cross sections from a surface engineering geological investigation can be helpful in planning the depths of excavations required in a subsurface investigation. In general, borings or other direct investigative techniques should extend deep enough (a) to identify materials that have not been subjected to movements in the past but might be involved in future movements, and (b) to clearly identify underlying stable materials. The exploration program plan should be flexible enough to allow for expanding the depth of investigation when the data obtained suggest deeper movements are possible (McGuffey and others, 1996).

Samples and Sampling

Soil and rock samples are taken primarily for laboratory strength and compressibility tests and for the measurement of in-situ material properties. Samples that may be obtained from subsurface borings and excavations belong to one of two basic categories: disturbed and undisturbed samples. Disturbed samples are collected primarily for soil classification tests where the preservation of the soil structure is not essential, or for remolding in the laboratory and subsequent strength and compressibility tests. Undisturbed samples do not entirely represent truly undisturbed soil or rock conditions because the process of sampling and transporting inevitably introduces some disturbance into the soil or rock structure.

Samples of the weathered and/or colluvial soil, the existing landslide rupture materials, and the weakest components of rock units should be taken for laboratory measurement of engineering properties. Special care should be taken to obtain oriented samples of existing zones of weakness or rupture surfaces. For shallow landslides it may be possible to expose and sample critical zones of weakness in the walls of trenches or test pits. For deep-seated landslides it often is extremely difficult to sample the zones of weakness with small-diameter, geotechnical drilling equipment, and it may be appropriate to consider using bucket auger drilling and down-hole geologic logging and sampling techniques (Scullin, 1994).

It is the responsibility of the field supervising geologist or engineer to accurately label and locate the collected samples. He or she is also responsible for the proper transportation of collected samples, particularly undisturbed samples, to prevent sample disturbance by excessive shaking, allowing samples to dry or slake, or by exposing samples to heat or freezing conditions. A large variety of soil boring techniques and sampler types is available. A detailed explanation of the many types is beyond the scope of these Guidelines, but is readily available in the literature (Hvorslev, 1948; ASTM, 2008; U.S. Bureau of Reclamation, 1974 and 1989; U.S. Navy, 1986; Hunt, 1984a; Krynine and Judd, 1957; Acker, 1974; Scullin, 1994; Johnson and DeGraff, 1988; McGuffey and others, 1996; Blake and others, 2002).

Subsurface Water

The presence of subsurface water can be a major contributing factor to the dynamic instability of slopes and existing landslides. Therefore, the identification and measurement of subsurface water in areas of suspected or known slope instability should be an integral part of the subsurface investigation. The location and extent of groundwater, perched groundwater and potential water barriers should be defined and identified in cross-sectional view. Subsurface water conditions within many landslides are best considered as complex, multiple, partially connected flow systems. McGuffey and others (1996) have listed the following recommendations:

1. Surface observations are essential in determining the effect of subsurface water on landslide instability.

2. Periodic or seasonal influx of surface water to subsurface water will not be detected unless subsurface water observations are conducted over extended time periods.

3. Landslide movements may open cracks and develop depressions at the head of a landslide that increase the rate of infiltration of surface water into the slide mass.

4. Ponding of surface water anywhere on the landslide may cause increased infiltration of water into the landslide and should be investigated.

5. Disruption of surface water channels and culverts may also result in increased infiltration of surface water into the landslide.

6. Landslide movements may result in blockage of permeable zones that were previously freely draining. Such blockage may cause a local rise in the groundwater table and increased saturation and instability of the landslide materials. Subsurface observations should therefore be directed to establishing subsurface water conditions in the undisturbed areas surrounding the landslide.

7. Low permeability soils, which are commonly involved in landslides, have slow response times to changes in subsurface water conditions and pressures. Long-term subsurface water monitoring is required in these soils.

8. Accurate detection of subsurface water in rock formations is often difficult because shale or claystone layers, intermittent fractures, and fracture infilling may occlude subsurface water detection by boring or excavation.

9. Borings should never be the only method of subsurface water investigation; nevertheless they are a critical component of the overall investigation.

Geotechnical Laboratory Testing

The geotechnical testing of soil and rock materials typically follows accepted published standards (ASTM, 2008; Head, 1989). Good professional judgment is expected in the selection of appropriate samples, shear tests, and interpretation of the results in arriving at strength characteristics appropriate for the present and anticipated future slope conditions. The following guidelines are provided for evaluating soil properties:

1. Soil properties, including unit weight and shear strength parameters (cohesion and friction angle), may be based on appropriate conventional laboratory and field tests.

2. Testing of earth materials should be in accordance with the appropriate ASTM Standards that are updated annually (ASTM, 2008).

3. Prior to shear tests, samples should be soaked a sufficient length of time to approximate a saturated moisture condition.

4. Stability analyses generally should use the lowest values derived from the suite of samples tested.

5. Residual test values should be used for static analysis of existing landslides, along shale bedding planes, highly distorted bedrock, over-consolidated fissured clays, and for paleosols and topsoil zones under fill. Peak values may be used for pseudo-static or dynamic calculations if the buildup of pore pressures is not anticipated and if permitted by the lead agency. Consideration of reducing the strength values for dynamic analyses should be made in light of the measured material properties and anticipated subsurface water conditions (see section on Effective-Stress vs. Total-Stress Conditions below).

6. Appropriate analyses of existing failures (back-calculated strengths) in slopes similar to that under consideration in terms of height, geology, and soil or rock materials may be helpful in determining or verifying proposed shear strength parameters.

7. Laboratory shear strength values used for design of fill slopes steeper than two horizontal to one vertical (2:1) and for buttress fills should be verified by testing during slope grading. In the event that the shear strength values from field samples are less than those used in design, the slope should be reanalyzed and modified as necessary to provide the required factor of safety for stability.

Effective-Stress vs. Total-Stress Conditions

In principle, a pseudo-static or Newmark analysis can be performed on either a total-stress or effective-stress basis. The geotechnical industry practice for 'typical' developments has been to determine shear strength parameters from direct shear tests and perform the analysis assuming drained soil conditions, where the effective stresses are known and static and dynamic shear strengths are considered the same. For most investigations where the slopes are unsaturated or partially saturated, this assumption will be valid and the results of the analysis will tend to be conservative. However, for saturated slopes this assumption ignores the build-up of pore pressures due to dynamic loading, which can lower the shear resistance to failure and, in some cases, result in unconservative stability evaluations. For such conditions a total-stress analysis is required that assumes undrained soil response.

Seed (1966) presented an approach to a total-stress analysis for earth embankments that uses dynamic shear tests to derive a factor of safety that accounts for (a) initial conditions; (b) changes in stress and reorientation of principal stress; (c) decrease in strength due to cyclic loading conditions; and (d) decrease in strength due to undrained conditions during earthquake loading. This method is rigorous, and provides good estimates of the dynamic behavior of saturated materials but may be too costly for most projects.

A simpler approach to a total stress analysis would be to determine total-stress strength parameters (i.e., $c = Su$, $\phi = 0$ for saturated conditions; values of c, ϕ for partially saturated conditions) from undrained triaxial shear tests and use those values in the stability analysis. Jibson and Keefer (1993) showed how to conduct such an analysis, and their results indicated that factors of safety and critical slip surfaces differed significantly from those generated from an effective-stress analysis. The U.S. Army Corps of Engineers practice is to use a composite shear strength envelope (based on a consolidated-drained test at low confining pressures and a

consolidated-undrained test at high confining pressures) for permeable soils, and a consolidated-undrained strength envelope for soils with low permeability (Hynes and Franklin, 1984).

Slope Stability Analysis

General Considerations

Slope stability analysis will generally be required by the lead agency for cut, fill, and natural slopes whose slope gradient is steeper than two horizontal to one vertical (2:1), and on other slopes that possess unusual geologic conditions such as unsupported discontinuities or evidence of prior landslide activity. Analysis generally includes deep-seated and surficial stability evaluation under both static and dynamic (earthquake) loading conditions.

Evaluation of deep-seated slope stability should be guided by the following:

1. The potential failure surface used in the analysis may be composed of circles, planes, wedges or other shapes considered to yield the minimum factor of safety against sliding for the appropriate soil or rock conditions. The potential failure surface having the lowest factor of safety should be sought.

2. The anticipated placement of fill material based on the proposed grading plan should be the incorporated. The areas of grading should be the focus area for the slope stability analysis.

3. Forces to be considered include the gravity loads of the potential failure mass, structural surcharge loads and supported slopes, and loads due to anticipated earthquake forces. The potential for hydraulic head (or significant pore-water pressure) should be evaluated and its effects included when appropriate. Total unit weights for the appropriate soil moisture conditions are to be used.

Evaluation of surficial slope stability should be guided by the following:

1. Structural discontinuities in the steep bedrock slopes should be evaluated for rock fall and rockslide type failures. Comparing these potential zones of weakness to the slope geometry can be done using stereo plot diagrams and available rock-failure software.

2. Calculations may be based either on analysis procedures for stability of an infinite slope with seepage parallel to the slope surface or on another method acceptable to the lead agency. For the infinite slope analysis, the minimum assumed depth of soil saturation is the smaller of either a depth of one (1) meter or depth to firm bedrock. Soil strength characteristics used in analysis should be obtained from representative samples of surficial soils that are tested under conditions approximating saturation and at normal loads approximating conditions at very shallow depth.

3. Ravines, swales, and hollows on natural slopes warrant special attention as potential sources of fast-moving debris flows and other types of landslides. If possible, structures should be located away from the base or axis of these types of features.

In both deep-seated and surficial slope stability evaluations, appropriate mitigation procedures and stabilization should be recommended, in order to provide the required level of slope stability. Recommendations for mitigation of damage to the proposed development caused by failure of off-site slopes should be made unless slope-specific investigations and analyses demonstrate that the slopes are stable.

Analysis Methods

The first and simplest approach to a dynamic slope stability calculation is a **pseudo-static analysis,** in which the earthquake load is simulated by an "equivalent" static horizontal acceleration acting on the mass of the landslide, in a limit-equilibrium analysis (Terzaghi, 1950; Janbu, 1973; Bromhead, 1986; Nash, 1987; Chowdhury, 1978; Morgenstern and Sangrey, 1978; Seed, 1979; Hunt, 1984b; Duncan, 1996). The pseudo-static approach has certain limitations (Cotecchia, 1987; Kramer, 1996), but this methodology is considered to be generally conservative, and is the one most often used in current practice. Expanding the work of Bray and Rathje (1998), Blake and others (2002) and Stewart and others (2003) have developed a procedure to select a pseudo-static seismic coefficient on the basis of site-specific ground motion parameters that can serve as an initial "screening analysis" to determine whether a more rigorous analysis is warranted.

The second procedure is known as a **Newmark or cumulative displacement analysis** (Newmark, 1965; Makdisi and Seed, 1978; Wilson and Keefer, 1983; Hynes and Franklin, 1984; Jibson, 1993; Bray, 2007). The procedure involves the calculation of the "yield" acceleration, which is the horizontal acceleration that causes the slide mass' static factor of safety to reach 1.0, usually from a limit-equilibrium slope stability analysis. The procedure then uses earthquake strong-motion records, modified if necessary for site conditions or scaled to match seismological conditions, which are numerically integrated twice to calculate the cumulative displacement of the sliding mass relative to the ground below the slip surface. These analytical displacements are then evaluated in light of the slope material properties and the requirements of the proposed development. The pseudo-static and Newmark displacement analyses will be described in more detail in the following sections.

Pseudo-Static Analysis

The ground –motion parameter used in a pseudo-static analysis is referred to as the seismic coefficient "k." The selection of a seismic coefficient has relied heavily on engineering judgment and local code requirements because there is no simple method for determining an appropriate value.

Cautionary Note: *The seismic coefficient "k" is* ***not*** *equivalent to the peak horizontal ground acceleration value, either probabilistic or deterministic; therefore PGA should not be used as a seismic coefficient in pseudo-static analyses. The use of PGA will usually result in overly*

conservative factors of safety (Seed, 1979; Chowdhury, 1978). Furthermore, the practice of reducing the PGA by a "repeatable acceleration" factor to obtain a pseudo-static coefficient has no basis in the scientific or engineering literature.

There have been a number of published articles that provide guidance in the selection of an appropriate seismic coefficient for pseudo-static analyses. Seed's 1979 article (the 19th Rankine Lecture) summarizes the factors to be considered in evaluating dynamic stability of earth-and rock-fill embankments. After evaluating all of the available data on earthquake-induced deformations of embankment dams, Seed recommended some basic guidelines for making preliminary evaluations of embankments to ensure acceptable performance (i.e., permanent deformations which would not imperil the overall structural integrity of an embankment dam). These recommendations were: using a pseudo-static coefficient of 0.10 for magnitude 6½ earthquakes and 0.15 for magnitude 8¼ earthquakes, with an acceptable factor of safety of the order of 1.15. Seed believed that his guidelines would ensure that permanent ground deformations would be acceptably small. Seed also made extensive commentary on the choice of appropriate material strengths, and limited his recommendations to those embankments composed of materials that do not undergo severe strength loss due to seismic shaking with an expected crest acceleration of less than 0.75g.

The limitations to selecting seismic coefficients on the basis of these references are twofold. First, the magnitude of acceptable displacements for earth embankments, roughly one meter, is far greater than what is acceptable for structures meant for human occupancy. Second, they only peripherally account for differences in earthquake magnitude and distance at differing sites, implying that resulting stability analyses will be over-conservative in some cases and under-conservative in others.

To address these significant limitations, Blake and others (2002) and Stewart and others (2003) used the simplified design procedures developed by Bray and others (1998) to develop a "screen analysis procedure," based on a pseudo-static approach that accounts for the anticipated seismicity at a site and allows for different levels of acceptable displacements. By their formulation, the seismic coefficient, k_{eq}, is derived from,

$$k_{eq} = f_{eq} * MHA_r$$

where MHA_r is the maximum horizontal acceleration at the site for a soft rock site condition; g is the acceleration due to gravity; and f_{eq} is a factor related to the seismicity of the site. The formula for f_{eq} is,

$$f_{eq} = \frac{NRF}{3.477}\left[1.87 - \log_{10}\left(\frac{u}{(MHA_r / g) * NRF * D_{5-95}}\right)\right]$$

where NRF is a factor that accounts for the nonlinear response of the materials above the slide plane; u is displacement; and D_{5-95} is the duration of strong shaking, a function of earthquake magnitude and distance.

Blake and others (2002) have simplified the process of estimating f_{eq} for ranges of magnitude and distance by preparing sets of curves for two displacement (u) values, 5 cm and 15 cm. These curves are reproduced in Figure 1.

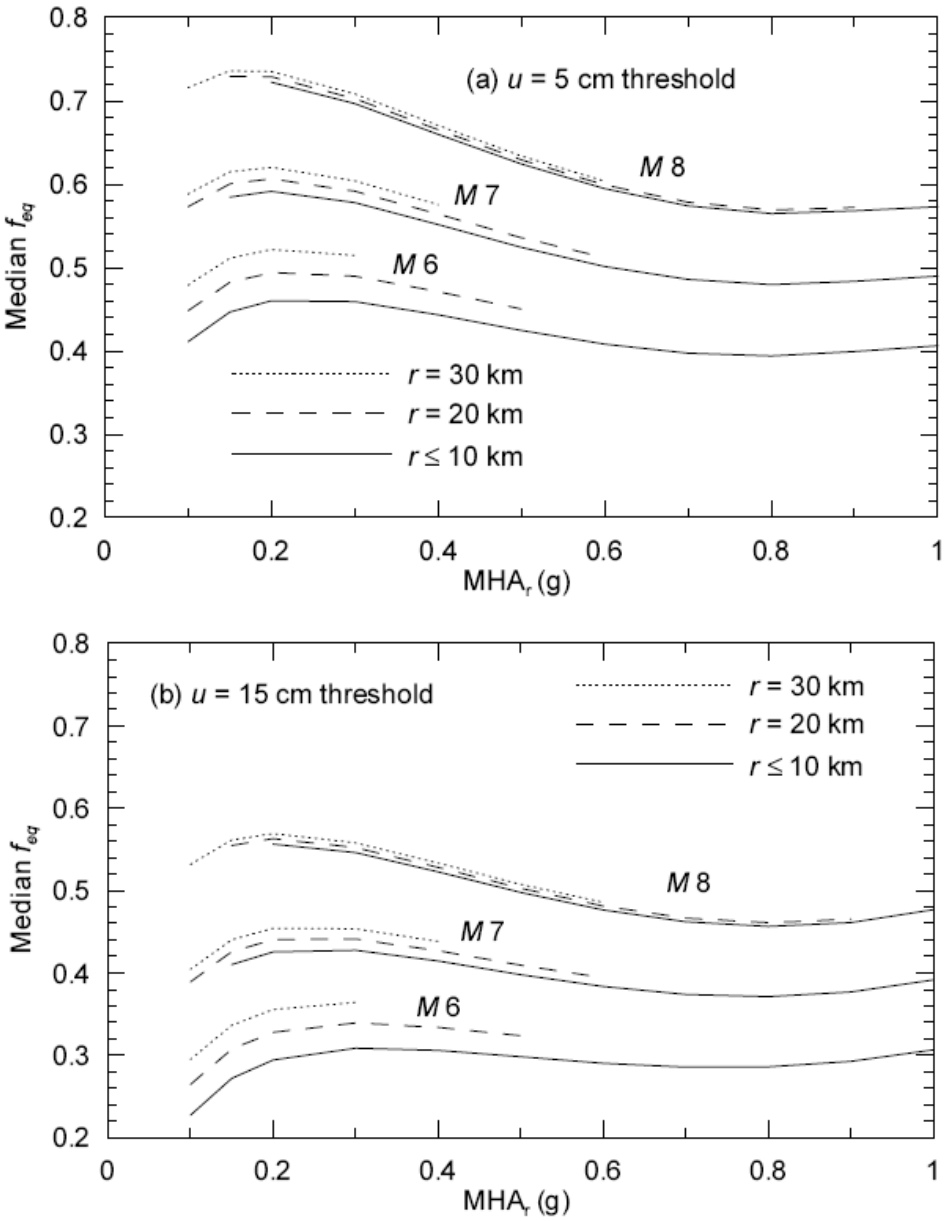


Figure 1. Values of f_{eq} as a Function of MHA_r, Magnitude and Distance for Threshold Displacements of (a) 5 cm and (b) 15 cm (Modified from Blake and others, 2002).

The value of threshold displacement used to determine f_{eq} should be based on consideration of the quality of the site geotechnical information used, the level of understanding of the underlying geologic materials and their discontinuities, the significance of the project development (critical facilities), and the value considered acceptable by the local regulatory agency. Blake and others (2002) provide a thorough description of how their screening analysis procedure is performed, and Stewart and others (2003) provide the rationale for the procedure.

Newmark Displacement Analysis

A Newmark displacement analysis consists of three basic steps, as outlined below:

1. The first step is to perform a limit-equilibrium stability analysis to determine the location and shape of the critical slip surface (the slip surface with the lowest factor of safety), and the yield acceleration (a_y), defined as the acceleration required to bring the factor of safety to 1.0. Most computer-based slope stability programs include iterative routines for finding both of these parameters. If a computer program with these options is not available, the critical slip surface can be obtained through iterative trial-and-error, and the yield acceleration can be calculated from Newmark's relation

$$a_y = (FS - 1)g \sin \alpha$$

   where FS is the static factor of safety, g is the acceleration due to gravity, and α is the angle from the horizontal that the center of mass of the landslide first moves.

2. The second step is to select acceleration time histories that represent the expected ground motions at the project site. The selection process typically involves estimating magnitude, source-to-site distance, peak ground acceleration and spectral response relevant to the project site, and searching for existing strong-motion records that have parameters that closely match the estimated values. For Newmark analyses, Jibson (1993) recommended using: (1) Arias Intensity (Wilson and Keefer, 1985; Wilson, 1993), (2) magnitude and source distance, and (3) PGA and duration as criteria for selecting a suite of strong-motion records having characteristics of interest at a project site. In general, site-specific PGA should be roughly equivalent to that derived from a probabilistic seismic hazard analysis for a 475-year return period, and mode magnitude and mode distance derived from de-aggregation of that hazard level. Procedures for determining these site parameters and selecting a representative strong-motion record are outlined in Chapter 4. Analysis of multiple records spanning a range of estimated shaking characteristics produces a range of calculated displacements, which provides a better basis for judgment of slope performance than one displacement calculated from a single record that may have unique idiosyncrasies. If the slopes to be analyzed are composed of soils or weakly cemented rock, and a strong-motion recording with similar site characteristics cannot be found, a seismic site response analysis should be performed. Bray and Rathje (1998) described a method of using a one-dimensional wave propagation program (e.g., SHAKE91, Idriss and Sun, 1992; SHAKE, Schnabel and others, 1972) to find the average response at the slip surface prior to calculating displacements.

3. The final step in a Newmark analysis is to calculate the cumulative displacements anticipated for the landslide under investigation. Computer software capable of calculating displacements from strong-motion records is available (Jibson and Jibson, 2003) and can greatly simplify the analysis.

Types of Sliding Block Models

Newmark (1965) regarded a landslide mass as a rigid body and showed that both infinite slope and circular failures could be modeled as a rigid block on an inclined plane. A rigid-block sliding model is appropriate for displacement analyses for relatively thin slide masses, such as what occurs on natural slopes during earthquakes. However, the rigid-block assumption can be very un-conservative for thicker, compliant slope-forming materials (Kramer and Smith, 1997; Rathje and Bray, 1999; Wartman, and others, 2003).

Makdisi and Seed (1978) accounted for the effects of earthquake ground shaking within a slide mass by first performing a dynamic response analysis for an earth embankment, and then double integrating the resulting time histories to estimate cumulative displacements at different locations in the embankment – a process referred to as a ”decoupled analysis.” Modern computers and commercially available software have allowed for more frequent use of dynamic models that calculate displacements considering the effects of ground motion input from below the slide mass and the effects of ground motions within the slide mass – referred to as a “fully coupled analysis.” Wartman and others (2003) have defined the parameters where rigid-block, decoupled and fully coupled sliding block analyses are most appropriate.

Simplified Newmark Displacement Estimation Procedures

Several screening tools have been developed for estimating ground displacements, and in some cases have been found to produce reasonable results for actual landslides (Pradel and others, 2005). Jibson (2007) prepared regression models for Newmark rigid sliding block displacement in terms of yield acceleration ratio (a_y/PGA), yield acceleration ratio and earthquake magnitude, Arias Intensity and yield acceleration, and Arias Intensity and yield acceleration ratio. Bray and others (1998) and Rathje and Bray (1998) developed a simplified procedure based on a large number of strong motion records processed through a decoupled displacement analysis. This procedure requires as input rock PGA, input rock mean period, input rock significant duration ($D_{5\text{-}95}$), yield acceleration, slide mass thickness, and average shear wave velocity. Bray and Travasarou (2007) developed a semi-empirical procedure by processing over 600 strong motion records through a one-dimensional fully coupled non-linear displacement analysis. This procedure requires estimates of the initial fundamental period of the sliding mass (T_s) and its yield coefficient (k_y), site-specific acceleration response spectral value at 1.5 T_s (S), and the controlling earthquake magnitude, (M), to estimate the likely seismic displacement, (D in cm), with a probability of exceedance of 50% or lower as:

$$\ln(D) = 11.10 - 2.83 \ln(k_y) - 0.333(\ln(k_y))^2 + 0.566 \ln(k_y)\ln(S)$$
$$+ 3.04\ln(S) - 0.244(\ln(S))^2 + 1.5T_s + 0.278(M - 7)$$

Saygili and Rathje (2008) developed regression models for rigid sliding block displacement based on over 2,000 strong motion records. The models are a function of the yield acceleration and different combinations of ground motion parameters, including peak ground acceleration (PGA), peak ground velocity (PGV), Arias Intensity, and Mean Period.

Evaluation of Potential Earthquake-Induced Landslide Hazards

The determination of dynamic slope stability (i.e., pseudo-static factors of safety or analytical displacements), and the acceptable parameters used in the analysis, should follow the standards defined by the lead agency. If no standards exist, the following general values may be used for defining the stability of slopes for static and dynamic loads.

Pseudo-Static Analysis

Slopes that have a pseudo-static factor of safety greater than 1.0 using a seismic coefficient derived from the screening analysis procedure of Stewart and others (2003) can be considered stable. If the pseudo-static analysis results in a factor of safety lower than 1.0, the project engineer can either employ a Newmark displacement analysis (or other displacement-type analysis method if acceptable to the lead agency) to determine the magnitude of slope displacements, or design appropriate mitigation measures.

Newmark Displacement Analysis

The Newmark analysis models a highly idealized and simplistic failure mechanism; thus, as discussed previously, the calculated displacements should be considered order-of-magnitude estimates of actual field behavior. Rather than being an accurate guide of observable landslide displacement in the field, Newmark displacements provide an index of probable seismic slope performance, and considerable judgment is required in evaluating seismic stability in terms of Newmark displacements. In some jurisdictions, less than 10 cm is considered stable, whereas, more than 30 cm is considered unstable. As a general guideline,

1. Newmark displacements of 0 to 15 cm are unlikely to correspond to serious landslide movement and damage.

2. In the 15 to 100 cm range, slope deformation may be sufficient to cause serious ground cracking or enough strength loss to result in continuing (post-seismic) failure. Determining whether displacements in this range can be accommodated safely requires good professional judgment that takes into account issues such as landslide geometry and material properties.

3. Calculated displacements greater than 100 cm are very likely to correspond to damaging landslide movement, including possible catastrophic failure, and such slopes should be considered unstable.

CHAPTER 6

ANALYSIS OF LIQUEFACTION HAZARDS

Screening Investigations for Liquefaction Potential

The purpose of screening investigations for sites within zones of required investigation for liquefaction is to determine whether a given site has obvious indicators of a low potential for liquefaction failure (e.g., bedrock near the surface or deep ground water without perched water zones), or whether a more comprehensive field investigation is necessary to determine the potential for damaging ground displacements during earthquakes.

If a screening investigation can ***clearly*** demonstrate the absence of liquefaction hazards at a project site, and if the lead agency technical reviewer concurs with this finding, the screening investigation will satisfy the site-investigation report requirement. If there is a reasonable expectation that liquefiable soils exist on the site and the engineering geologist and/or civil engineer can demonstrate that large lateral spread displacements (of more than 0.5 meter) are unlikely (e.g., Youd and others, 2002; Bardet and others, 2002; Zhang and others, 2004), the local agency may give them the option to forego the quantitative evaluation of liquefaction hazards and provide a structural mitigation for certain classes of structures. These mitigation methods are outlined in the mitigation section of this chapter. If the findings of the investigation fall outside these two options, then the more-comprehensive quantitative evaluation described below needs to be conducted.

Screening investigations for liquefaction hazards should address the following basic questions:

- **Are potentially liquefiable soil types present?**

Given the highly variable nature of Holocene deposits that are likely to contain liquefiable materials, most sites will require borings to determine whether liquefiable materials underlie the project site. Borings used to define subsurface soil properties for other purposes (e.g., foundation investigations, environmental or groundwater studies) may provide valuable subsurface geologic and/or geotechnical information.

The vast majority of liquefaction hazards are associated with sandy soils and silty soils of low plasticity. Cohesive soils are generally not considered susceptible to soil liquefaction. Analysis of fine-grained soils affected by the 1999 earthquakes in Taiwan and Turkey has led to rejection of the so-called “Chinese Criteria”, particularly grain size, as an indicator of potential soil failure. Although soils having a plasticity index (PI) greater than 7 have generally been expected to behave like clays (Boulanger and Idriss, 2006), Bray and Sancio (2006) found loose soils with a PI < 12 and moisture content > 85% of the liquid limit are susceptible to liquefaction. Moreover, sensitive soils having PI > 18 can undergo severe strength loss, so engineering judgment must be applied

when using screening criteria. It is recommended that both PI and moisture content criteria be considered for screening purposes.

In addition to sandy and silty soils, some gravelly soils are potentially vulnerable to liquefaction. Most gravelly soils drain relatively well, but when: (a) their voids are filled with finer particles, or (b) they are surrounded by less pervious soils, drainage can be impeded and they may be vulnerable to cyclic pore pressure generation and liquefaction. Gravelly geologic units tend to be deposited in a more-turbulent depositional environment than sands or silts, tend to be fairly dense, and so generally resist liquefaction. Accordingly, conservative "preliminary" methods may often suffice for evaluation of their liquefaction potential. For example, gravelly deposits that can be shown to be pre-Holocene in age (older than about 11,000 years) are generally not considered susceptible to liquefaction.

- **If present, are the potentially liquefiable soils saturated or might they become saturated?**

In order to be susceptible to liquefaction, potentially liquefiable soils must be saturated or nearly saturated. In general, liquefaction hazards are most severe in the upper 50 feet of the surface, but on a slope near a free face or where deep foundations go beyond that depth, liquefaction potential should be considered at greater depths. If it can be demonstrated that any potentially liquefiable materials present at a site: (a) are currently unsaturated (e.g., are above the water table), (b) have not previously been saturated (e.g., are above the historic-high water table), and (c) are highly unlikely to become saturated (given foreseeable changes in the hydrologic regime), then such soils generally do not constitute a liquefaction hazard that would require mitigation. Note that project development, changes in local or regional water management patterns, or both, can significantly raise the water table or create zones of perched water. Extrapolating water table elevations from adjacent sites does not, by itself, demonstrate the absence of liquefaction hazards, except in those unusual cases where a combination of uniformity of local geology and very low regional water tables permits very conservative assessment of water table depths. Screening investigations should also address the possibility of local "perched" water tables, the raising of water levels by septic systems, or the presence of locally saturated soil units at a proposed project site.

- **Is the geometry of potentially liquefiable deposits such that they pose significant risks requiring further investigation, or might they be mitigated by relatively inexpensive foundation strengthening?**

Relatively thin seams of liquefiable soils (on the order of only a few centimeters thick), if laterally continuous over sufficient area, can represent potentially hazardous planes of weakness and sliding, and may thus pose a hazard with respect to lateral spreading and related ground displacements. Thus, the screening investigation should identify the presence of gently sloping ground and nearby free faces (cut slopes, stream banks, and shoreline areas), whether on or off-site, to determine whether lateral spreading and related ground displacements might pose a hazard to the project. If such features are found, the quantitative evaluation of liquefaction usually will be warranted because of potential life-safety concerns.

Even when it is not possible to demonstrate the absence of potentially liquefiable soils or prove that such soils are not and will not become saturated, it may be possible to demonstrate that any

potential liquefaction hazards can be adequately mitigated through a simple strengthening of the foundation of the structure, as described in the mitigation section of this chapter, or other appropriate methods.

- **Are in-situ soil densities sufficiently high to preclude liquefaction?**

If the screening evaluation indicates the presence of potentially liquefiable soils, either in a saturated condition or in a location that might subsequently become saturated, then the resistance of these soils to liquefaction and/or significant loss of strength due to cyclic pore pressure generation under seismic loading should be evaluated. If the screening investigation does not conclusively eliminate the possibility of liquefaction hazards at a proposed project site (a factor of safety of 1.5 or greater), then more extensive studies are necessary.

A number of investigative methods may be used to perform a screening evaluation of the resistance of soils to liquefaction. These methods are somewhat approximate, but in cases wherein liquefaction resistance is very high (e.g., when the soils in question are very dense) then these methods may, by themselves, suffice to adequately demonstrate sufficient level of liquefaction resistance, eliminating the need for further investigation. It is emphasized that the methods described in this section are more approximate than those discussed in the quantitative evaluation section, and so require very conservative application.

Methods that satisfy the requirements of a screening evaluation, at least in some situations, include:

1. Direct in-situ relative density measurements, such as the ASTM D 1586-92 and ASTM D6066-96e1 (Standard Penetration Test [SPT]) or ASTM D3441-94 (Cone Penetration Test [CPT]).

2. Preliminary analysis of hydrologic conditions (e.g., current, historical and potential future depth(s) to subsurface water). Current groundwater level data, including perched water tables, may be obtained from permanent wells, driller's logs and exploratory borings. Historical groundwater data can be found in reports by various government agencies, although such reports often provide information only on water from production zones and ignore shallower water.

3. Non-standard penetration test data. It should be noted that correlation of non-standard penetration test results (e.g., sampler size, hammer weight/drop, hollow stem auger) with SPT resistance is very approximate, and so requires very conservative interpretation, unless direct SPT and non-standard test comparisons are made at the site and in the materials of interest.

4. Geophysical measurements of shear-wave velocities.

5. "Threshold strain" techniques represent a conservative basis for screening of some soils and some sites (National Research Council, 1985). These methods provide only a very conservative bound for such screening, however, and so are conclusive only for sites where the potential for liquefaction hazards is very low.

Quantitative Evaluation of Liquefaction Resistance

Liquefaction investigations are best performed as part of a comprehensive investigation. These Guidelines are to promote uniform evaluation of the resistance of soil to liquefaction.

Detailed Field Investigation

Engineering Geologic Investigations

Engineering geologic investigations should determine:

1. The presence, texture (e.g., grain size), and distribution (including depth) of unconsolidated deposits;

2. The age of unconsolidated deposits, especially for Quaternary Period units (both Pleistocene and Holocene Epochs);

3. Zones of flooding or historic liquefaction; and,

4. The groundwater level to be used in the liquefaction analysis, based on data from well logs, boreholes, monitoring wells, geophysical investigations, or available maps. Generally, the historic high groundwater level should be used unless other information indicates a higher or lower level is appropriate.

The engineering geologic investigations should reflect relative age, soil classification, three-dimensional distribution and general nature of exposures of earth materials within the area. Surficial deposits should be described as to general characteristics (including environment of deposition) and their relationship to present topography and drainage. It may be necessary to extend the mapping into adjacent areas. Geologic cross sections should be constrained by boreholes and/or trenches when available.

Geotechnical Field Investigation

The vast majority of liquefaction hazards are associated with sandy and/or silty soils. For such soil types, there are at present two approaches available for quantitative evaluation of the soil's resistance to liquefaction. These are: (1) correlation and analyses based on in-situ Standard Penetration Test (SPT) (ASTM D1586-92 and ASTM D6066-96e1) data, and (2) correlation and analyses based on in-situ Cone Penetration Test (CPT) (ASTM D3441-94) data. Both of these methods have some relative advantages (see Table 4). Either of these methods can suffice for some site conditions, but there is also considerable advantage to using them jointly.

Seed and others (1985) provide guidelines for performing "standardized" SPT, and also provide correlations for conversion of penetration resistance obtained using most of the common alternate combinations of equipment and procedures in order to develop equivalent "standardized"

penetration resistance values — $(N_1)_{60}$. These "standardized" penetration resistance values can then be used as a basis for evaluating liquefaction resistance.

Table 4. Comparative advantages of SPT and CPT methods.

SPT ADVANTAGES	CPT ADVANTAGES
Retrieves a sample. This permits identification of soil type ***with certainty***, and permits evaluation of fines content (which influences liquefaction resistance). Note that CPT provides poor resolution with respect to soil classification, and so usually requires some complementary borings with samples to more reliably define soil types and stratigraphy.	Provides ***continuous*** penetration resistance data, as opposed to averaged data over discrete increments (as with SPT), and so is less likely to "miss" thin layers and seams of liquefiable material.
Liquefaction resistance correlation is based primarily on field case histories, and the vast majority of the field case history database is for in-situ SPT data	Faster and less expensive than SPT, as no borehole is required.

Cone penetration test (CPT) tip resistance (q_c) may also be used as a basis for evaluation of liquefaction resistance, by either (a) direct empirical comparison between qc data and case histories of seismic performance (Olsen, 1988), or (b) conversion of q_c-values to "equivalent" $(N_1)_{60}$-values and use of correlations between $(N_1)_{60}$ data and case histories of seismic performance. At present, Method (b) — conversion of qc to equivalent $(N_1)_{60}$— is preferred because the field case history database for SPT is well developed compared to CPT correlations. A number of suitable correlations between qc and $(N_1)_{60}$ are available (e.g., Robertson and Campanella, 1985; Seed and De Alba, 1986). These types of conversion correlations depend to some extent on knowledge of soil characteristics (e.g., soil type, mean particle size (D_{50}), fines content). When the needed soil characteristics are either unknown or poorly defined, then it should be assumed that the ratio

$$\frac{q_c(kg/cm^2)}{N(blows/\ ft)}$$

is approximately equal to five for conversion from q_c to "equivalent" N-values.

The simplified procedure for evaluating liquefaction resistance is becoming more standardized (Youd and others, 2001), and is continuing to evolve as new data from post-earthquake investigations around the world improve correlations between liquefaction and penetration resistance (e.g. Cetin and others, 2004; Moss and others, 2006; Idriss and Boulanger, 2008). These developments should be followed and new, improved correlations used as appropriate.

Geotechnical Laboratory Testing

The use of laboratory testing (e.g., cyclic triaxial, cyclic simple shear, cyclic torsional tests) on "undisturbed" soil samples as the sole basis for the evaluation of in-situ liquefaction resistance is not recommended, as unavoidable sample disturbance and/or sample densification during reconsolidation prior to undrained cyclic shearing causes a largely unpredictable, and typically unconservative, bias to such test results. Laboratory testing is recommended for determining grain-size distribution (including mean grain size D_{50}, effective grain size D_{10}, and percent passing #200 sieve), unit weights, moisture contents, void ratios, and relative density.

In addition to sandy and silty soils, some gravelly soils are potentially vulnerable to liquefaction (Evans and Fragaszy, 1995, Evans and Zhou, 1995). Most gravelly soils drain relatively well, but when their voids are filled with finer particles, or they are surrounded (or "capped") by less pervious soils, drainage can be impeded and they may be vulnerable to liquefaction. Gravelly soils tend to be deposited in a more turbulent environment than sands or silts, and are fairly dense, and so are generally resistant to liquefaction. Accordingly, conservative "preliminary evaluation" methods (e.g., geologic assessments and/or shear-wave velocity measurements) often suffice for evaluation of their liquefaction potential. When preliminary evaluation does not suffice, more accurate quantitative methods must be used. Unfortunately, neither SPT nor CPT provides reliable penetration resistance data in soils with high gravel content, as the large particles impede these small-diameter penetrometers. At present, the best available technique for quantitative evaluation of the liquefaction resistance of coarse, gravelly soils involves correlations and analyses based on in-situ penetration resistance measurements using the very large-scale Becker-type Hammer system (Harder, 1988).

Evaluation of Potential Liquefaction Hazards

The factor of safety for liquefaction resistance has been defined:

$$\text{Factor of Safety} = \frac{CRR}{CSR}$$

where CSR is the cyclic stress ratio generated by the anticipated earthquake ground motions at the site, and CRR is the cyclic stress ratio required to generate liquefaction (Seed and Idriss, 1982). For the purposes of evaluating the results of a quantitative assessment of liquefaction potential at a site, a factor of safety against the occurrence of liquefaction greater than about 1.3 can be considered an acceptable level of risk. This factor of safety assumes that high-quality, site-specific penetration resistance and geotechnical laboratory data were collected, and that ground motions as prescribed in the latest edition of the California Building Code were used in the analyses. If lower factors of safety are calculated for some soil zones, then an evaluation of the level (or severity) of the hazard associated with potential liquefaction of these soils should be made.

Such hazard assessment requires considerable engineering judgment. The following is, therefore, only a guide. The assessment of hazard associated with potential liquefaction of soil deposits at a

site must consider two basic types of hazard: 1) translational site instability (sliding, edge failure, lateral spreading, flow failure, etc.) that potentially may affect all or large portions of the site, and 2) more localized hazard at and immediately adjacent to the structures and/or facilities of concern (e.g., bearing failure, settlement, localized lateral movements).

As Bartlett and Youd (1995) have stated: "Two general questions must be answered when evaluating the liquefaction hazards for a given site:

(1) ‘Are the sediments susceptible to liquefaction?' and

(2) ‘If liquefaction does occur, what will be the ensuing amount of ground deformation?'"

Lateral Spreading and Site Displacement Hazards

Lateral spreading on gently sloping ground generally is the most pervasive and damaging type of liquefaction failure (Bartlett and Youd, 1995). Assessment of the potential for lateral spreading and other large site displacement hazards may involve the need to determine the residual undrained strengths of potentially liquefiable soils. If required, this should be done using in-situ SPT or CPT test data (e.g., Seed and Harder, 1990). The use of laboratory testing for this purpose is not recommended, as a number of factors (e.g., sample disturbance, sample densification during reconsolidation prior to undrained shearing, and void ratio redistribution) render laboratory testing a potentially unreliable, and, therefore, unconservative basis for assessment of in-situ residual undrained strengths. Assessment of residual strengths of silty or clayey soils may, however, be based on laboratory testing of "undisturbed" samples.

Assessment of potential lateral spread hazards must consider dynamic loading as a potential "driving" force, in addition to gravitational forces. It should again be noted, that relatively thin seams of liquefiable material, if fairly continuous over large lateral areas, might serve as significant planes of weakness for translational movements. If prevention of translation or lateral spreading is ascribed to structures providing "edge containment," then the ability of these structures (e.g., berms, dikes, sea walls) to resist failure must also be assessed. Special care should be taken in assessing the containment capabilities of structures prone to potentially "brittle" modes of failure (e.g., brittle walls which may break, tiebacks which may fail in tension). If a hazard associated with potentially large translational movements is found to exist, then either: (a) suitable recommendations for mitigation of this hazard should be developed, or (b) the proposed "project" should be discontinued.

When suitably sound lateral containment is demonstrated to prevent potential sliding on liquefied layers, then potentially liquefiable zones of finite thickness occurring at depth may be deemed to pose no significant risk beyond the previously defined minimum acceptable level of risk. Suitable criteria upon which to base such an assessment include those proposed by Ishihara (1985, Figure 88; 1996, Chapter 16).

For information on empirical models that might be appropriate to use in these analyses, see Youd and others (2002), Bardet and others (2002), and Idriss and Boulanger (2008).

Localized Liquefaction Hazards

If it can be shown that no significant risk of large translational movements exists, or if suitable mitigation measures can be developed that address such risks, then studies should proceed to consideration of five general types of more localized potential hazards, including:

1. ***Potential foundation bearing failure, or large foundation settlements due to ground softening and near-failure in bearing***. To form a basis for concluding that no hazard exists, a high factor of safety (FS > 1.5) should be based on a realistic appraisal of the minimum soil strengths likely to be mobilized to resist bearing failure (including residual undrained strengths of soils considered likely to liquefy or to suffer significant strength loss due to cyclic pore pressure generation). If such hazard does exist, then appropriate recommendations for mitigation of this hazard should be developed.

2. ***Potential structural and/or site settlements***. Settlements for saturated and unsaturated clean sands can be estimated using simplified empirical procedures (e.g., Tokimatsu and Seed, 1987; Ishihara and Yoshmine, 1992). These procedures, developed for relatively clean, sandy soils, have been found to provide reasonably reliable settlement estimates for sites not prone to significant lateral spreading. Improved relations suitable for spreadsheet analysis are available that are based on fines-corrected penetration resistance (Idriss and Boulanger, 2008).

   Any prediction of liquefaction-related settlements is necessarily approximate, and related hazard assessment and/or development of recommendations for mitigation of such hazard should, accordingly, be performed with suitable conservatism. Similarly, it is very difficult to reliably estimate the amount of localized differential settlement likely to occur as part of the overall predicted settlement: localized ***differential*** settlements on the order of up to two-thirds of the total settlements anticipated should be assumed unless more precise predictions of differential settlements can be made.

3. Localized lateral displacement; "lateral spreading" and/or lateral compression. Methods for prediction of lateral ground displacements due to liquefaction-related ground softening are not yet well supported by data from case histories of field performance. As such case history data are now being developed, significant advances in the reliability and utility of techniques for prediction of lateral displacements may be expected over the next few years. Finite element models represent the most sophisticated method currently in use for calculating permanent displacements due to liquefaction lateral spreading. Like the dynamic analysis for landslide displacements, this method evaluates time histories of the stresses and strains for a strong-motion time history. This method is a state-of-the-art approach to liquefaction hazards and will likely take time to become the state-of-the-practice.

   Consultants performing liquefaction hazard assessment should do their best to keep abreast of such developments (e.g. Idriss and Boulanger, 2008). At present, lateral ground displacement magnitudes can be predicted with reasonable accuracy and reliability only for cases wherein such displacements are likely to be "small" (e.g., on the order of 15 cm or less). Larger

displacements may be predicted with an accuracy of ± one meter or more; this level of accuracy may suffice for design of some structures (e.g., earth and rock-fill dams), but does not represent a sufficiently refined level of accuracy as to be of use for design of foundations for most types of structures.

It may be possible to demonstrate that localized lateral displacements will be 0.5 meter or less based on: (a) evaluation of soil stratigraphy, residual undrained strengths, and duration and severity of seismic loading, or (b) simplified empirical methods. Youd and others (2002) and Bardet and others (2002) empirical procedures use an existing field case history database of lateral spread occurrences. Other empirical methods, such as those based on estimating permanent shear strains in liquefied zones, or more complex analyses, may yield somewhat different results but should be allowed if the methods are documented and the results justified. When likely maximum lateral displacements can be shown to be less than 0.5 meter it may be possible to design foundations with sufficient strength to withstand the expected movements without complete failure. In all other cases, more extensive recommendations are needed for mitigation of the hazard associated with potential lateral displacements.

4. ***Floatation of light structures with basements, or underground storage structures***. Light structures, which extend below the groundwater table and contain large void spaces, may "float" or rise out of the ground during, or soon after an earthquake. Structures that are designed for shallow groundwater conditions typically rely on elements, such as cantilevered walls or tie-downs that resist the buoyant or uplift forces produced by the water. If the material surrounding these elements liquefies, the resisting forces can be significantly reduced and the entire structure may be lifted out of the ground.

5. ***Hazards to Lifelines***. To date, most liquefaction hazard investigations have focused on assessing the risks to commercial buildings, homes, and other occupied structures. However, liquefaction also poses problems for streets and lifelines—problems that may, in turn, jeopardize lives and property. For example, liquefaction locally caused natural gas pipelines to break and catch fire during the Northridge earthquake, and liquefaction-caused water line breakage greatly hampered firefighters in San Francisco following the 1906 earthquake. Thus, although lifelines are not explicitly mentioned in the Seismic Hazards Mapping Act, cities and counties may wish to require investigation and mitigation of potential liquefaction-caused damage to lifelines.

CHAPTER 7

GUIDELINES FOR MITIGATING SEISMIC HAZARDS

Introduction

Michael Scullin wrote the consummate book on grading practices in southern California (Scullin, 1983). His book describes the prevailing excavation, grading, inspection and code enforcement techniques used to construct engineered fill in Los Angeles and Orange County during the mid-1970's. Beginning in 1990, local implementation of the Seismic Hazards Mapping Act (SHMA) began requiring mitigation for landslide and liquefaction hazard found in zones of required investigation. This chapter presents specific mitigation measures for earthquake-induced landslides and liquefaction summarized from the previous version of Special Publication 117, information from the two publications listed below, and various techniques described in professional workshops conducted over the past 10 years (Seed, 1998):

1. "Recommended Procedures for Implementation of CGS Special Publication 117- Guidelines for Analyzing and Mitigating Liquefaction Hazards in California", (Martin and Lew, 1999); and,

2. "Recommended Procedures for Implementation of CGS Special Publication 117-Guidelines for Analyzing and Mitigating Landslide Hazards in California" (Blake and others, 2002).

Although there are numerous structural and foundation treatments available to decrease earthquake damages, the focus of this chapter is on the use of grading techniques, surface and ground water control and geotechnical ground improvement methods to reduce the hazards of earthquake-induced ground failures. There are projects that are clearly not feasible because of safety limits or economic constraints where the grading needed to ensure stability is either very complex or involves excessive yardages. However, there is a whole range of stability conditions that can be feasibly mitigated. Earthquake induced hazards can be treated in three general ways:

1. **Avoid the Hazard**: Where the potential for failure is beyond an acceptable level of safety during the life of the project and not preventable by practical means, the hazard should be avoided. Developments should be built sufficiently far away from the threat that they will not be affected by potential offsite failures. Proposed development areas at or near the base of unstable slopes should be avoided and relocated to areas where stabilization is feasible;

2. **Reduce the Hazard to an Acceptable Level**: Several techniques can be used to increase the factor of safety to a level that is acceptable to the local permitting agency. The commonly accepted factor of safety for slopes is > 1.5 for static and > 1.1 for dynamic loads. For

liquefaction hazards, reducing surface settlement to 1”/30’ is generally accepted, depending upon the nature of the building (Boone, 1996); and,

3. **Accommodate the hazard:** Where conditions exist that will cause some measurable amount of strain, engineering techniques based on performance can be used to accommodate the stress. Reducing the hazard may not ensure that the project will remain stable indefinitely; however, the continued success of mitigation often depends on timely inspection, maintenance and ongoing repair.

   The objectives of this chapter are to a) Describe and recommend geotechnical techniques that lessen the earthquake-induced landslide and liquefaction hazards found within zones of required investigation, and b) Promote the consistent, statewide use of these mitigation techniques for projects subject to the Seismic Hazards Mapping Act.

Basic Considerations

In general, only removal or densification of all potentially unstable soils, or permanently lowering the groundwater can fully eliminate landslide and liquefaction hazards. However, foundation treatments and other structural methods may be used to reduce excessive settlement. For example, in areas where liquefaction may cause displacements, designing the foundation to withstand the expected displacement will significantly reduce future damages from liquefaction.

Permitting agencies may set suitable levels of protection prior to project approval (CGOA, 2005). However, these recommended levels may vary among agencies. One of the methods of standardizing requirements is to set statewide, allowable limits based on project performance. Where the structural load is light in weight, such as in typical single-family residential houses, a post- tensioned slab foundation system may be used to accommodate differential settlements up to one inch. The reinforced slab gives the slab sufficient rigidity to span voids that may develop due to differential settlements. For heavier buildings with heavier loads and a relatively uniform mass distribution, a thicker mat foundation is feasible. Buildings supported on continuous spread footings with isolated footings can be interconnected with grade beams to improve support.

Slope stability depends upon the slope geometry, driving forces, distribution of earth materials, ground water conditions, material densities, and material strengths (Varnes, 1978). Stability analyses result in a factor of safety, which is defined as the sum of the driving forces minus resisting forces. A slope is considered to be at the point of failure when the factor of safety equals one, i.e., when the shear strength exactly balances the shear stress induced by gravity. A slope has reserve strength when FS is greater than one. Historically, most jurisdictions require a slope stability analysis for cut, fill and natural slopes that have a slope gradient steeper than two horizontal to one vertical (2:1) or slopes that possess adverse geologic conditions, show prior landslide activity or are unstable under seismic loading conditions.

It is common at construction sites to use multiple methods to achieve adequate mitigation. The geotechnical techniques used depending upon the geotechnical hazards present and the types of structures proposed. The intent of the Seismic Hazards Mapping Act is to balance development

costs and safety by requiring adequate site analysis and promoting appropriate mitigation techniques for the conditions found.

Mitigation of Landslide Hazards

The two types of grading commonly used to mitigate landslide hazards in California are “hillside” construction of building pads and “flat land” construction of engineered mats. These grading techniques are used to prepare level building lots, to provide a means of removing and replacing poor soils, to stabilize landslides, to assure proper drainage, minimize liquefaction and reduce differential settlement. The grading practices used to minimize slope instability on hillside projects are better developed than the grading practices used to minimize liquefaction on flatland projects. This is partially because rainfall-induced slope failures occur more often and are more widespread than earthquake-induced liquefaction failures. As a result, most permitting agencies developed guidelines for hillside grading well before mitigation was required under the Seismic Hazards Mapping Act. Four general categories of earthquake-induced slope failures are discussed below; rotational landslides, fill displacements, soil flows and rock falls.

Rotational Landslides

Rotational slides are characterized by a somewhat cohesive slide mass that rotates along a relatively deep failure plane. The rotational failure occurs at the base of the landslide along one discrete, or several relatively thin zones, of weakness. The principal failure mechanism is the loss of shear strength at depth along a rupture surface that results in sliding of the rock or soil mass within the slope.

Hazard Description

Complex features that develop on a slide mass include rotated blocks and extensional grabens near the head scarp, compressive ridges in the main body and debris or earth flows near the toe of the slide. These features can stress buildings on the slide mass. They also provide conduits for infiltration of water, which can increase the driving force of the failed material. If naturally occurring landslides are not sufficiently removed before engineered fill is placed, movement below a fill can be reactivated along the pre-existing failure plane and transmitted to the surface, causing settlement of building pads (Rogers, 1992). Strong earthquake shaking can cause this type of slope failure even in properly engineered fill that has been placed above a graded surface. Material strength changes, water content and settlement that occur through time in the fill can add to the failure potential.

Recommended Mitigation

Appropriate mitigation depends upon accurate and complete hazard recognition. The standard practice for ensuring stability against earthquake-induced rotational slides is to adequately explore all potential instabilities and treat them during the rough grading phase before construction begins. The overall grading goal is to reduce the driving forces in the upper parts of the slide mass and to increase the resisting forces in the toe area of the slope by providing shear keys or buttresses in the subsurface. Most deep fills need to have water diverted from the fill to enhance stability. Sub-drain galleries are used to prevent pore water pressure build-up in constructed engineered fill. Surface drains, hydra-augered sub-drains, tarps, ditches and grading are used to help stabilize the slide mass once failure has occurred. During re-construction of a landslide mass, the standard practice for stabilizing is to perform all of the following:

1. Remove the unstable soil and rock from the existing slide;

2. Regrade the slide mass to a more stable configuration;

3. Scarify the failure plane to form a bond between the in-place soils and the fill soils;

4. Install sub-drains to relieve hydrostatic pressure at the base of the fill; and,

5. Apply slope stabilization methods such as key trenches, buttress fills or crib walls as appropriate.

Grading can totally remove the landslide or flatten the surface slope angle by ‘laying back’ the slope face to a stable angle. Grading is also used to reduce the weight of the slide mass and direct water away from the surface to prevent infiltration. In some cases, lightweight fill materials will be used to lighten the weight at the head of the slide and layered geofabrics used during recompaction will be used to increase shear strength in the body of the slide. A buttress fill constructed at the toe of the slide will help support the upslope portion of the mass. Buttress fills have a wide base, typically ranging from one third to almost the full height of the slope being buttressed. Fill should be compacted to a minimum of 90 percent of the maximum density as per ASTM D1557 (AASHTO, 2002).

Smaller scale slope failures can occur on graded benches. This type of failure is often a function of improper erosion control measures and lack of drain upkeep. The common mitigation for this type of failure is to prepare adequately compacted fill and stable cut slopes, and ensure an adequate setback. Although considerable engineering and geologic judgment is required for each site, the general geometry for setbacks has been a part of the Uniform Building Code for years (ICBO, 1997). The general heights and distances for compacted fill are provided by code and considered typical regulatory minimums for graded lots. However as development has moved into steeper slopes, the geometry is an inadequate parameter measure of slope safety. Stability on difficult lots depends upon material strength, compaction, and aspect of bedding and other discontinuities rather than geometry.

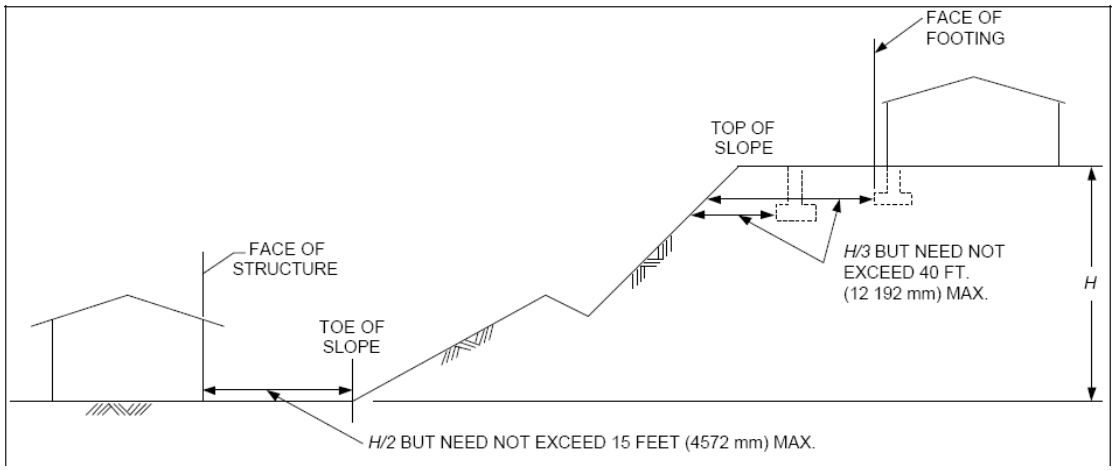


Figure 2. Minimum Setbacks established by the California Building Code.

Fill Displacements

Fill displacement failures are displacements that commonly occur at depth beneath a deep fill or between the natural ground at the edge of a cut slope and the engineered fill of the bench or pad. This type of failure is caused by static gravity force, and results in gradual settlement over time or accelerated settlement in response to dynamic earthquake forces. If there are significant differences, bedrock will be impacted differently than fill material during ground shaking because of the dissimilar material properties.

Hazard Description

The most common fill displacement hazard is differential settlement, which can severely damage building foundations, roads and lifelines. Cut-and-Fill transitions are a special case of differential settlement (Stewart and others, 2001). This hazard impacts side hill benches that have been cut for house pads and roads built on fill. Excessive settlement and fissures can also occur in deep canyons that have been filled in with imported material. Because fills are typically less dense than the underlying materials, much of the adjustment to settlement takes place either at the fill boundary with the natural canyon wall or near the center of the fill where material is the thickest.

Recommended Mitigation

The standard practice for stabilizing settlement failures at cut-fill transitions is to over-excavate during construction and grade the bedrock surface in multiple steps to provide a gradual slope transition (Figure 3). Fill should be compacted to a minimum of 90 percent of the maximum density as per ASTM D1557. Scarification provides a bond between the fill material and the underlying native rock. The overall grading goal is to minimize the difference in bearing capacity across the cut-fill boundary.

Although the California Building Code may be adequate for homogeneous engineered fill, the suggested geometry does not adequately consider bedding plane weaknesses, weathering, hydrostatic pressures or shear strength of the material.

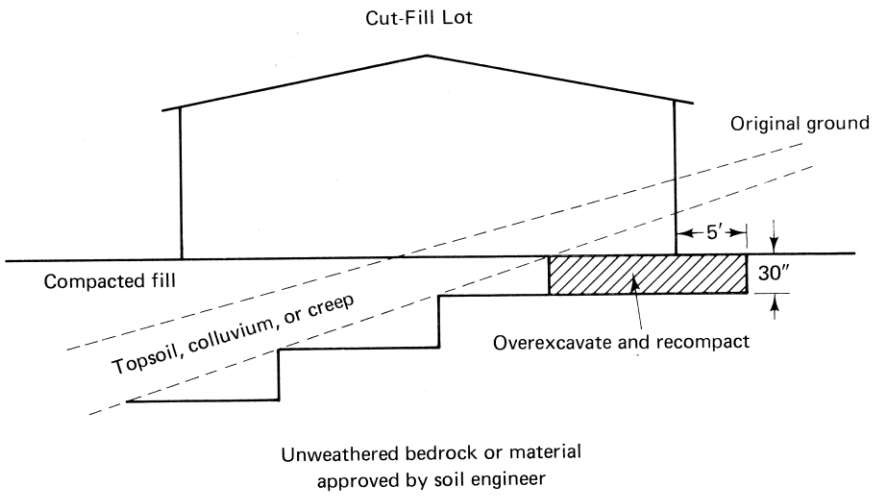


Figure 3. The typical mitigation for a Cut-and-Fill lot is to construct a gradual "stepped" transition between bedrock and fill, overexcavating unstable soils and recompacting suitable fill beneath the footprint (Stewart and others, 2001).

A common grading solution for excess settlement in deep canyon fill failures is to flatten the canyon walls during grading and compact the fill in "zones" at different depths and positions in the fill (Noorany, 1997). The final density of deep fills is determined by the water content, relative compaction and dry density of each fill zone during placement. The gradual reduction in soil strength needs to be considered in assessing the long-term performance of fills. This reduction often results from increased pore pressure due to irrigation, precipitation and earthquake-induced settlement.

The long-term stability of cut and fill slopes and deep canyon fills requires drainage and erosion control measures and ongoing maintenance. That responsibility must be transferred through the life of the development. These maintenance activities include the following tasks:

1. Establish erosion-resistant vegetation on the slope face;

2. Maintain irrigation systems so they do not introduce excess water into the fill;

3. Ensure that sub-drains are kept open and control pore pressures at the base;

4. Keep surface drains in working order and discharging to acceptable outflows;

5. Control surface drainage, especially on building pads located above slopes; and,

6. Repair erosion failures and surficial slope failures before they progress.

Soil Flows

Soil flows/slips are generic terms for shallow disrupted slides composed of loose combinations of soil, surficial deposits, rock fragments, weathered rock and vegetation. The principal failure mechanism in this type of flow is fluidization of the soil mass, caused by a reduction in shear strength due to increased pore water pressure during rain. This type of failure can be triggered by additional forces acting on hill slope materials during strong earthquake shaking, which can also induce dynamic compaction and increase pore water pressure, further weakening the slide mass. Soil flows can be subdivided by grain size into debris flows where the material is coarse-grained and earth flows where fine-grained. The geomorphic character, speed and travel distance of a soil flow is dependent on the particle size, slope and water content within the slide mass. Debris flows form steep, unvegetated scars in the head region and irregular, hummocky deposits at the toe. They most commonly occur on slopes greater than 65 percent. The 1994 Northridge Earthquake in southern California triggered more than 11,000 shallow disrupted slides (Harp & Jibson, 1995).

Hazard Description

Earth flows are characteristically slow moving and may continue to move for a period of days to weeks after initiating. The main hazard from flows occurs where they impact projects in the downslope or runout area. They have a main slide plane at their base and, in larger landslides of this type, sliding occurs on many discontinuous shear surfaces throughout the landslide mass, leading to a surface expression that resembles the flow of a viscous liquid.

Debris flows may initiate as slides, but almost immediately break up and turn into flows. They are typically triggered by periods of prolonged rainfall following a period of less intense precipitation. They can move very rapidly and travel relatively long distances, making them a significant threat to life and property. Individual debris flows are typically small in areal extent and their deposits are relatively thin**.** They form run-out deposits on the flatter ground below the failure. The extent of runout is based on volume and speed of the debris mass. Loose material that has accumulated in swales on steep slopes provides the flow material. Flows can also occur on the outer slope of engineered fill faces where saturated surface soils lay above more highly compacted engineered fill.

Recommended Mitigation

Because this type of hazard usually develops in distinct chutes, the main mitigation is to either avoid the hazardous zone or deflect the flow material (Hollingsworth and Kovacs, 1981). The most common solution is to provide an adequate setback from the runout zone. Grading solutions include removing excess material from the upslope swales, reshape the gully profile to reduce the driving forces, lowering the slope gradient and restricting water inflow into the soil mass. Offsite flows can be mitigated using catchment basins, protective structures such as embankments, diversion or barrier walls and by requiring setback distances. The most effective measure to protect structures against earth flows and debris flows is to accurately define the potential failure area and require a setback from the runout path.

Rock Falls & Topples

Rock falls and topples consist of weakly cemented, loose or intensely fractured and weathered material on slopes. The falling blocks are created by sets of fractures or intact blocks in a weak matrix. Natural fracturing patterns and incipient failure planes determine block sizes. The principal failure mechanism in this type of failure is loss of tensile strength on very steep slopes. This loss of tensile strength is commonly accentuated or triggered by infiltration of water, freeze-thaw cycles or strong earthquake ground shaking.

Hazard Description

Rock falls commonly occur on high angle cut slopes, ledges, steep slopes, and in particular, highway and railroad cuts where slopes have been undercut either during construction or over steepened by progressive removal of small slope failures and ongoing maintenance. They pose a substantial hazard to vehicles along roadways and to structures downslope at the base of canyons.

Recommended Mitigation

The most common mitigation on steep slopes with large blocks and well-defined discontinuities is to increase the resisting force by pinning individual blocks and slide masses with rock bolts and anchors. More highly fractured rock masses can be contained by installing reinforced caissons, covering the slope with wire mesh or by scaling overhanging rock from the slope face. Another common solution is to separate the structure from the hazard with an adequate setback, build a graded berm to divert or adequately contain the material. In more homogeneous, fine-grained material, grading can be used to decrease the steepness of the slope and reduce the driving forces. These soil/weathered rock mixtures can also be pinned using soil nail or sprayed with gunite to stabilize the slope faces. In some cases, the unstable material must be removed from the slope face using mechanical means or hand labor.

Category	Recommended Mitigation Method	Important Considerations
Initial Grading	Excavate to competent material and and replace with engineered fill.	Most commonly used method of large-scale landslide treatment during initial grading. Drainage galleries, benching, compaction and scarification provided by design. Requires sufficient stability to resist maximum allowable seismic "triggering" displacement.
Remedial Grading	Reconfigure the mass to a more stable configuration at a lower slope angle.	Grade to reduce the slope geometry: remove material from the head and add counterweight material and key trenches in the toe area. Usually done in conjunction with dewatering. Area must be accessible to equipment and a disposal site is required for excavated material.
Engineered Fill	Construct cut and fill benches to provide level building sites, roads and utilities.	Overexcavate all transition pads or avoid building over a cut-fill transition contact to reduce uneven seismic ground response.
De-watering and Drainage	Prevent "loading" of natural or engineered slopes.	Reduce water content by grading, draining or pumping water to surface ditches. French drains and dewatering wells need to be routed to a stable drain outlet.
Slope Reinforcement	Construct buttress fill and compacted earth or rock berm at the toe of landslides.	Support the toe of a slope with properly engineered fill that is keyed into competent material below potential slip circles or adverse bedding.
Internal Slope Strengthening	Install rock bolts and/or soil nails to bind material together.	Effectiveness depends upon the grain size and character of the material and anchoring. May be used with gunite to strengthen slope face.
External Retaining Structures	Build gravity and cantilliever structures.	Must have sufficient mass or angular resistance to overcome the overturning earth pressures
Internal Retaining Structures	Install pilings and/or cassions.	Piling must be founded well below the potential slide plane and close spaced or tied together with grade beams.
Avoidance	Require the use of setbacks and deflection barriers.	Avoid the runout path, install a flow deflection barrier, provide and maintain upslope debris basins and clean out colluvial hollows.
Containment	Cover slope face with wire netting, may be used in conjunction with grouting or shotcret to increase strength.	The common treatment for rock falls and topples is to install wire netting on the rock face and barriers at the slope base or remove loose material from the face of slope by mechanical means.

Table 5: Recommended Landslide Mitigation Techniques (Modified from Popescu, 2001).

Mitigation of Liquefaction Hazards

There are two general levels of liquefaction hazards; large-scale displacement, and more localized failures including the loss of bearing strength, differential settlement and small-scale flows and lateral spreads. Areas with a potential for large-scale displacements will often require multiple methods of remediation to protect against liquefaction. Treating the site with soil improvement methods can often mitigate smaller scale ground deformations. These methods help reduce future settlements due to the static forces created by building loads and the dynamic forces from earthquake-imposed stress. With improvement, safe construction can be accomplished on marginal soils; i.e., loose sand, unconsolidated fill, collapsible soil, expandable clay and mine spoils. The following discussion illustrates some of the current techniques used to mitigate common liquefaction hazards like large-scale displacements, loss of bearing strength, settlement, and lateral spreads.

Large-Scale Displacements

Youd (1989), citing data from Japan, suggests that structural mitigation may be acceptable where displacements of less than one foot horizontal and less than four inches vertical are predicted. Therefore, for this paper, large-scale ground displacements are defined as those that exceed 1-3 feet horizontally and 4-6 inches vertically.

Large Spreads and Flows

Lateral spreads most often occur on gentle sloping ground, but can also occur on flat-lying terrain adjacent to a free face where an underlying layer liquefies in response to earthquake ground motions. The material moves on laterally continuous layers of loose, saturated gravel, sand, silt or sensitive clay. This type of failure commonly occurs on flood plains, river channel alluvium and in artificial fill on slopes as gentle as 0.3 degrees (Keefer, 1984), and can produce displacements of a few inches to tens of feet. Materials range in composition from clay and silt to fine-grained sand and may include sandy gravel.

Hazard Description

The main type of destructive movement in large-scale displacements is lateral extension accompanied by shearing or tensile fracturing. In response, the overlying material may break into tilted blocks and be rafted a few meters to tens of meters. In extreme cases, ground movements can disrupt structures, roads and utilities such as in Turnagain Heights during the 1964 Alaska earthquake. One of the problems with large-scale lateral movement is the lack of hazard recognition during development. The potential for failure can be overlooked because of subsurface data and the widespread, diffuse nature of the liquefiable layers.

Recommended Mitigation

Only removal and densification of liquefiable soils, or permanently lowering the groundwater by dewatering, can fully eliminate liquefaction hazards. Large-scale displacements may be mitigated to some degree using the following techniques:

1. Edge containment structures that provide lateral support;

2. Densification of liquefiable soils to reduce liquefaction potential;

3. Modification of site geometry to reduce the risk of movement; and

4. Drainage to lower groundwater below the level of the liquefiable soils.

A common method used to limit large-scale displacements near harbors and marinas is to restrict movement using edge containment, coupled with deep dynamic compaction to densify and compact the subsurface soils. The lateral extent where improvement is required is related to the bearing capacity of the soil and the distance that excess pore pressures will propagate beyond the structure footprint. Studies by Iai (1988) indicate that, in the presence of liquefiable clean sands, an area of softening can occur a distance beyond the foundation that is up to two-thirds the thickness of the liquefiable layer. For example, a sixty-foot thick vertical layer can cause failure up to 40 feet laterally from the edge of improved ground. Edge containment structures may include berms, dikes, sea walls, retaining structures or compacted soil zones. In extreme cases, additional deep foundation support may be required to ensure building safety.

Localized Failures

Localized ground failures are smaller scale displacements that can often be mitigated by treating the site with soil improvement methods. There are several published articles with additional information on the success of specific soil improvement techniques (Hayden and Baez, 1994). Suitable mitigation alternatives may include one or more of the following:

1. Excavation and removal or re-compaction of potentially liquefiable soils;

2. Soil densification or other types of in-situ ground modifications;

3. Deep foundations that have been designed to accommodate liquefaction effects; and,

4. Reinforced shallow foundations and improved structural design to withstand predicted vertical and lateral ground displacements.

Three types of deformations cause most of the damage in small-scale failures; loss of bearing strength, differential settlement and soil spreads and flows.

Loss of Bearing Strength

Loss of bearing strength due to liquefaction can occur in saturated clean sand under strong earthquake loading conditions. This type of failure often occurs in natural deposits of clean sands that have interbedded lenses of finer-grained sediments at some depth below the ground surface. In addition, overburden pressure tends to increase density with depth. The fill deposits most susceptible to liquefaction and excessive settlement are thick accumulations of clean, cohesionless sand that are saturated and do not strengthen substantially with depth.

Hazard Description

In structures with supporting columns, loss of bearing strength and soil-structure-soil interaction affects such as the "punching" phenomena caused by the rocking motions of structures during earthquakes. This motion can lead to tilting and uneven settlement of buildings and damage to foundations from differential settlements.

Recommended Mitigation

The most widely used technique to mitigate loss of bearing strength is in-situ densification of liquefiable soils using vibro-compaction, vibro-replacement, deep dynamic compaction, and compaction grouting (Hayden and Baez, 1994). Vibro-compaction and vibro-replacement techniques use similar equipment, but use different backfill material to achieve densification of soils at depth. In vibro-compaction a sand backfill is generally used, whereas in vibro-replacement stone is used as backfill material. Vibro-compaction is generally effective if the soils to be densified are sands containing less than approximately 10 percent fine-grained material passing the No. 200 sieve. Vibro-replacement is generally effective in soils containing less than 15 to 20% fines. However, even non-plastic sandy silts can be densified by a combination of vibro-replacement and vertical band (wick) drains.

Differential Settlement

Differential settlement is a localized loss of support under the footprint or across the span of a building. It commonly occurs in interbedded sediments at alluvial sites. The variable lensing character of the material makes the extent and thickness of the liquefiable layers; and therefore, the amount of settlement, hard to predict. Building sites require sufficient test borings and adequate testing to accurately determine the settlement potential.

Hazard Description

A major problem with lensing is the potential for uneven or differential settlement and associated fissuring across the footprint of a building which, when transmitted through the foundation, can cause structural damage. This type of failure coupled with lateral spreading is also of particular concern to the stability of dikes and levees along rivers and deltas, and to bulkhead walls and other port and harbor structures. Grading solutions include excavating and re-compacting the subsurface

with properly engineered material and techniques. Internal clay core zoning and over-top protection are important additions to the mitigation program for levees, berms and dams.

Recommended Mitigation

The typical grading solution to this type of failure is to estimate the amount of potential vertical settlement, then design and construct a mat of compacted fill that is thick enough to form a uniform bearing surface. Designing the thickness of engineered mats is intended to dissipate different amounts of displacement (Martin and Lew, 1999). The main technique used is to remove and re-compact a soil mat to give the foundation a more stable base. A variation of the technique is to actually construct the engineered mat above the existing ground level instead of excavating below grade. In general, the thicker the mat, the greater amount of settlement it can accommodate. A raised mat has the added impact of providing greater separation from a shallow water table

Piles or caissons: extending to non-liquefiable soil or bedrock below the potentially liquefiable soils may be feasible. Such designs should take into account the possible down drag forces on the foundation elements due to settlement within the liquefiable upper soils. Because there may be a considerable loss of lateral soil stiffness and capacity during shaking, the piles or caissons will have to transmit the lateral loads to the deeper supporting soils.

It should be recognized that structural mitigation might not reduce the potential of the soils to liquefy during an earthquake. There will remain some risk that the structure could still suffer damage and may not be useable if liquefaction occurs. Utilities and lifeline services provided from outside the structure could still suffer disruption unless mitigation measures are employed that would account for the soil deformations that could occur between the structure and the supporting soils. Repair and remedial work should be anticipated after a liquefaction event if structural mitigation is used.

Vibro-compaction: All soil improvement can be thought of as constructing an engineered mat with denser properties than the original soil. Densification methods include deep dynamic compaction, compaction grouting, permeation grouting, jet grouting, and deep soil mixing. Design aids are available to assist in selecting suitable methods of mitigation. For example, Figure 4 indicates method suitability as a function of grain size for different soils (Hayward Baker Inc., 1997).

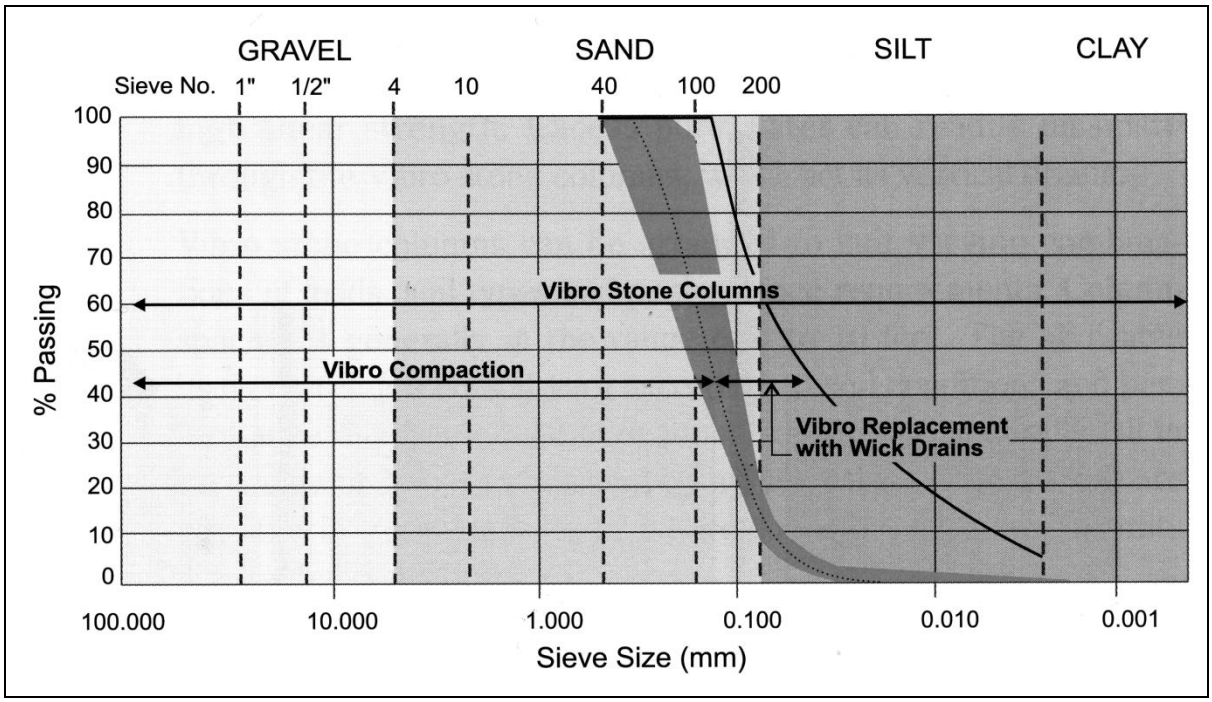


Figure 4. Gradation chart showing the range for some of the preferred soil treatment methods based on different soil contents (Hayward Baker, 1997).

Deep dynamic compaction: Deep dynamic compaction programs are used to reconstitute liquefiable soils to a denser condition using weights of 10 to 30 tons dropped from heights of about 50 to 120 feet. Free-fall impact energy is controlled by selecting the weight, drop height, number of drops per point and the grid spacing. The major limitations of the method are vibrations, flying matter, and noise. For these reasons, work often requires 100 to 200 feet clearance from adjacent occupied buildings or sensitive structures.

In general, treatment depths of up to 35 feet may be achievable in granular soils. If hard pans and saturated cohesive soils are present or the groundwater table is within 3 to 5 feet of the surface, a granular layer is often needed to limit the loss of impact energy and transfer the forces to greater depths. Pore water pressures of an area recently treated should be allowed to dissipate before secondary treatments are implemented.

Compaction grouting: uses low slump, mortar-type grout pumped under pressure to densify loose soils by displacement. Grout pipes are installed in a grid pattern that usually ranges from 5 to 9 feet on centers. The use of primary spacing patterns with secondary or tertiary intermediate patterns in-filled later is effective to achieve difficult densification criteria. Grouting volumes can typically range from 3 to 12 percent of the treated soil volume in granular soils, although volumes up to 20 percent have been reported for extremely loose sands or silty soils. Inadequate compaction is likely to occur when there is less than 8 to 10 feet of overburden to provide vertical confinement.

Permeation grouting: involves the injection of low viscosity liquid grout into the pore spaces of granular soils. The base material is typically sodium silicate or microfine cements. With successful

penetration and setting of the grout, a liquefiable soil with less that approximately 12 to 15 percent fine-grained fraction becomes a hardened mass.

Jet grouting: forms cylindrical or panel shapes of hardened soils to replace liquefiable, sensitive, or permeable soils with soil-cement having strengths up to 2,500 psi. The method relies on water pressure up to 7,000 psi at the nozzle to cut soils, mix the cement slurry in place and lift spoils to the surface. Control of the drill rotation and pull rates allows treatment of various types of soils. Lightweight drill systems can be used in confined spaces such as inside existing buildings that are found to be at risk of liquefaction after construction.

Deep soil-mixing: is a technique involving mixing of cement using a hollow-stem auger and paddle arrangement. Augers up to 3 feet or more in diameter are used to mix to depths of 100 feet or more. As the augers are advanced into the soil, the hollow stems are used as conduits to pump grout and inject into the soil at the tip. Confining cells are created with the process as the augers are worked in overlapping configurations to form walls. Liquefaction is controlled by re-distributing shear stresses from soils within the confining cells to the walls. As with jet grouting, treatment of the full range of liquefiable soils is possible and shear strengths of 2,500 psi or more can be achieved even in silty soils.

These site remediation measures, coupled with properly engineered foundations such as heavily reinforced mats, post tensioned slabs, piles, etc., have performed well in recent earthquakes, demonstrating that many liquefaction-prone sites can be safely developed (Mitchell, 1995).

Spreads and Flows

Localized lateral spreads and small-scale flows are formed by the displacement of a surface layer in response to liquefaction of an underlying layer. This type of failure is dependent upon a gentle slope or a nearby “free face” or open area that will allow the displacement.

Hazard Description

The most common type of engineered fill that is composed of clean sand is hydraulic fill where material is placed behind a cut-off wall or bulkhead. In early developments, this technique was used near lagoons and shorelines to fill in marshland for constructing projects. It was assumed that the natural consolidation and drying process would densify the sand and provide adequate support for overlying structures. These days it is hardly ever done without some form of artificial densification.

Recommended Mitigation

The key to mitigating localized lateral spreads is to require an adequate setback from an open face or sloping ground. If the distance and geometry is restricted, then bulkhead walls or another form of retaining structure must be installed. For smaller-scale, liquefaction-induced settlements (less that 2” total), a wide range of techniques is used for site-specific problems. They may range from removal and re-compaction of shallow soils to support concrete slabs and perimeter spread footings to deep, drilled pier foundations and structural strengthening.

Category	Recommended Mitigation Method	Important Considerations
Engineered Fill	Construct a thickened mat by removing liquefiable soil and replace it with non-liquefiable fill.	The common grading solution is to remove and compact the upper 18-24 inches below a shallow slab or spread footing to increase bearing strength and bridge minor settlement. In general, higher displacements require thicker mats.
Structural	Construct a thicker slab and/or strengthen the foundation footings.	Reinforce shallow foundations with grade beams, post-tensioned slab and construct engineered mat with or without geofabric to provide lateral support.
Piles	Support the structure with cast-in-place concrete piles.	Extremely thick liquefiable soils may rely on skin friction to provide some of the support. Surrounding ground and connections may be displaced after settlement.
Over consolidation	Pre-load the area with fill or other material to decrease the rebound effects after structural load is placed.	This is a common method for heavy buildings. Increasing the thickness of compacted sub-base material beneath concrete flatwork and asphalt surfaces will reduce minor ground settlement
Mechanical Soil Improvement	Dynamic Compaction	Soil improvement using dynamic compaction from heavy weights
Chemical Soil Improvement	Grouting or chemical replacement.	Various types of in-situ soil improvement chemicals using replacement, permeation and jet grouting.
Vibratory Soil Improvement	Deep Soil Mixing	In-situ addition of material to native material while reaming out of borehole. Technique limited to certain soil types.
Edge Containment	Stability depends upon adequate edge containment berms, dikes, sea walls and other retaining structure.	Additionally, deep foundations are often required beneath structures to provide stability.
Drainage	Either lower the water table or provide surface drainage.	Grading to modify the site geometry, permanently lower water table by pumping or gravity-fed bores. Divert water using surface drainage.
Pore water dissipation	Provide conduits to dissipate pore water pressure.	The use of gravel or prefabricated drains, installed without soil densification, is unlikely to provide pore pressure relief during strong earthquakes and may not prevent excessive settlement.

Table 6: Recommended Liquefaction Mitigation Techniques (Modified from Mitchell, 1995 and Hayward Baker, 1997).

Concluding Remarks

In 1997, the Seismic Hazards Mapping Act hazard maps began to require more rigorous investigations and peer review procedures to evaluate projects sited in zoned liquefaction and earthquake-induced landslide hazard areas. The mitigations proposed here are based on proven grading techniques that should result in lower earthquake losses due to earthquake-induced slope instability, differential settlement and loss of bearing capacity in zones of required investigation.

In general, only removal or densification of all landslide and liquefiable materials can fully eliminate potential failures. However, foundation treatments and other structural methods may be used to protect against excessive settlements. For example, in areas where liquefaction may potentially cause displacements, designing the foundation to withstand or accommodate the displacement can significantly reduce future damages. The success of mitigation depends on:

1. Thorough geologic and seismic evaluation of the proposed project and site conditions, with appropriate treatment of the conditions found;

2. Careful testing of the conditions encountered during the preliminary rough grading phase of development;

3. Continuous review and inspection during grading and fill placement;

4. Monitoring soil properties, moisture content, and relative compaction during construction; and,

5. Proper post-development maintenance of the drains, outlets and erosion control.

Considerable geotechnical judgment is needed to make appropriate recommendations for the mitigation of earthquake-induced landslide and liquefaction hazards. For complicated settings, a Registered Civil Engineer and a Certified Engineering Geologist working together should perform the review, inspection and evaluation of proposed mitigations.

The intent of the State's Seismic Hazard Map Zoning program is to ensure that a minimum level of public safety and protection is met for projects in zones of required investigation. The acceptable level of risk by State standards is one that ensures life safety in most residential and commercial structures. Hospitals, schools and other essential services buildings are held to higher levels of operability and are inspected and reviewed using different standards. None of the mitigation methods suggested here should limit or supersede additional requirements set by local jurisdictions for specific site conditions.

CHAPTER 8

GUIDELINES FOR REVIEWING SITE-INVESTIGATION REPORTS

The purpose of this chapter is to provide general guidance to regulatory agencies that have approval authority over projects and to engineering geologists and civil engineers who review reports of seismic hazard investigations. These Guidelines recognize that effective mitigation ultimately depends on the professional judgment and expertise of the developer's engineering geologist and/or civil engineer in concert with the lead agency's engineering geologist and/or civil engineer.

The required technical review is a critical part of the evaluation process of approving a project. The reviewer ensures compliance with existing laws, regulations, ordinances, codes, policies, standards, and good practice, helping to assure that significant geologic factors (hazards and geologic processes) are properly considered, and potential problems are mitigated prior to project development. Under the Seismic Hazards Mapping Act, the reviewer is responsible for determining that each seismic hazard site investigation, and the resulting report, reasonably addresses the geologic and soil conditions that exist at a given site. The reviewer acts on behalf of a governing agency— city, county, regional, state, or federal—not only to protect the government's interest but also to protect the interest of the community at large. Examples of the review process in a state agency are described by Stewart and others (1976). Review at the local level has been discussed by Leighton (1975), Hart and Williams (1978), Berkland (1992), and Larson (1992). Grading codes, inspections, and the review process are discussed in detail by Scullin (1983).

The Reviewer

Qualifications

CCR Title 14, Section 3724(c) states that the reviewer must be a licensed engineering geologist and/or civil engineer having competence in the field of seismic hazard evaluation and mitigation. California's Business and Professions Code limits the practice of geology and engineering to licensed geologists and engineers, respectively, thereby requiring that reviewers be licensed, or directly supervised by someone who is licensed, by the appropriate State board. Local and regional agencies may have additional requirements. Nothing in these Guidelines is intended to sanction or authorize the review of engineering geology reports by engineers or civil engineering reports by geologists.

The reviewer should be familiar with the investigative methods employed and the techniques available to these professions (see Chapters 3 through 6). The opinions and comments made by the

reviewer should be competent, prudent, objective, consistent, unbiased, pragmatic, and reasonable. The reviewer should be professional and ethical. The reviewer should have a clear understanding of the criteria for approving and not approving reports. Reviews should be based on logical, defensible criteria.

Reviewers must recognize their limitations. They should be willing to ask for the opinions of others more qualified in specialty fields.

If there is clear evidence of incompetence or misrepresentation in a report, this fact should be reported to the reviewing agency or licensing board. California Civil Code Section 47 provides immunity for statements made "in the initiation or course of any other proceedings authorized by law." Courts have interpreted this section as providing immunity to letters of complaint written to provide a public agency or board, including licensing boards, with information that the public board or agency may want to investigate (see *King v. Borges*, 28 Cal. App. 3d 27 [1972]; and *Brody v. Montalbano*, 87 Cal. App 3d 725 [1978]). Clearly, reviewers need to have the support of their agency in order to carry out these duties.

The primary purpose of the review procedure should always be kept in mind: to determine compliance with the regulations, codes, and ordinances that pertain to the development. The reviewer should demand that minimum standards are met. The mark of a good reviewer is the ability to sort out the important from the insignificant, to list appropriate requirements for compliance, and to assist the applicant and their consultants in meeting the regulations without doing the consultant's job.

Conflict of Interest

In cases where reviewers also perform geologic or engineering investigations, they should **never** be placed in the position of reviewing their own report, or that of their own agency or company.

Reviewing Reports

The Report

A report that is incomplete or poorly written should be **not** approved. The report should demonstrate that the project complies with applicable regulations, codes, and ordinances, or local functional equivalents, in order to be approved.

The reviewer performs four principal functions in the technical review:

1. Identify any known potential hazards and impacts that are not addressed in the consultant's report. The reviewer should require investigation of the potential hazards and impacts;

2. Determine that the report contains sufficient data to support and is consistent with the stated conclusions;

3. Determine that the conclusions identify the potential impact of known and reasonable anticipated geologic processes and site conditions during the lifespan of the project; and,

4. Determine that the recommendations are consistent with the conclusions and can reasonably be expected to mitigate those anticipated earthquake-related problems that could have a significant impact on the proposed development. The included recommendations also should address the need for additional geologic and engineering investigations (including any site inspections to be made as site remediation proceeds).

Report Guidelines and Standards

Investigators may save a great deal of time (and the client's money), and possibly misunderstandings, if they contact the reviewing geologist or engineer at the initiation of the investigation. Reviewers typically are familiar with the local geology and sources of information and may be able to provide additional guidance regarding their agency's expectations and review practices. Guidelines for geologic or geotechnical reports have been prepared by a number of agencies and are available to assist reviewers in their evaluation of reports (for example, CGS Notes 42, 44, 48, and 49). Distribution of copies of written policies and guidelines adopted by the agency usually alerts the applicants and consultants about procedures, report formats, and levels of investigative detail that will expedite review and approval of the project.

If a reviewer determines that a report is not in compliance with the appropriate requirements, this fact should be stated in the written record. After the reviewer is satisfied that the investigation and resulting conclusions and recommendations are reasonable and meet local requirements, approval of the project should be recommended to the reviewing agency.

Review of Submitted Reports

The review of submitted reports constitutes professional practice and should be conducted as such. The reviewer should study the available data and site conditions in order to determine whether the report is in compliance with local requirements. A field reconnaissance of the site should be conducted, preferably after the review of available stereoscopic aerial photographs, geologic maps, and reports on nearby developments.

For each report reviewed, a clear, concise, and logical written record should be developed. This review record may be as long or short as is necessary, depending upon the complexity of the project, the geology, the engineering analysis, and the quality and completeness of the reports submitted. At a minimum, the record should:

1. Identify the project, pertinent permits, applicant, consultants, reports and plans reviewed;

2. Include a clear statement of the requirements to be met by the parties involved, data required, and the plan, phase, project, or report being approved or denied;

3. Contain summaries of the reviewer's field observations, associated literature and air photo review, and oral communications with the applicant and the consultant;

4. Contain copies of any pertinent written correspondence; and,

5. The reviewer's name and license number(s), with any associated expiration dates.

The report, plans, and review record should be kept in perpetuity to document that compliance with local requirements was achieved and for reference during future development, remodeling, or rebuilding. Such records also can be a valuable resource for land-use planning and real-estate disclosure.

Report Filing Requirements

PRC Section 2697 requires cities and counties to submit one copy of each approved site-investigation report, including mitigation measures, if any, that are to be taken, to the State Geologist within 30 days of report approval. Section 2697 also requires that if a project's approval is not in accordance with the policies and criteria of the State Mining and Geology Board (CCR Title 14, Chapter 2, Division 8, Article 10), the city or county must explain the reasons for the differences in writing to the State Geologist, within 30 days of the project's approval. Reports should be sent to:

California Geological Survey
Attn: Seismic Hazard Reports
801 K Street, MS 12-31
Sacramento, CA 95814-3531

Waivers

PRC Section 2697 and CCR Title 14, Section 3725 outline the process under which lead agencies may determine that information from studies conducted on sites in the immediate vicinity may be used to waive the site-investigation report requirement. CCR Title 14, Section 3725 indicates that when a lead agency determines that "geological and geotechnical conditions at the site are such that public safety is adequately protected and no mitigation is required," it may grant a waiver. CCR Title 14, Section 3725 also requires that such a finding be based on a report presenting evaluations of sites in the immediate vicinity having similar geologic and geotechnical characteristics. Further, Section 3725 stipulates that lead agencies must review waiver requests in the same manner as it reviews site-investigation reports; thus, waiver requests must be reviewed by a licensed engineering geologist and/or civil engineer, competent in the field of seismic hazard evaluation and mitigation. Generally, in addition to the findings of the reports that are presented in support of the waiver request, reviewers should consider:

1. The proximity of the project site to sites previously evaluated;

2. Whether the project sites previously evaluated adequately "surround" the project site to preclude the presence of stream channel deposits, historically higher water table, gently sloping ground, stream channels and other types of free faces that may present an opportunity for lateral spread failures; and,

3. Whether the supporting reports do, in fact, conclude that no hazard exists.

Waiver Filing Requirements

CCR Title 14, Section 3725 provides that "All such waivers shall be recorded with the county recorder and a separate copy, together with the report and commentary, filed with the State Geologist within 30 days of the waiver." These materials should be sent to:

California Geological Survey
Attn: Seismic Hazard Reports
801 K Street, MS 12-31
Sacramento, CA 95814-3531

Appeals

In cases where the reviewer is not able to approve a site-investigation report, or can accept it only on a conditional basis, the developer may wish to appeal the review decision. However, every effort should be made to resolve problems informally prior to making a formal appeal. Appeal procedures are often specified by a city or county ordinance or similar instrument. An appeal may be handled through existing legal procedures, such as a hearing by a County Board of Supervisors, a City Council, or a specially appointed Technical Appeals and Review Panel. Several administrators note that the Technical Appeals and Review Panel, comprised of geoscientists, engineers, and other appropriate professionals, benefits decision makers by providing additional technical expertise for especially complex and/or controversial cases. Adequate notice should be given to allow time for both sides to prepare their cases. After an appropriate hearing, the appeals decision should be made promptly and in writing as part of the permanent record.

Another way to remedy conflicts between the investigator and the reviewer is by means of a third party review. Such a review can take different paths ranging from the review of existing reports to in-depth field investigations. Third party reviews are usually done by consultants; not normally associated with the reviewing/permitting agency.

REFERENCES CITED

AASHTO, 2002, Standards in Building codes, 39th edition: American Society of Testing & Materials, International, ASTM D1557, 4 volume set on one CD-ROM with 1,500 searchable standards at http://www.astm.org

Acker, W.L., Jr., 1974, Basic procedures for soil sampling and core drilling: Acker Drill Co., Scranton, PA, 246 p.

Arias, A., 1970, A measure of earthquake intensity, in, Hansen. R.J., editor, Seismic Design for Nuclear Power Plants: Massachusetts Institute of Technology Press, Cambridge, Mass., p. 438-483.

Ashford, S.A. and Sitar, N., 1994, Seismic response of steep natural slopes: University of California, Berkeley, Earthquake Engineering Research Center, Report No. UCB/EERC - 94/05, 207 p.

ASTM, 2008, American Society for Testing and Materials, on-line digital library: http://www.astm.org/Standard/index.shtml

Bardet, J.P, Tobita, T., Mase, N., and Hu, J. (2002). Regional Modeling of Liquefaction-Induced Ground Deformation: Earthquake Spectra, v. 18, p. 19-46.

Bartlett, S.F. and Youd, T.L., 1995, Empirical prediction of liquefaction-induced lateral spread: American Society of Civil Engineers, Journal of Geotechnical Engineering, v. 121, n. 4, p. 316-329.

Berkland, J.O., 1992, Reviewing the geologic review process at the county level: Association of Engineering Geologists, Proceedings, 35th Annual Meeting, p. 333-336.

Blake, T.F., Hollingsworth, R.A., and Stewart, J.P., 2002, Recommended Procedures for Implementation of DMG Special Publication 117-Guidelines for Analyzing and Mitigating Landslide Hazards in California: Committee organized through the ASCE, Los Angeles Section Geotechnical Group, Document published by the Southern California Earthquake Center, 101 p.

Boone, S.J., 1996, Ground-Movement Related Building Damage: ASCE Journal of Geotechnical Engineering, v. 122, n. 11, November, 1996 issue, p 886-896, and addendum, May 1998, v. 124, n. 5, p462-465.

Boulanger, R.W., and Idriss, I.M., 2006, Liquefaction Susceptibility Criteria for Silts and Clays: American Society of Civil Engineers, Journal of the Geotechnical Engineering Division, v. 132, n. 11, 1413-1426.

Bray, J.D. and Rathje, E.M., Augello, A.J., and, Merry, S.M., 1998, Simplified seismic design procedure for geosynthetic-lined, solid waste landfills: Geosynthetics International, v. 5, n. 1-2, p. 203-235.

Bray, J.D., and Sancio, R.B., 2006, Assessment of the Liquefaction Susceptibility of Fine-Grained Soils: American Society of Civil Engineers, Journal of the Geotechnical and Geoenvironmental Engineering, v. 132, n. 9, p. 1165-1177.

Bray, J.D. and Travasarou, T., 2007, Simplified procedure for estimating earthquake-induced deviatoric slope displacements: Journal of Geotechnical and Geoenvironmental Engineering, ASCE, v. 133, p. 381-392.

Bromhead, E.N., 1986, The stability of slopes: Chapman and Hall, New York, 373 p.

CBC, 2007, California Code of Regulations, Title 24, Part 2, volume 1: California Building Standards Commission, based on 2006 International Building Code (periodically updated).

California Department of Conservation, Division of Mines and Geology: Guidelines to geologic/seismic reports. DMG Note 42.

California Department of Conservation, Division of Mines and Geology: Guidelines for preparing engineering geologic reports. DMG Note 44.

California Department of Conservation, Division of Mines and Geology: Checklists for the review of geologic/seismic reports for California public schools, hospitals, and essential services buildings. DMG Note 48.

California Department of Conservation, Division of Mines and Geology: Guidelines for evaluating the hazard of surface fault rupture to geologic/seismic reports. DMG Note 49.

California Grading Officials Association, 2005, "Allowable Ground Settlement Criteria for Subdivision Projects", CGOA Guideline N. 02-05, Issued July 28, 2005.

Cetin, K.O., Seed, R.B., Der Kiureghian, A., Tokimatsu, K., Harder, L.F., Kayen, R.E., and Moss, R.E.S., 2004, Standard Penetration Test-based probabilistic and deterministic assessment of seismic soil liquefaction potential: Journal of the Geotechnical and Geoenvironmental Engineering, v. 130, n.12, p.1314–1340.

Chowdhury, R.N., 1978, Slope analysis: Elsevier Scientific Publishing Company, Amsterdam, 423 p.

Cornell, C.A., 1968, Engineering seismic risk analysis: Bulletin of the Seismological Society of America, v. 58, p. 1583-1606.

Cotecchia, V., 1987, Earthquake-prone environments, in Anderson, M.G. and Richards, K.S., editors, Slope stability, geotechnical engineering and geomorphology: John Wiley & Sons, New York, p. 287-330.

dePolo, C.M. and Slemmons, D.B., 1990, Estimation of earthquake size for seismic hazards, in Krinitzsky, E.L. and Slemmons, D.B., editors, Neotectonics in earthquake evaluations: Geological Society of America, Reviews in Engineering Geology, v. VIII, chapter 1, p. 1-28.

Duncan J.M., 1996, Chapter 13, soil slope stability analysis, in Turner, A.K. and Schuster, R.L., editors, Landslides—investigation and mitigation: Transportation Research Board, National Research Council, Special Report 247, p. 337-371.

Earthquake Spectra special issue on Next Generation Attenuation (NGA), v. 24, n.1, 2008.

Evans, M.D. and Fragaszy, R.J., editors, 1995, Static and dynamic properties of gravelly soils: American Society of Civil Engineers, Geotechnical Special Publication No. 56, 155 p.

Evans, M.D. and Zhou, S., 1995, Liquefaction behavior of sand-gravel composites: American Society of Civil Engineers, Journal of Geotechnical Engineering, v. 121, n. 3, p. 287-298.

Harder, L.F., 1988, Use of penetration tests to determine the cyclic loading resistance of

gravelly soils during earthquake shaking: Ph.D. dissertation, Department of Civil Engineering, University of California, Berkeley.

Harp, E.L., and Jibson, R.W., 1995, Inventory of Landslides Triggered by the 1994 Northridge, California, Earthquake: U.S. Geological Survey Open-File Report 95-213, 17 p., 2 Pl.

Hart, E.W. and Williams, J.W., 1978, Geologic review process: CALIFORNIA GEOLOGY, v. 31, p. 235-236.

Hayes, W.W., 1985, Workshop on probabilistic earthquake hazards assessments: U.S. Geological Survey, Proceedings of Conference XXXIV, Open-File Report 86-185, 385 p.

Hayden, R.F. and Baez, J.I., 1994, "State of Practice for Liquefaction Mitigation in North America", International Workshop on Remedial Treatment of Liquefiable Soils, Tsukuba Science City, Japan, July 4-6, 1994.

Hayward Baker Inc., A Keller Company, 1997, Ground Modification Seminar Notes, 102 p.

Hollingsworth, R. and Kovacs, G.S., 1981, Soil slips and debris flows, prediction and protection: Bulletin of the Association of Engineering Geologists, v. 1B, n. 1, p. 17-28.

Head, K.H., 1989, Soil technicians handbook: Pentech Press, John Wiley & Sons, London, 158 p.

Hryciw, R.D., editor, 1995, Soil improvement for earthquake hazard mitigation: American Society of Civil Engineers, Geotechnical Special Publication No. 49, 141 p.

Hunt, R.E., 1984a, Geotechnical investigation manual: McGraw-Hill Book Co., New York, 983 p.

Hunt, R.E., 1984b, Geotechnical engineering techniques and practices: McGraw-Hill Book Co., New York, 729 p. Hvorslev, M. J., 1948, Subsurface exploration and sampling of soils for civil engineering purposes: U.S. Army Corps of Engineers, Waterways Experiment Station, Vicksburg, Mississippi, 465 p.

Hynes, M.E. and Franklin, A.G., 1984, Rationalizing the seismic coefficient method: U.S. Army Corps of Engineers, Waterways Experiment Station, Vicksburg, Mississippi, Miscellaneous Paper GL-84-13, July 1984.

Iai, S., Noda, S. and Tsuchida, H., 1988, "Consideration for Designing the Area of the Ground Compaction as a Remedial Measure Against Liquefaction," U.S.-Japan Joint Workshop on Remedial Measures for Liquefiable Soils, Jackson, WY, May 11-13.

Idriss, I. M. and Boulanger, R. W., 2008, Soil Liquefaction During Earthquakes. Oakland, CA: Earthquake Engineering Research Institute.

Idriss, I.M. and Sun, J.I., 1992, User's manual for SHAKE91, a computer program for conducting equivalent linear seismic response analyses of horizontally layered soil deposits: University of California-Davis, Center for Geotechnical Modeling, Department of Civil and Environmental Engineering, August 1992.

ICBO, 1997, Uniform Building Code: International Conference of Building Officials, Whittier, California, volumes 1 and 2; especially Chapter 16, Structural Forces (earthquake provisions); Chapter 18, Foundations and Retaining Walls; and Chapter A33, Excavation and Grading.

Ishihara, K., 1985, Stability of natural deposits during earthquakes: Proceedings, 11th International Conference on Soil Mechanics and Foundation Engineering, San Francisco, v. 1, p. 321-376.

Ishihara, K., 1996, Soil behavior in earthquake geotechnics: Oxford University Press, New York, 350 p.

Ishihara, K. and Yoshimine, M.,1992, Evaluation of settlements in sand deposits following liquefaction during earthquakes: Soil and Foundations, Japanese Society of Soil Mechanics and Foundation Engineering, v. 32, n. 1, p. 173-188.

Janbu, N., 1973, Slope stability computations, in Hirschfeld, R.C. and Poulos, S.J., editors, Embankment-dam engineering: John Wiley & Sons, New York, p. 47-86.

Jibson, R.W. and Jibson, M.W., 2003, Java programs for using Newmark's method and simplified decoupled analysis to model slope performance during earthquakes: U.S. Geological Survey Open File Report OF-03-0005.

Jibson, R.W., 1993, Predicting earthquake-induced landslide displacements using Newmark's sliding block analysis: Transportation Research Board, National Research Council, Transportation Research Record 1411, 17 p.

Jibson, R.W. and Keefer, D.K., 1993, Analysis of the seismic origin of landslides: Examples from the New Madrid seismic zone: Geological Society of America Bulletin, v. 105, p. 521-536.

Johnson, R.B. and DeGraff, J.V., 1988, Principles of engineering geology: John Wiley & Sons, Inc., New York, 497 p. Keaton, J.R. and DeGraff, J.V., 1996, Chapter 9, Surface observation and geologic mapping, in Turner, A.K. and Schuster, R.L., editors, Landslides—investigation and mitigation, Transportation Research Board, National Research Council, Special Report 247, p. 178-230.

Keefer, D.K., 1984, Landslides caused by earthquakes: Geological Society of America Bulletin, v. 95, n. 4, p. 406-421.

Kramer, S.L., 1996, Geotechnical earthquake engineering: Prentice Hall, New Jersey, 653 p.

Kramer, S.L. and Smith, M.W., 1997, Modified Newmark model for seismic displacements of compliant slopes: Journal of Geotechnical and Geoenvironmental Engineering, ASCE, v. 123, n.7, p. 635-644.

Krynine, D.P. and Judd, W.R., 1957, Principles of engineering geology and geotechnics: McGraw-Hill, New York, 730 p. Larson, R.A., 1992, A philosophy of regulatory review: Association of Engineering Geologists, Proceedings, 35th Annual Meeting, p. 224-226.

Leighton, F.B., 1975, Role of geotechnical consultants and reviewers for the County of San Mateo: CALIFORNIA GEOLOGY, v. 28, n. 8, p. 178-181.

Martin, G.R. and Lew, M., 1999, Recommended Procedures for Implementation of DMG Special Publication 117, Guidelines for Analyzing and Mitigating Liquefaction Hazards in California: Organized through the Southern California Earthquake Center, University of Southern California. 43 p.

Makdisi, F.I. and Seed, H.B., 1978, Simplified procedure for estimating dam and embankment earthquake-induced deformations: Proceedings of the American Society of Civil Engineers, Journal of Geotechnical Engineering, v. 104, n. GT7, p. 849-867.

McGuffey, V.C., Modeer, V.A., Jr., and Turner, A.K., 1996, Chapter 10, Subsurface exploration, in Turner, A.K. and Schuster, R.L., editors, Landslides— investigation and mitigation, Transportation Research Board, National Research Council, Special Report 247, p. 231-277.

McGuire, R.K., 2004, Seismic Hazard and Risk Analysis: Earthquake Engineering Research Institute Monograph MNO-10, 221 p.

Mitchell, J.K., Baxter, C.D.P., and Munson, T.C., 1995, Performance of improved ground during earthquakes, in Hryciw, R.D., editor, Soil improvement for earthquake hazard mitigation: American Society of Civil Engineers, Geotechnical Special Publication No. 49, p. 1-36.

Morgenstern, N.R. and Sangrey, D.A., 1978, Chapter 7, Methods of stability analysis, in Schuster, R.L. and Krizek, R.J., editors, Landslides— analysis and control: National Academy of Sciences, Washington, D.C., p. 155-172.

Moss, R.E.S., Seed, R.B., Kayen, R.E., Stewart, J.P., Der Kiureghian, A., Cetin, K.O., 2006, CPT-Based Probabilistic and Deterministic Assessment of In Situ Seismic Soil Liquefaction Potential: Journal of Geotechnical and Geoenvironmental Engineering, ASCE, v. 132, n. 8, p. 1032-1051.

Nash, D.F.T., 1987, A comparative review of limit equilibrium methods of stability analysis, in Anderson, M.G. and Richards, K.S., editors, Slope stability— geotechnical engineering and geomorphology: John Wiley & Sons, New York, p. 11-76.

National Research Council, 1985, Liquefaction of soils during earthquakes: National Academy Press, Washington, D.C., 240 p.

National Research Council, 1988, Probabilistic seismic hazard analysis: National Research Council, National Academy Press, 97 p.

Newmark, N.M., 1965, Effects of earthquakes on dams and embankments: Geotechnique, v. 15, n. 2, p. 139-160.

Noorany, I., 1997, "Structural Fills: Design, Construction and Performance Review." ASCE Geotechnical Special Publication No. 68, Unsaturated Soil Engineering Practice, p. 233-254.

Okumura, T. and Shinozuka, M., 1990, Seismic hazard analysis for assessment of liquefaction potential: Proceedings of Fourth U.S. National Conference on Earthquake Engineering, v. 1, p. 771-780.

Olsen, R.S., 1988, Using the CPT for dynamic site response characterization, in Von Thun, J.L., editor, Earthquake engineering and soil dynamics II— recent advances in ground motion evaluation: American Society of Civil Engineers, Geotechnical Special Publication No. 20, p. 374-388.

Popescu, M.E., (Chairman), 2001, International Geotechnical Societies' UNESCO Working Party on World Landslide Inventory. Working Group on Landslide Causes, Bulletin IAEG, 50:71-74.

Pradel, D., Smith, P.M., Stewart, J.P., and Raad, G., 2005, Case History of landslide movement during the Northridge earthquake: Journal of Geotechnical and Geoenvironmental Engineering, v. 131, n. 11, p. 1360-1369.

Rathje, E. M, and Bray, J. D. (1999), "An Examination of Simplified Earthquake-

Induced Displacement Procedures for Earth Structures," Canadian Geotechnical Journal, V. 36, N. 1, Feb., p. 72-87.

Reiter, L., 1990, Earthquake Hazard Analysis: Columbia University Press, New York, 252 p.

Robertson, P.K. and Campanella, R.G., 1985, Liquefaction potential of sands using the CPT: American Society of Civil Engineers, Journal of Geotechnical Engineering, v. 111, n. 3, p. 384-403.

Rogers, J. David, 1992, "Mechanisms of Seismically-Induced Slope Movements," Paper No. 920882, Transportation Research Board, 71st Annual Meeting, Jan 12-16, Washington D.C.

Saygili, G. and Rathje, E.M. 2008. "Empirical Predictive Models for Earthquake-Induced Sliding Displacements of Slopes," *Journal of Geotechnical and Geoenvironmental Engineering*, ASCE, v. 134, n. 6, p.790-803.

Schnabel, P.B., Lysmer, J., and Seed, H.B., 1972, SHAKE, a computer program for earthquake response analysis of horizontally layered sites: University of California, Berkeley, Earthquake Engineering Research Center, Report No. EERC 72-12, 38 p.

Scullin, C.M., 1983, Excavation and grading code administration, inspection, and enforcement: Prentice-Hall, Inc., Englewood Cliffs, NJ, 405 p.

Scullin, C.M., 1994, Subsurface exploration using bucket auger borings and down-hole geologic inspection: Bulletin of the Association of Engineering Geologists, v. 31, n. 1, p. 99-105.

Seed, H.B., 1966, A method for earthquake resistant design of earth dams: Proceedings of the American Society of Civil Engineers, Journal of the Soil Mechanics and Foundations Division, v. 92, n. SM1, p. 13-41.

Seed, H.B., 1979, Considerations in the earthquake-resistant design of earth and rockfill dams: Geotechnique, v. 29, n. 3, p. 215-263.

Seed, H.B. and DeAlba, P., 1986, Use of SPT and CPT tests for evaluating the liquefaction resistance of sands, in Clemence, S.P., editor, Use of in situ tests in geotechnical engineering: New York, American Society of Civil Engineers, Geotechnical Special Publication No. 6, p. 281-302.

Seed, H.B. and Idriss, I.M., 1982, Ground motions and soil liquefaction during earthquakes: Earthquake Engineering Research Institute, Monograph, 134 p.

Seed, H.B., Idriss, I.M., and Arango, I., 1983, Evaluation of liquefaction potential using field performance data: American Society of Civil Engineers, Journal of Geotechnical Engineering, v. 109, n. 3, p. 458-482.

Seed, H.B., Tokimatsu, K., Harder, L.F., and Chung, R.M., 1985, Influence of SPT procedures in soil liquefaction resistance evaluations: American Society of Civil Engineers, Journal of Geotechnical Engineering, v. 111, n. 12, p. 1425-1445.

Seed, R.B. and Harder, L.F., 1990, SPT-based analysis of cyclic pore pressure generation and undrained residual strength: Proceedings, H. Bolton Seed Memorial Symposium, BiTech Publishers, Ltd., Vancouver, v. 2, p. 351-376.

Seed R. B., 1998, Evaluation and Mitigation of Seismic Hazards: Short Course sponsored by California Division of Mines and Geology and Southern California Earthquake Center, Organized and presented by Geotechnical

Engineering Program, University of California, Berkeley

Smith, W.K., 1994a, Characteristics of selected strong-motion records from the October 18, 1989, Loma Prieta, California, earthquake and the November-December 1985 Nahanni, Northwest Territories, Canada, earthquakes: U.S. Geological Survey Open-File Report 94-139, 7 p.

Smith, W.K., 1994b, Database of Newmark displacements, Arias intensities, and Dobry durations for selected horizontal-component strong-motion records: U.S. Geological Survey Open-File Report 94-248, 14 p.

Stewart, R.M., Hart, E.W., and Amimoto, P.Y., 1976, The review process and the adequacy of geologic reports: Bulletin of the International Association of Engineering Geology, n 14, p. 83-88. (Reprinted in CALIFORNIA GEOLOGY, 1977, v. 30, n. 10, p. 224-229.)

Stewart, J.P., Bray, J.D., McMahon, D.J., Smith, P.M., and Kropp, A.L. (2001). "Seismic performance of hillside fills," Journal of Geotechnical and Geoenvironmental Engineering., ASCE, 127 (11), 905-919.

Stewart, J.P., Blake, T.F., and Hollingsworth, R.A., 2003, A screen analysis procedure for seismic slope stability: Earthquake Spectra, v. 19, n.3, p. 697-712.

Tokimatsu, K. and Seed, H.R., 1987, Evaluation of settlements in sands due to earthquake shaking: Journal of Geotechnical Engineering, v. 113, n. 8, p. 861-878

U.S. Bureau of Reclamation, 1974, Earth manual, second edition: Water Resources Technical Publication, U.S. Department of Interior, Bureau of Reclamation, U.S. Government Printing Office, Washington, D.C., 810 p.

U.S. Bureau of Reclamation, 1989, Engineering geology field manual: U.S. Department of Interior, Bureau of Reclamation, Denver, Colorado, 599 p.

U.S. Navy, Department of, 1986, Foundations and earth structures, Design Manual 7.1: Naval Facilities Engineering Command, Alexandria, VA, NAVFAC DM-7.1, May 1986.

Varnes, D.J., 1978, Slope Movement Types and Processes, in Schuster, R.L., and Krizek, R.J., eds., Landslides--Analysis and control: National Research Council, Washington, D.C., Transportation Research Board, Special Report 176, p. 11-33.

Wartman, J., Bray, J.D., and Seed, R.B., 2003, Inclined plane studies of the Newmark sliding block procedure: Journal of Geotechnical and Geoenvironmental Engineering, V. 129, N. 8, p.673-684.

Wells, D.L. and Coppersmith, K.J., 1994, New empirical relationships among magnitude, rupture length, rupture width, rupture area, and surface displacement: Bulletin of the Seismological Society of America, v. 84, p. 974-1002.

Wilson, R.C., 1993, Relation of Arias intensity to magnitude and distance in California: U.S. Geological Survey Open-File Report 93-556, 42 p.

Wilson, R.C. and Keefer, D.K., 1983, Dynamic analysis of a slope failure from the 1979 Coyote Lake, California, earthquake: Bulletin of the Seismological Society of America, v. 73, p. 863-877.

Wilson, R.C. and Keefer, D.K., 1985, Predicting areal limits of earthquake-induced landsliding, in Ziony, J.I., editor, Evaluating earthquake

hazards in the Los Angeles region— an earth-science perspective: U.S. Geological Survey Professional Paper 1360, p. 317-345.

Working Group on California Earthquake Probabilities, 1990, Probabilities of large earthquakes in the San Francisco Bay region, California: U.S. Geological Survey Circular 1053, 51 p.

Working Group on California Earthquake Probabilities, 1995, Seismic hazards in Southern California— probable earthquakes, 1994 to 2024: Bulletin of the Seismological Society of America, v. 85, n. 2, p. 379-439.

Working Group on California Earthquake Probabilities, 2008, The Uniform California Earthquake Rupture Forecast, Version 2 (UCERF 2): CGS Special Report 203, USGS Open File Report 2007-1437, 96p. Appendices on CD-ROM.

Youd, T.L., 1989, Ground Failure Damage to Buildings During Earthquakes: American Society of civil Engineers, Proceedings of the Congress on Foundation Engineering, June 25-29, v. 1, p 758-770.

Youd, T.L., Hansen, C.M., and Bartlett, S.F., 2002, Revised Multilinear Regression Equations for Prediction of Lateral Spread Displacement: Journal of Geotechnical and Geoenvironmental Engineering, v. 128, p. 1007-1017.

Youngs, R.R. and Coppersmith, K.J., 1985, Implications of fault slip rates and earthquake recurrence models to probabilistic seismic hazard estimates: Bulletin of the Seismological society of America, v.75, p. 939-964.

Zhang, G., Robertson, P.K., Brachman, W.I., 2004, Estimating Liquefaction-Induced Lateral Displacements Using the Standard Penetration Test or Cone Penetration Test: American Society of Civil Engineers, Journal of the Geotechnical Engineering Division, v. 107, n. GT7, p. 929-942.

RELATED REFERENCES

Bishop, A.W., 1955, The use of the slip circle in the stability analysis of earth slopes: Geotechnique, v. 5, n. 1, p. 7-17

Boore, D.M., Joyner, W.B., and Fumal, T.E., 1993, Estimation of response spectra and peak accelerations from western North American earthquakes – an interim report: U.S. Geological Survey Open-File Report 93-509, 72 p.

Boore, D.M., Joyner, W.B., and Fumal, T.E., 1994, Estimation of response spectra and peak accelerations from western North American earthquakes – an interim report: U.S. Geological Survey Open-File Report 94-127, 40 p.

Boore, D.M., Joyner, W.B., and Fumal, T.E., 1997, Equations for estimating horizontal response spectra and peak acceleration from western North American earthquakes – a summary of recent work: Seismological Research Letters, v. 68, n. 1, p. 128-153.

Bray, J.D. "Chapter 14: Simplified Seismic Slope Displacement Procedures," Earthquake Geotechnical Engineering, 4th International Conference on Earthquake Geotechnical Engineering - Invited Lectures, in Geotechnical, Geological, and Earthquake Engineering Series, Pitilakis, Kyriazis D., Ed., Springer, V. 6, p. 327-353, 2007.

Carrara, A., 1983, Multivariate models for landslide hazard evaluation: Mathematical Geology, v. 15, n. 3, p. 403-426.

Carrara, A., Cardinali, M., Detti, R., Guzzetti, F., Pasqui, V., and Reichenbach, P., 1991, GIS techniques and statistical models in evaluation landslide hazards: Earth Surface Processes and Landforms, v. 16, n. 5, p. 427-445.

Clark, B.R., Leighton, F.B., Cann, L.R., and Gaffey, J.T., 1979, Surficial landslides triggered by seismic shaking, San Fernando earthquake of 1971: Menlo Park, California, Final Technical Report to U.S. Geological Survey Contract 14-08-001-16810, 42 p.

Coppersmith, K.J., 1991, Seismic source characterization for engineering seismic hazard analyses: Proceedings, Fourth International Conference on Seismic Zonation, Stanford, California, v. 1, p. 3-60.

Cotecchia, V., 1978, Systematic reconnaissance mapping and registration of slope movements: International Association of Engineering Geologists Bulletin, n. 17, p. 5-37.

Evernden, J.F. and Thomson, J.M., 1988, Predictive model for important ground motion parameters associated with large and great earthquakes: U.S. Geological Survey Bulletin 1838, 27 p.

Fumal, T.E., and Tinsley, J.C., 1985, Mapping shear-wave velocities of near-surface geologic materials, *in* Ziony, J.I., editor, Evaluating earthquake hazards in the Los Angeles region – an earth-science perspective: U.S. Geological Survey Professional Paper 1360, p. 127-149.

Goodman, R.E., and Seed, H.B., 1966, Earthquake-induced displacement in sand embankments: Proceedings of the American Society Civil Engineers, Journal of the Soil Mechanics and Foundations Division, v. 92, n. SM2, p. 125-146.

Harp, E.L., Keefer, D.K., and Wilson, R.C., 1980, A comparison of artificial and natural slope failures, the Santa Barbara earthquake of August 13, 1978: California Geology, v. 33, p. 102-105.

Harp, E.L., Wilson, R.C., and Wieczorek, G.F., 1981, Landslides from the February 4, 1976, Guatemala earthquake: U.S. Geological Survey Professional Paper 1204-A, 35 p.

Hendron, A.J., Jr., Cording, E.J., and Aiyer, A.K., 1980, Analytical and graphical methods for the analysis of slopes in rock masses: U.S. Army Waterways Experiment Station Tech. Report GL-80-2, Vicksburg, Miss.

Hoek, E. and Bray, J.W., 1981, Rock slope engineering, revised 3rd edition: Institute of Mining and Metallurgy, London, 358 p.

Kachadoorian, R., 1971, An estimate of the damage, *in* The San Fernando, California, Earthquake of February 9, 1971: U.S. Geological Survey Professional Paper 733, p5.

Kane, W.F. and Tehaney, J.M., editors, 1995, Foundation upgrading and repair for infrastructure improvement: American Society of Civil Engineers, Geotechnical Special Publication No. 50, 120 p.

Keefer, D.K., 1984, Rock avalanches caused by earthquakes – source characteristics: Science, v. 223, n. 4642, p. 1288-1290.

Keefer, D.K. and Carlton, L.H., editors, 1995, Landslides under static and dynamic conditions – analysis, monitoring, and mitigation: American Society of Civil Engineers, Geotechnical Special Publication No. 52, 128 p.

Keefer, D.K. and Tannaci, N.E., 1981, Bibliography on landslides, soil liquefaction, and related ground failures in selected historic earthquakes: U.S. Geological Survey Open-File Report 81-572, 39 p.

Keefer, D.K., Wieczorek, G.F., Harp, E.L., and Tuel, D.H., 1978, Preliminary assessment of seismically induced landslide susceptibility *in* Proceedings, Second International Conference on Microzonation: San Francisco, California, v. 1, p. 279-290.

Kramer, Stephen and Siddharthan, Raj, editors, 1995, Earthquake-induced movements and seismic remediation of existing foundations and abutments: American Society of Civil Engineers, Geotechnical Special Publication No. 55, 148 p.

Manson, M.W., Keefer, D.K., and McKittrick, M.A., compilers, 1991, Landslide and other geologic features in the Santa Cruz Mountains, California, resulting from the Loma Prieta Earthquake of October 17, 1989: California Department of Conservation, Division of Mines and Geology Open-File Report 91-05.

McCrink, T.P., 1995, Ridge-top landslides triggered by the Northridge Earthquake *in* The Northridge, California, Earthquake of 17 January 1994: California Department of Conservation, Division of Mines and Geology Special Publication 116, p. 273-287.

Morgenstern, N.R. and Price, V.E., 1965, The analysis of the stability of general slip surfaces: Geotechnique, v. 15, n. 1, p. 79-93.

Morton, D.M., 1971, Seismically triggered landslides in the area above the San Fernando Valley in The San Fernando, California, Earthquake of February 9, 1971: U.S. Geological Survey Professional Paper 733, p. 99-104.

Morton, D.M., 1975, Seismically triggered landslides in the area above the San Fernando Valley in Oakeshott, G.B., editor, San Fernando, California, earthquake of February 9, 1971: California Department of Conservation, Division of Mines and Geology Bulletin 196, p. 145-154.

Nelson, C.V. and Christenson, G.E., 1992, Establishing guidelines for surface fault rupture hazard investigations – Salt Lake County, Utah: Association of Engineering Geologists, Proceedings, 35th Annual Meeting, p. 242-249.

Pike, R.J., 1988, The geometric signature: Quantifying landslide-terrain types from digital elevation models: Mathematical Geology, v. 20, n. 5, p. 491-511.

Rathje, E.M., Abrahamson, N.A., and Bray, J.D., 1998, Simplified frequency content estimates of earthquake ground motions: Journal of Geotechnical and Geoenvironmental Engineering, ASCE, v. 124, n. 2, p. 150-159.

Rib, H.T. and Liang, T., 1978, Recognition and Identification *in* Schuster, R.L. and Krizek, R.J., editors, Landslides – analysis and control: Transportation Research Board, National Academy of Sciences, Special Report 176, p. 34-80.

Rogers, J.D. and Olshansky, R.B., 1992, Science verses advocacy – the reviewer's role to protect the public interest: Association of Engineering Geologists, Proceedings, 35th Annual Meeting, p. 371-378.

Sarna, S.K., 1973, Stability analysis of embankments and slopes: Geotechnique, v. 23, n. 3, p. 423-433.

Sarna, S.K., 1979, Stability analysis of embankments and slopes: Proceedings of the American Society of Civil Engineers, Journal of the Geotechnical Engineering Division, v. 105, n GT12, p. 1511-1524.

Sarna, S.K. and Bhave, M.V., 1974, Critical acceleration versus static safety factor in stability analysis of earth dams and embankments: Geotechnique, v. 24, n. 4, p. 661-665.

Seed, H.B., 1967, Slope stability during earthquakes: Proceedings of the American Society of Civil Engineers, Journal of the Soil Mechanics and Foundation Engineering Division, v. 93, n. SM4, p. 299-323.

Seed, H.B., 1968, Landslides during earthquakes due to soil liquefaction: Proceedings of the American Society of Civil Engineers, Journal of the Soil Mechanics and Foundation Engineering. Division, v. 94, n. SM5, p. 1053-1122.

Seed, H.B., 1987, Design problems in soil liquefaction: American Society of Civil Engineers, Journal of Geotechnical Engineering, v. 113, n. 8, p. 827-845.

Seed, H.B. and Martin, G.R., 1966, The seismic design coefficient in earth dam design: Proceedings of the American Society of Civil Engineers, Journal of the Soil Mechanics and Foundation Engineering. Division, v. 92, n. SM3, p. 25-58.

Skempton, A.W., 1985, Residual strength of clays in landslides, foliated strata, and the laboratory: Geotechnique, v. 35, n. 1, p. 3-18.

Sowers, G.F. and Royster, D.L., 1978, Field investigation in Schuster, R.L., and Krizek, R.J., editors, Landslides – analysis and control: Transportation Research Board, National Academy of Sciences, Special Report 176, p. 81-111.

Spencer, E., 1967, A method of analysis of the stability of embankments assuming parallel inter-slice forces: Geotechnique, v. 17, n. 1, p. 11-26.

Spencer, E., 1981, Slip circles and critical shear planes: Proceedings of the American Society of Civil Engineers, Journal of the Geotechnical Engineering Division, v. 107, n. GT7, p. 929-942.

Spittler, T.E. and Harp, E.L., 1990, Preliminary map of landslide features and coseismic fissures triggered by the Loma Prieta earthquake of October 17, 1989: California Department of Conservation, Division of Mines and Geology Open-File Report 90-6, map scale 1:48,000.

Taylor, F. and Brabb, E.E., 1986, Map showing the status of landslide inventory and susceptibility mapping in California: U.S. Geological Survey Open-File Report 86-100.

Terzaghi, K., 1950, Mechanism of landslides in Paige, S., editor, Application of Geology to Engineering Practice, Berkey Volume: Geological Society of America, p. 83-123.

Terzaghi, K., 1962, Stability of steep slopes on hard, unweathered rock: Geotechnique, v. 12, n. 12, p. 251-270.

Terzaghi, K., Peck, R.B., and Mesri, G., 1995, Soil mechanics in engineering practice: John Wiley & Sons, New York, 592 p.

Turner, A.K. and Schuster, R.L., editors, Landslides – Investigation and mitigation: Transportation Research Board, National Research Council, Special Report 247, 672 p.

Turner, J.P., editor, 1995, Performance of deep foundations under seismic loading: American Society of Civil Engineers, Geotechnical Special Publication No. 51, 88 p.

U.S. Army, Office of the Chief Engineers, 1982, Engineering and design – stability of earth and rockfill dams: Engineering Manual, EM-1110-2-1902, Washington, D.C.

Wieczorek, G.F., Wilson, R.C., and Harp, E.L., 1985, Map of slope stability during earthquakes in San Mateo County, California: U.S. Geological Survey Miscellaneous Investigations Map I-1257-E, scale 1:62,500.

Wilson, R.C. and Keefer, D.K., 1985, Predicting areal limits of earthquake-induced landsliding in Ziony, J.I., editor, Evaluating earthquake hazards in the Los Angeles region – an earth-science perspective: U.S. Geological Survey Professional Paper 1360, p. 317-345.

Wolfe, J., 1975, More on registration: California Geology, v. 28, p. 155-156.

Yeats, R.S., Sieh, K.E., and Allen, C.R., 1997, The geology of earthquakes: Oxford University Press, 568 p.

Youd, T.L., 1980, Ground failure displacement and earthquake damage to buildings: American Society of Civil Engineers, Proceedings of the Specialty Conference on Civil Engineering and Nuclear Power, v. 2, p. 7-6-1 to 7-6-26.

Youd, T.L., 1984, Recurrence of liquefaction at the same site: Proceedings, Eighth World Conference on Earthquake Engineering, San Francisco, California, v. 3, p. 231-238

Youd, T.L., and Hoose, S.N., 1978, Historic ground failures in northern California Triggered by earthquakes: U.S. Geological Survey Professional Paper 993, 177 p., map scale 1:250,000.

Youd, T.L., 1991, Mapping of earthquake-induced liquefaction for seismic zonation:

Proceedings of the Fourth International Conference on Seismic Zonation, Stanford, California, v. 1, p. 111-138.

APPENDIX A

SEISMIC HAZARDS MAPPING ACT

CALIFORNIA PUBLIC RESOURCES CODE

Division 2. Geology, Mines and Mining

CHAPTER 7.8. SEISMIC HAZARDS MAPPING

2690. This chapter shall be known and may be cited as the Seismic Hazards Mapping Act.

2691. The Legislature finds and declares all of the following:

(a) The effects of strong ground shaking, liquefaction, landslides, or other ground failure account for approximately 95 percent of economic losses caused by an earthquake.

(b) Areas subject to these processes during an earthquake have not been identified or mapped statewide, despite the fact that scientific techniques are available to do so.

(c) It is necessary to identify and map seismic hazard zones in order for cities and counties to adequately prepare the safety element of their general plans and to encourage land use management policies and regulations to reduce and mitigate those hazards to protect public health and safety.

2692.

(a) It is the intent of the Legislature to provide for a statewide seismic hazard mapping and technical advisory program to assist cities and counties in fulfilling their responsibilities for protecting the public health and safety from the effects of strong ground shaking, liquefaction, landslides, or other ground failure and other seismic hazards caused by earthquakes.

(b) It is further the intent of the Legislature that maps and accompanying information provided pursuant to this chapter be made available to local governments for planning and development purposes.

(c) It is further the intent of the Legislature that the California Geological Survey, in implementing this chapter, shall, to the extent possible, coordinate its activities with, and use existing information generated from, the earthquake fault zones mapping program

pursuant to Chapter 7.5 (commencing with Section 2621), and the inundation maps prepared pursuant to Section 8589.5 of the Government Code.

2692.1. The State Geologist may include in maps compiled pursuant to this chapter information on the potential effects of tsunami and seiche when information becomes available from other sources and the State Geologist determines the information is appropriate for use by local government. The State Geologist shall not be required to provide this information unless additional funding is provided both to make the determination and to distribute the tsunami and seiche information.

2693. As used in this chapter:

(a) "City" and "County" includes the City and County of San Francisco.

(b) "Geotechnical" report means a report prepared by a certified engineering geologist or a civil engineer practicing within the area of his or her competence, which identifies seismic hazards and recommends mitigation measures to reduce the risk of seismic hazard to acceptable levels.

(c) "Mitigation" means those measures that are consistent with established practice and that will reduce seismic risk to acceptable levels.

(d) "Project" has the same meaning as in Chapter 7.5 (commencing with Section 2621), except as follows:

(1) A single-family dwelling otherwise qualifying as a project may be exempted by the city or county having jurisdiction of the project.

(2) "Project" does not include alterations or additions to any structure within a seismic hazard zone which do not exceed either 50 percent of the value of the structure or 50 percent of the existing floor area of the structure.

(e) "Commission" means the Seismic Safety Commission.

(f) "Board" means the State Mining and Geology Board.

2694.

(a) A person who is acting as an agent for a seller of real property that is located within a seismic hazard zone, as designated under this chapter, or the seller, if he or she is acting without an agent, shall disclose to any prospective purchaser the fact that the property is located within a seismic hazard zone.

(b) Disclosure is required pursuant to this section only when one of the following conditions is met:

(1) The transferor, or transferor’s agent, has actual knowledge that the property is within a seismic hazard zone.

(2) A map that includes the property has been provided to the city or county pursuant to Section 2622, and a notice has been posted at the offices of the county recorder, county assessor, and county planning agency that identifies the location of the map and any information regarding changes to the map received by the county.

(c) In all transactions that are subject to Section 1103 of the Civil Code, the disclosure required by subdivision (a) of this section shall be provided by either of the following means:

(1) The Local Option Real Estate Transfer Disclosure Statement as provided in Section 1102.6a of the Civil Code.

(2) The Natural Hazards Disclosure Statement as provided in Section 1103.2 of the Civil Code.

(d) If the map or accompanying information is not of sufficient accuracy or scale that a reasonable person can determine if the subject real property is included in a seismic hazard zone, the agent shall mark "Yes" on the Natural Hazard Disclosure Statement. The agent may mark "No" on the Natural Hazard Disclosure Statement if he or she attaches a report prepared pursuant to subdivision (c) of Section 1103.4 of the Civil Code that verifies the property is not in the hazard zone. Nothing in this subdivision is intended to limit or abridge any existing duty of the transferor or the transferor's agents to exercise reasonable care in making a determination under this subdivision.

(e) For purposes of the disclosures required by this section, the following persons shall not be deemed agents of the seller:

(1) Persons specified in Section 1103.11 of the Civil Code.

(2) Persons acting under a power of sale regulated by Section 2924 of the Civil Code.

(f) For purposes of this section, Section 1103.13 of the Civil Code applies.

(g) The specification of items for disclosure in this section does not limit or abridge any obligation for disclosure created by any other provision of law or that may exist in order to avoid fraud, misrepresentation, or deceit in the transfer transaction.

2695.

(a) On or before January 1, 1992, the board, in consultation with the director and the commission, shall develop all of the following:

(1) Guidelines for the preparation of maps of seismic hazard zones in the state.

(2) Priorities for mapping of seismic hazard zones. In setting priorities, the board shall take into account the following factors:

(a) The population affected by the seismic hazard in the event of an earthquake.

(b) The probability that the seismic hazard would threaten public health and safety in the event of an earthquake.

(c) The willingness of lead agencies and other public agencies to share the cost of mapping within their jurisdiction.

(d) The availability of existing information.

(3) Policies and criteria regarding the responsibilities of cities, counties, and state agencies pursuant to this chapter. The policies and criteria shall address, but not be limited to, the following:

(a) Criteria for approval of a project within a seismic hazard zone, including mitigation measures.
(b) The contents of the geotechnical report.
(c) Evaluation of the geotechnical report by the lead agency.

(4) Guidelines for evaluating seismic hazards and recommending mitigation measures.

(5) Any necessary procedures, including, but not limited to, processing of waivers pursuant to Section 2697, to facilitate the implementation of this chapter.

(b) In developing the policies and criteria pursuant to subdivision (a), the board shall consult with and consider the recommendations of an advisory committee, appointed by the board in consultation with the commission, composed of the following members:

(1) An engineering geologist registered in the state.

(2) A seismologist.

(3) A civil engineer registered in the state.

(4) A structural engineer registered in the state.

(5) A representative of city government, selected from a list submitted by the League of California Cities.

(6) A representative of county government, selected from a list submitted by the County Supervisors Association of California.

(7) A representative of regional government, selected from a list submitted by the Council of Governments.

(8) A representative of the insurance industry.

(9) The Insurance Commissioner

All of the members of the advisory committee shall have expertise in the field of seismic hazards or seismic safety.

(c) At least 90 days prior to adopting measures pursuant to this section, the board shall transmit or cause to be transmitted a draft of those measures to affected cities, counties, and state agencies for review and comment.

2696.

(a) The State Geologist shall compile maps identifying seismic hazard zones, consistent with the requirements of Section 2695. The maps shall be compiled in accordance with a time schedule developed by the director and based upon the provisions of Section 2695 and the level of funding available to implement this chapter.

(b) The State Geologist shall, upon completion, submit seismic hazard maps compiled pursuant to subdivision (a) to the board and all affected cities, counties, and state agencies for review and comment. Concerned jurisdictions and agencies shall submit all comments to the board for review and consideration within 90 days. Within 90 days of board review, the State Geologist shall revise the maps, as appropriate, and shall provide copies of the official maps to each state agency, city, or county, including the county recorder, having jurisdiction over lands containing an area of seismic hazard. The county recorder shall record all information transmitted as part of the public record.

(c) In order to ensure that sellers of real property and their agents are adequately informed, any county that receives an official map pursuant to this section shall post a notice within five days of receipt of the map at the office of the county recorder, county assessor, and county planning agency, identifying the location of the map and any information regarding changes to the map and the effective date of the notice.

2697.

(a) Cities and counties shall require, prior to the approval of a project located in a seismic hazard zone, a geotechnical report defining and delineating any seismic hazard. If the city or county finds that no undue hazard of this kind exists, based on information resulting from studies conducted on sites in the immediate vicinity of the project and of similar soil composition to the project site, the geotechnical report may be waived. After a report has been approved or a waiver granted, subsequent geotechnical reports shall not be required, provided that new geologic datum, or data, warranting further investigation is not recorded. Each city and county shall submit one copy of each approved geotechnical report, including the mitigation measures, if any, that are to be taken, to the State Geologist within 30 days of its approval of the report.

(b) In meeting the requirements of this section, cities and counties shall consider the policies and criteria established pursuant to this chapter. If a project's approval is not in accordance with the policies and criteria, the city or county shall explain the reasons for the differences in writing to the State Geologist, within 30 days of the project's approval.

2698. Nothing in this chapter is intended to prevent cities and counties from establishing policies and criteria which are more strict than those established by the board.

2699. Each city and county, in preparing the safety element to its general plan pursuant to subdivision (g) of Section 65302 of the Government Code, and in adopting or revising land use planning and permitting ordinances, shall take into account the information provided in available seismic hazard maps.

2699.5

(a) There is hereby created the Seismic Hazards Identification Fund, as a special fund in the State Treasury.

(b) Upon appropriation by the Legislature, the moneys in the Strong-Motion Instrumentation and Seismic Hazards Mapping Fund shall be allocated to the division for purposes of this chapter and Chapter 8 (commencing with Section 2700).

(c) On and after July 1, 2004, the Seismic Hazards Identification Fund shall be known as the Strong-Motion Instrumentation and Seismic Hazards Mapping Fund.

2699.6. This chapter shall become operative on April 1, 1991.

APPENDIX B

SEISMIC HAZARDS MAPPING REGULATIONS

CALIFORNIA CODE OF REGULATIONS

Title 14. Natural Resources

Division 2. Department of Conservation

Chapter 8. Mining and Geology

ARTICLE 10. SEISMIC HAZARDS MAPPING

3720. Purpose

These regulations shall govern the exercise of city, county and state agency responsibilities to identify and map seismic hazard zones and to mitigate seismic hazards to protect public health and safety in accordance with the provisions of Public Resources Code, Section 2690 et seq. (Seismic Hazards Mapping Act).

Authority cited: Public Resources Code Section 2695
Reference: Public Resources Code Section 2695(a)(1)and (3)-(5)

3721. Definitions

(a) "Acceptable Level" means that level that provides reasonable protection of the public safety, though it does not necessarily ensure continued structural integrity and functionality of the project.

(b) "Lead Agency" means the city, county or state agency with the authority to approve projects.

(c) "Registered civil engineer" or "certified engineering geologist" means a civil engineer or engineering geologist who is registered or certified in the State of California.

Authority cited: Public Resources Code Section 2695
Reference: Public Resources Code Sections 2690-2696.6

3722. Requirements for Mapping Seismic Hazard Zones

(a) The Department of Conservation, Division of Mines and Geology, shall prepare one or more State-wide probabilistic ground shaking maps for a suitably defined reference soil column. One of the maps shall show ground-shaking levels, which have a 10% probability of being exceeded in 50 years. These maps shall be used with the following criteria to define seismic hazard zones:

(1) Amplified shaking hazard zones shall be delineated as areas where historic occurrence of amplified ground shaking, or local geological and geotechnical conditions indicate a potential for ground shaking to be amplified to a level such that mitigation as defined in Public Resources Code Section 2693(c)would be required.

(2) Liquefaction hazard zones shall be delineated as areas where historic occurrence of liquefaction, or local geological, geotechnical and ground water conditions indicate a potential for permanent ground displacements such that mitigation as defined in Public Resources Code Section 2693(c) would be required.

(3) Earthquake-induced landslide hazard zones shall be delineated as areas where Holocene occurrence of landslide movement, or local slope of terrain, and geological, geotechnical and ground moisture conditions indicate a potential for permanent ground displacements such that mitigation as defined in Public Resources Code Section 2693(c) would be required.

(b) Highest priority for mapping seismic hazard zones shall be given to areas facing urbanization or redevelopment in conjunction with the factors listed in Section 2695(a)(2)(A), (B), (C) and (D) of the Public Resources Code.

Authority cited: Public Resources Code Section 2695
Reference: Public Resources Code Section 2695(a)(1)

3723. Review of Preliminary Seismic Hazard Zones Maps

(a) The Mining and Geology Board shall provide an opportunity for receipt of public comments and recommendations during the 90-day period for review of preliminary seismic hazard zone maps provided by the Public Resources Code Section 2696. At least one public hearing shall be scheduled for that purpose.

(b) Following the end of the review period, the Board shall forward its comments and recommendations, with supporting data received, to the State Geologist for consideration prior to revision and official issuance of the maps.

Authority cited: Public Resources Code Section 2696
Reference: Public Resources Code Section 2696

3724. Specific Criteria for Project Approval

The following specific criteria for project approval shall apply within seismic hazard zones and shall be used by affected lead agencies in complying with the provisions of the Act:

(a) A project shall be approved only when the nature and severity of the seismic hazards at the site have been evaluated in a geotechnical report and appropriate mitigation measures have been proposed.

(b) The geotechnical report shall be prepared by a registered civil engineer or certified engineering geologist, having competence in the field of seismic hazard evaluation and mitigation. The geotechnical report shall contain site-specific evaluations of the seismic hazard affecting the project, and shall identify portions of the project site containing seismic hazards. The report shall also identify any known off-site seismic hazards that could adversely affect the site in the event of an earthquake. The contents of the geotechnical report shall include, but shall not be limited to, the following:

(1) Project description.

(2) A description of the geologic and geotechnical conditions at the site, including an appropriate site location map.

(3) Evaluation of site-specific seismic hazards based on geological and geotechnical conditions, in accordance with current standards of practice.

(4) Recommendations for appropriate mitigation measures as required in Section 3724(a), above.

(5) Name of report preparer(s), and signature(s) of a certified engineering geologist and/or registered civil engineer, having competence in the field of seismic hazard evaluation and mitigation.

(c) Prior to approving the project, the lead agency shall independently review e geotechnical report to determine the adequacy of the hazard evaluation and proposed mitigation measures and to determine the requirements of Section 3724(a), above, are satisfied. Such reviews shall be conducted by a certified engineering geologist or registered civil engineer, having competence in the field of seismic hazard evaluation and mitigation.

Authority cited: Public Resources Code Section 2695
Reference: Public Resources Code Section 2695(a)(3)(A), (B), and (C)

3725. Waivers of Geotechnical Report Requirements

For a specific project, the lead agency may determine that the geological and geotechnical conditions at the site are such that public safety is adequately protected and no mitigation is required. This finding shall be based on a report presenting evaluations of sites in the immediate vicinity having similar

geologic and geotechnical characteristics. The report shall be prepared by a certified engineering geologist or register civil engineer, having competence in the field of seismic hazard evaluation and mitigation. The lead agency shall review submitted reports in the same manner as in Section 3724(c) of this article. The lead agency shall also provide a written commentary that addresses the report conclusions and the justification for applying the conclusions contains in the report to the project site. When the lead agency makes such a finding, it may waive the requirement of a geotechnical report for the project. All such waivers shall be recorded with the county recorder and a separate copy, together with the report and commentary, filed with the State Geologist within 30 days of the waiver.

Authority cited: Public Resources Code Section 2695
Reference: Public Resources Code Section 2697(a)(5)

APPENDIX C

TECHNICAL TERMS AND DEFINITIONS

ASTM	American Society for Testing and Materials
CPT	Cone Penetration Test (ASTM D3441-94).
CSR	Cyclic stress ratio— a normalized measure of cyclic load severity imposed by an earthquake, expressed as equivalent uniform cyclic deviatoric load divided by some measure of initial effective overburden or confining stress.
CRR	The equivalent uniform cyclic stress ratio required to induce liquefaction within a given number of loading cycles [that number of cycles considered representative of the earthquake under consideration].
DSHA	Deterministic seismic hazard analysis
FS	Factor of safety— the ratio of the forces available to resist failure divided by the driving forces.
Ground Loss	Localized ground subsidence.
k	Seismic coefficient used in a pseudo-static slope stability analysis
Liquefaction	Significant loss of soil strength due to pore pressure increase.
N	Penetration resistance measured in SPT tests (blows/ft).
N_1	Normalized SPT N-value (blows/ft); corrected for overburden stress effects to the N-value which would occur if the effective overburden stress was 1.0 tons/ft^2.
$(N_1)_{60}$	Standardized, normalized SPT-value; corrected for both overburden stress effects and equipment and procedural effects (blows/ft).
PI	Plasticity Index; the difference between the Atterberg Liquid Limit (LL) and the Atterberg Plastic Limit (PL) for a cohesive soil. [PI(%) = LL(%) - PL(%)].
PSHA	Probabilistic seismic hazard analysis

q_c Tip resistance measured by CPT probe (force/length^2).

$q_{c,1}$ Normalized CPT tip resistance (force/length^2); corrected for overburden stress effects to the qc value which would occur if the effective overburden stress was 1.0 tons/ ft^2.

Sand Boiling Localized ejection of soil and water to relieve excess pore pressure.

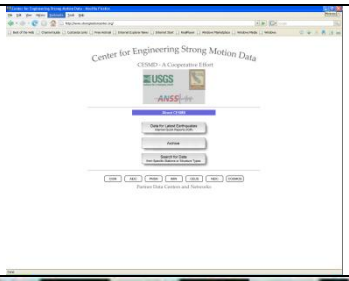
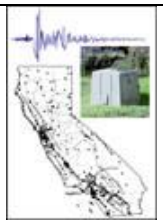
SPT Standard Penetration Test (ASTM D1586-92 and ASTM D6066-96e1).

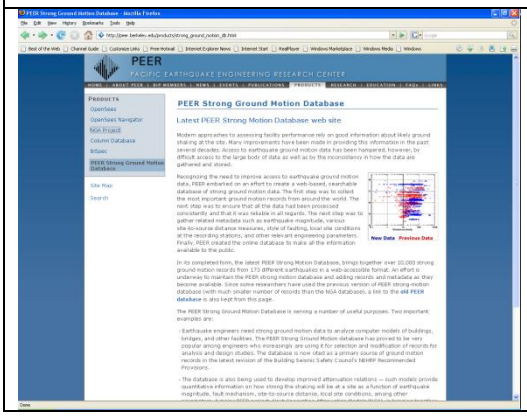
APPENDIX D

SOURCES FOR STRONG-MOTION RECORDS

Earthquake Strong Motion

It is clear that destructive earthquakes pose a continuing major threat to lives and property throughout California. Earthquake strong motion data provide information for engineers to improve earthquake resistance for buildings and other structures. The California Strong Motion Instrumentation Program (CSMIP) records the strong shaking of the ground and in structures during earthquakes for the engineering and scientific communities through a statewide network of strong motion instruments. The measured ground strong shaking is used immediately after an event to assist in emergency response by agencies like OES. Structural measurements are studied after events to analyze the performance of structures, with the goal of mitigating future earthquake impacts through improved building codes for safer, more earthquake resistant structures.

	Strong-motion data for engineering applications after major earthquakes are distributed via the Internet Quick Report (IQR) and the Internet Data Report (IDR) at CGS. The IQR and the IDR are based on the design concept of the traditional Quick Report and is streamlined in an automated fashion. The release of IQR is usually accompanying with the release of ShakeMap and is for earthquakes of magnitude 4.0 or above and for events with strong-motion recordings. The release of IDR is for significant historic earthquakes.
	The Center for Engineering Strong Motion Data is jointly operated by the California Department of Conservation's Strong Motion Instrumentation Program (CSMIP) in cooperation with the USGS/National Strong Motion Program (NSMP). A primary goal of the Engineering Data Center as well as the other two Earthquake Data Management Centers in CISN is to provide rapid information after an earthquake, ranging from the ShakeMap to distribution of the data and calculated parameters: http://www.strongmotioncenter.org/
	A ShakeMap is a representation of ground shaking produced by an earthquake. The information it presents is different from the earthquake magnitude and epicenter that are released after an earthquake because ShakeMap focuses on the ground shaking produced by the earthquake, rather than the parameters describing the earthquake source. ShakeMaps are generated automatically following moderate and large earthquakes. These are preliminary ground shaking maps, normally posted within several minutes of the earthquake origin time. Under the CISN project, ShakeMaps currently are generated in both Northern and Southern California and at CGS.
	The California Strong Motion Instrumentation Program (CSMIP) was established in 1972 by California Legislation to obtain vital earthquake data for the engineering and scientific communities through a statewide network of strong motion instruments. When the planned network is completed, statewide coverage will ensure that strong ground motion for any moderate to larger size earthquake in the state will be recorded. Please visit: http://www.conservation.ca.gov/cgs/smip/Pages/index.aspx

	The PEER Strong Motion Database is cited as a primary source of ground motion records in the latest revision of the Building Seismic Safety Council's NEHRP Recommended Provisions. The PEER NGA Database is a select set of strong-motion records used to develop the Next Generation Attenuation Models (NGA). For latest reports on NGA models and link to the PEER Strong Motion Database, please visit: http://peer.berkeley.edu/nga/

APPENDIX E

GEOLOGIC ENVIRONMENTS LIKELY TO PRODUCE EARTHQUAKE-INDUCED LANDSLIDES

Landslide Type	Type of Material	Minimum Slope	Remarks
Rock falls	Rocks weakly cemented, intensely fractured, or weathered; contain conspicuous planes of weakness dipping out of slope or contain boulders in a weak matrix.	40° 1.7:1	Particularly common near ridge crests and on spurs, ledges, artificially cut slopes, and slopes undercut by active erosion.
Rock slides	Rocks weakly cemented, intensely fractured, or weathered; contain conspicuous planes of weakness dipping out of slope or contain boulders in a weak matrix.	35° 1.4:1	Particularly common in hillside flutes and channels, on artificially cut slopes, and on slopes undercut by active erosion. Occasionally reactivate preexisting rockslide deposits.
Rock Avalanches	Rocks intensely fractured and exhibiting one of the following properties: significant weathering, planes of weakness dipping out of slope, weak cementation, or evidence of previous landsliding.	25° 2.1:1	Usually restricted to slopes of greater than 500 feet (150 m) relief that have been undercut by erosion. May be accompanied by a blast of air that can knock down trees and structures beyond the limits of the deposited debris
Rock slumps	Intensely fractured rocks, preexisting rock slump deposits, shale, and other rocks containing layers of weakly cemented or intensely weathered material.	15° 3.7:1	
Rock block slides	Rocks having conspicuous bedding planes or similar planes of weakness dipping out of slopes.	15° 3.7:1	
Soil falls	Granular soils that are slightly cemented or contain clay binder	40° 1.7:1	Particularly common on stream-banks, terrace faces, coastal bluffs, and artificially cut slopes.

Landslide Type	Type of Material	Minimum Slope	Remarks
Disrupted soil slides	Loose, unsaturated sands.	15° 3.7:1	
Soil avalanches	Loose, unsaturated sands.	25° 2.1:1	Occasionally reactivate preexisting soil avalanche deposits.
Soil slumps	Loose, partly to completely saturated sand or silt; uncompacted or poorly compacted manmade fill composed of sand, silt, or clay, preexisting soil slump deposits.	10° 11:1	Particularly common on embankments built on soft, saturated foundation materials, in hillside cut-and-fill areas, and on river and coastal flood plains.
Soil block slumps	Loose, partly or completely saturated sand or silt; uncompacted or slightly compacted manmade fill composed of sand or silt, bluffs containing horizontal or subhorizontal layers or loose, saturated sand or silt.	5° 11:1	Particularly common in areas of preexisting landslides along river and coastal flood plains, and on embankments built of soft, saturated foundation materials.
Low earth flows	Stiff, partly to completely saturated clay and preexisting earth-flow deposits.	10° 5.7:1	
Soil lateral spreads	Loose, partly or completely saturated silt or sand, uncompacted or slightly compacted manmade fill composed of sand.	0.3° 190:1	Particularly common on river and coastal flood plains, embankments built on soft, saturated foundation materials, delta margins, sand dunes, sand spits, alluvial fans, lakeshores and beaches.
Rapid soil flow	Saturated, uncompacted or slightly compacted manmade fill composed of sand or sandy silt (including hydraulic fill earth dams and tailings dams); loose, saturated granular soils.	2.3° 25:1	Includes debris flows that typically originate in hollows at heads of streams and adjacent hillsides; typically travel at tens of miles per hour or more and may cause damage miles from the source area.
Subaqueous landslides	Loose, saturated granular soils.	0.5° 110:1	Particularly common on delta margins.

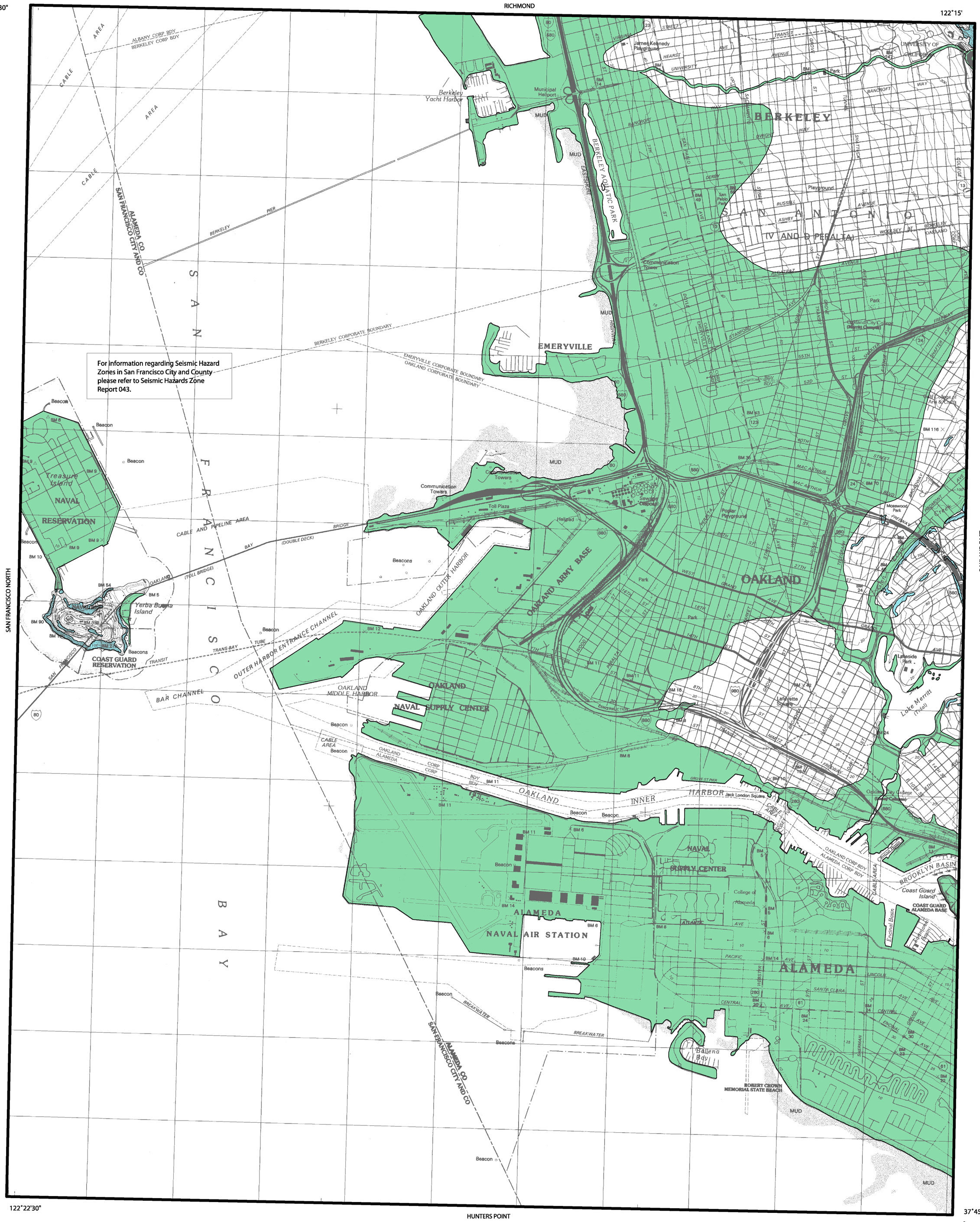
Modified from Keefer (1984).

STATE OF CALIFORNIA-GRAY DAVIS, GOVERNOR
THE RESOURCES AGENCY-MARY D. NICHOLS, SECRETARY
DEPARTMENT OF CONSERVATION-DARRYL W. YOUNG, DIRECTOR

CALIFORNIA GEOLOGICAL SURVEY
JAMES F. DAVIS, STATE GEOLOGIST

SEISMIC HAZARD ZONES
Oakland West Quadrangle

SAN QUENTIN | 122°22'30" | RICHMOND | 122°15' | BRIONES VALLEY | 37°52'30"



Base Map prepared by U.S. Geological Survey, 1997.
Zones of required investigation boundaries may reflect updated digital topographic data that can differ significantly from contours shown on the base map.

PURPOSE OF MAP

This map will assist cities and counties in fulfilling their responsibilities for protecting the public from the effects of earthquake-triggered ground failure as required by the Seismic Hazards Mapping Act (Public Resources Code Sections 2690-2699.6).

For information regarding the general approach and recommended methods for preparing this map, see DMG Special Publication 118, *Recommended Criteria for Delineating Seismic Hazard Zones in California*.

For information regarding the scope and recommended methods to be used in conducting the required site investigations, see DMG Special Publication 117, *Guidelines for Evaluating and Mitigating Seismic Hazards in California*.

For a general description of the Seismic Hazard Mapping Program, the Seismic Hazards Mapping Act and regulations, and related information, please refer to the website at **www.conservation.ca.gov/cgs/.**

IMPORTANT - PLEASE NOTE

1) This map may not show all areas that have the potential for liquefaction, landsliding, strong earthquake ground shaking or other earthquake and geologic hazards. Also, a single earthquake capable of causing liquefaction or triggering landslide failure will not uniformly affect the entire area zoned.

2) Liquefaction zones may also contain areas susceptible to the effects of earthquake-induced landslides. This situation typically exists at or near the toe of existing landslides, downslope from rockfall or debris flow source areas, or adjacent to steep stream banks.

3) This map does not show Alquist-Priolo earthquake fault zones, if any, that may exist in this area. Please refer to the latest official map of earthquake fault zones for disclosures and other actions that are required by the Alquist-Priolo Earthquake Fault Zoning Act. For more information on this subject and an index to available maps, see DMG Special Publication 42.

4) Landslide zones on this map were determined, in part, by adapting methods originally developed by the U.S. Geological Survey (USGS). Landslide hazard maps prepared by the USGS typically use experimental approaches to assess earthquake-induced and other types of landslide hazards. Although aspects of these new methodologies may be incorporated in future California Geological Survey (CGS) seismic hazard zone maps, USGS maps should not be used as substitutes for these Official SEISMIC HAZARD ZONES maps.

5) U.S. Geological Survey base map standards provide that 90 percent of cultural features be located within 40 feet (horizontal accuracy) at the scale of this map. The identification and location of liquefaction and earthquake-induced landslide zones are based on available data. However, the quality of data used is varied. The zone boundaries depicted have been drawn as accurately as possible at this scale.

6) Information on this map is not sufficient to serve as a substitute for the geologic and geotechnical site investigations required under Chapters 7.5 and 7.8 of Division 2 of the Public Resources Code.

7) DISCLAIMER: The State of California and the Department of Conservation make no representations or warranties regarding the accuracy of the data from which these maps were derived. Neither the State nor the Department shall be liable under any circumstances for any direct, indirect, special, incidental or consequential damages with respect to any claim by any user or any third party on account of or arising from the use of this map.

SCALE 1:24,000

1 .5 0 1 MILE
1000 0 1000 2000 3000 4000 5000 6000 7000 FEET
1 .5 0 1 KILOMETER

STATE OF CALIFORNIA

SEISMIC HAZARD ZONES

Delineated in compliance with
Chapter 7.8, Division 2 of the California Public Resources Code
(Seismic Hazards Mapping Act)

OAKLAND WEST QUADRANGLE

OFFICIAL MAP

Released: February 14, 2003

STATE GEOLOGIST

MAP EXPLANATION

Zones of Required Investigation:

Liquefaction

Areas where historical occurrence of liquefaction, or local geological, geotechnical and ground-water conditions indicate a potential for permanent ground displacements such that mitigation as defined in Public Resources Code Section 2693(c) would be required.

Earthquake-Induced Landslides

Areas where previous occurrence of landslide movement, or local topographic, geological, geotechnical and subsurface water conditions indicate a potential for permanent ground displacements such that mitigation as defined in Public Resources Code Section 2693(c) would be required.

NOTE: Seismic Hazard Zones identified on this map may include developed land where delineated hazards have already been mitigated to city or county standards. Check with your local building/planning department for information regarding the location of such mitigated areas.

DATA AND METHODOLOGY USED TO DEVELOP THIS MAP ARE PRESENTED IN THE FOLLOWING:

Seismic Hazard Zone Report of the Oakland West 7.5-Minute Quadrangle, Alameda County California: California Geological Survey, Seismic Hazards Zone Report 081.

For additional information on seismic hazards in this map area, the rationale used for zoning, and additional references consulted, refer to CGS's World Wide Web site

www.conservation.ca.gov/cgs/

Copyright© 2003 by the California Department of Conservation, California Geologic Survey. All rights reserved.

UCERF3: A New Earthquake Forecast for California's Complex Fault System

With innovations, fresh data, and lessons learned from recent earthquakes, scientists have developed a new earthquake forecast model for California, a region under constant threat from potentially damaging events. The new model, referred to as the third Uniform California Earthquake Rupture Forecast, or "UCERF3" (http://www.WGCEP.org/UCERF3), provides authoritative estimates of the magnitude, location, and likelihood of earthquake fault rupture throughout the state. Overall the results confirm previous findings, but with some significant changes because of model improvements. For example, compared to the previous forecast (UCERF2), the likelihood of moderate-sized earthquakes (magnitude 6.5 to 7.5) is lower, whereas that of larger events is higher. This is because of the inclusion of multifault ruptures, where earthquakes are no longer confined to separate, individual faults, but can occasionally rupture multiple faults simultaneously. The public-safety implications of this and other model improvements depend on several factors, including site location and type of structure (for example, family dwelling compared to a long-span bridge). Building codes, earthquake insurance products, emergency plans, and other risk-mitigation efforts will be updated accordingly. This model also serves as a reminder that damaging earthquakes are inevitable for California. Fortunately, there are many simple steps residents can take to protect lives and property.

What is UCERF3?

California is sandwiched between the Pacific and North American tectonic plates, with the former migrating northwest about two inches per year compared to the latter. The plate boundary is far from smooth, reflecting more of a fragmented zone locked in a tectonic battle over which areas will give way, producing some of the steepest mountain ranges in the world. The sliding between plates is also not steady, but rather plays out in fits and starts with periods of rest interrupted by sudden slip along cracks in the Earth. These "fault ruptures" in turn cause the ground to shake, much like the ripples that radiate from a pebble tossed in a pond, and it is this shaking that causes the most damage in earthquakes.

Two kinds of scientific models are used to help safeguard against earthquake losses: an Earthquake Rupture Forecast, which tells us where and when the Earth might slip along the state's many faults, and a Ground Motion Prediction model, which estimates the subsequent shaking given one of the fault ruptures. UCERF3 is the first type of model, representing the latest earthquake-rupture forecast for California. It was developed and reviewed by dozens of leading scientific experts from the fields of seismology, geology, geodesy, paleoseismology, earthquake physics, and earthquake engineering. As such, it represents the best available science with respect to authoritative estimates of the magnitude, location, and likelihood of potentially damaging earthquakes throughout the state (further background on these models, especially with respect to ingredients, can be found in U.S. Geological Survey Fact Sheet 2008–3027, http://pubs.usgs.gov/fs/2008/3027/).

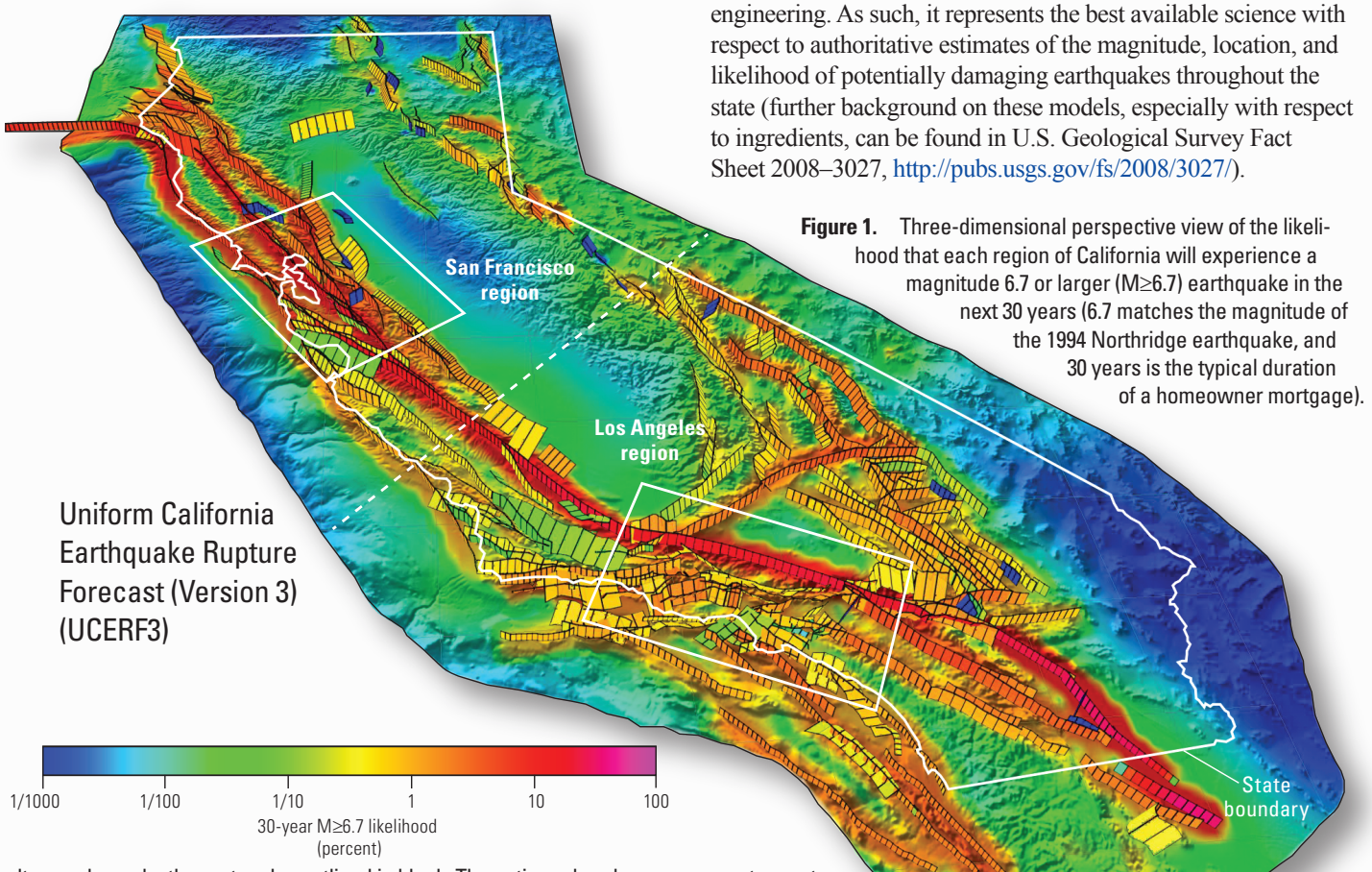


Figure 1. Three-dimensional perspective view of the likelihood that each region of California will experience a magnitude 6.7 or larger (M≥6.7) earthquake in the next 30 years (6.7 matches the magnitude of the 1994 Northridge earthquake, and 30 years is the typical duration of a homeowner mortgage). Faults are shown by the rectangles outlined in black. The entire colored area represents greater California, and the white line across the middle defines northern versus southern California. Results do not include earthquakes on the Cascadia Subduction Zone, a 750-mile offshore fault that extends about 150 miles into California from Oregon and Washington to the north.

U.S. Department of the Interior
U.S. Geological Survey

Printed on recycled paper

ISSN 2327-6916 (print) ISSN 2327-6932 (online)
http://dx.doi.org/10.3133/fs20153009

Fact Sheet 2015–3009
March 2015

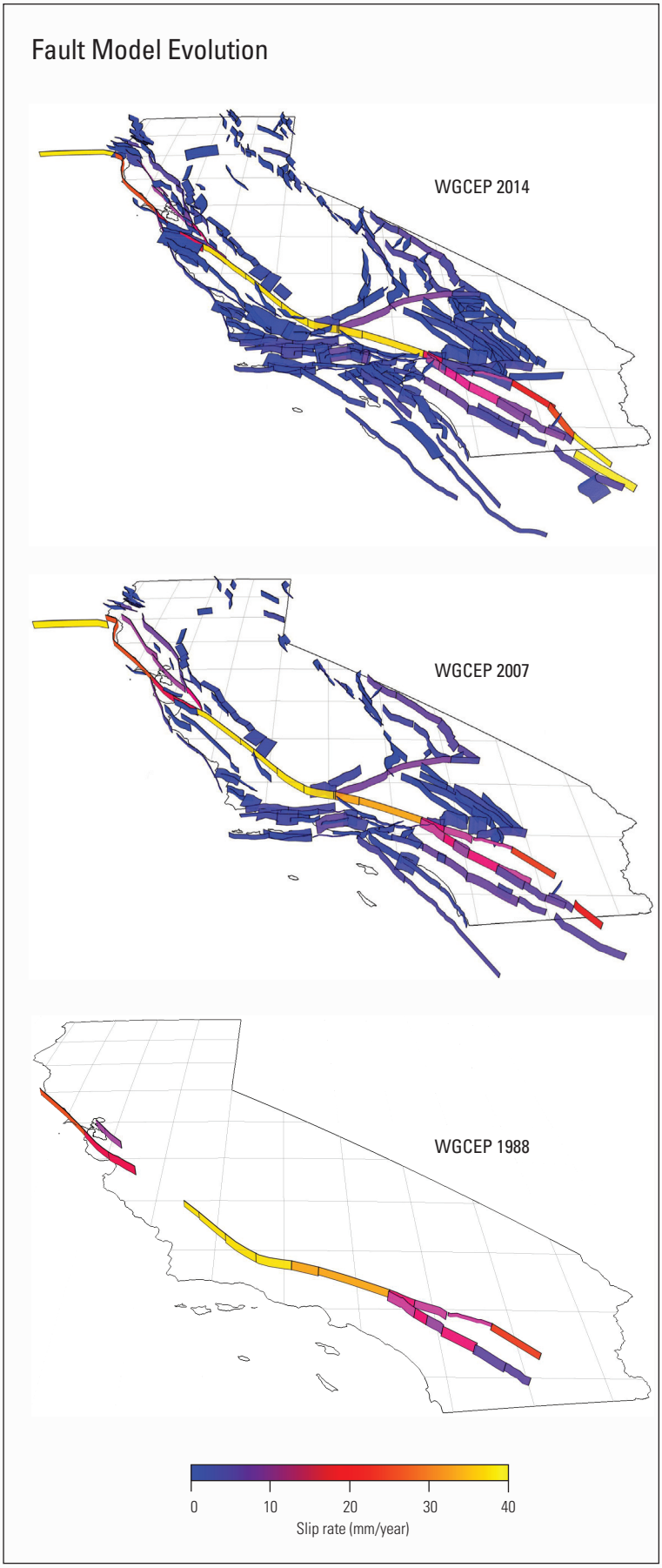


Figure 2. Changes with time of the inventory of faults used in California earthquake forecast models (WGCEP, Working Group on California Earthquake Probabilities).

Why a New Earthquake Forecast Model?

All scientific models, including earthquake rupture forecasts, are an approximation of the physical system they represent, in the same way that "the map is not the actual territory" (Korzbski, 1931). UCERF3 represents the latest model from the Working Group on California Earthquake Probabilities (WGCEP) (WGCEP, 2014), which also released forecasts in 1988, 1990, 1995, 2003, and 2007. This historical progression of models reflects increasingly accurate, detailed, and sophisticated representations of a particularly complex natural system.

A puzzling feature of previous models has been a forecasted rate of moderate-sized earthquakes (between magnitude 6.5 and 7.0) that is up to a factor of two higher than that observed historically. The first discovery of this discrepancy, by the 1995 WGCEP, was particularly disturbing in that one such event, the magnitude 6.7 1994 Northridge earthquake, had just surprised many as the costliest earthquake in U.S. history. In fact, the prospect of such events becoming more frequent contributed to an ensuing homeowner-insurance-availability crisis, as most insurance providers opted to pull out of the market altogether, rather than comply with a state law requiring they offer an earthquake option with each policy. This insurance availability crisis was ultimately solved in 1996 with the legislative creation of the California Earthquake Authority (http://www.earthquakeauthority.com), which has since become the largest earthquake insurance provider in the state. However, the discrepancy between the forecast rate and the observed rate at moderate magnitudes has remained through the most recent previous study (WGCEP, 2007), and scientists have hotly debated whether this is real or a result of some model limitation.

Recent earthquakes have fortunately provided clues. For example, the Northridge earthquake occurred on a previously unrecognized fault, which motivated scientists to search for other faults and quantify those that might be capable of producing damaging earthquakes. The effort has paid off. Whereas the 1988 WGCEP considered only 16 different faults, albeit the main ones, by the time of the WGCEP 2007 effort there were about 200. With UCERF3, there are now more than 350 fault sections in the model, thanks in part to using space-based geodesy where geologic data are limited. This historical progression is shown in the fault model evolution figure at left.

Another clue with respect to the moderate-magnitude rate discrepancy is that many recent earthquakes have plowed past previously inferred fault-rupture boundaries. That is, past models have generally assumed that earthquakes are either confined to separate faults, or that long faults like the San Andreas can be divided into different segments that only rupture separately. However, all three of the most-recent, largest earthquakes in California ruptured right past such boundaries, jumping from one fault to another as multifault ruptures. These were the 1992 magnitude 7.3 Landers, the 1999 magnitude 7.2 Hector Mine, and the 2010 magnitude 7.2 El Mayor–Cucapah earthquakes. The 2011 magnitude 9.0 Tohoku, Japan earthquake also violated previously defined fault-segment boundaries, resulting in a much larger fault-rupture area and magnitude than expected, and contributing to the deadly tsunami and Fukushima nuclear disaster.

Given these observations, the possibility of multifault ruptures clearly needed to be considered in our new model. In fact, as the inventory of California faults has grown over the years, it

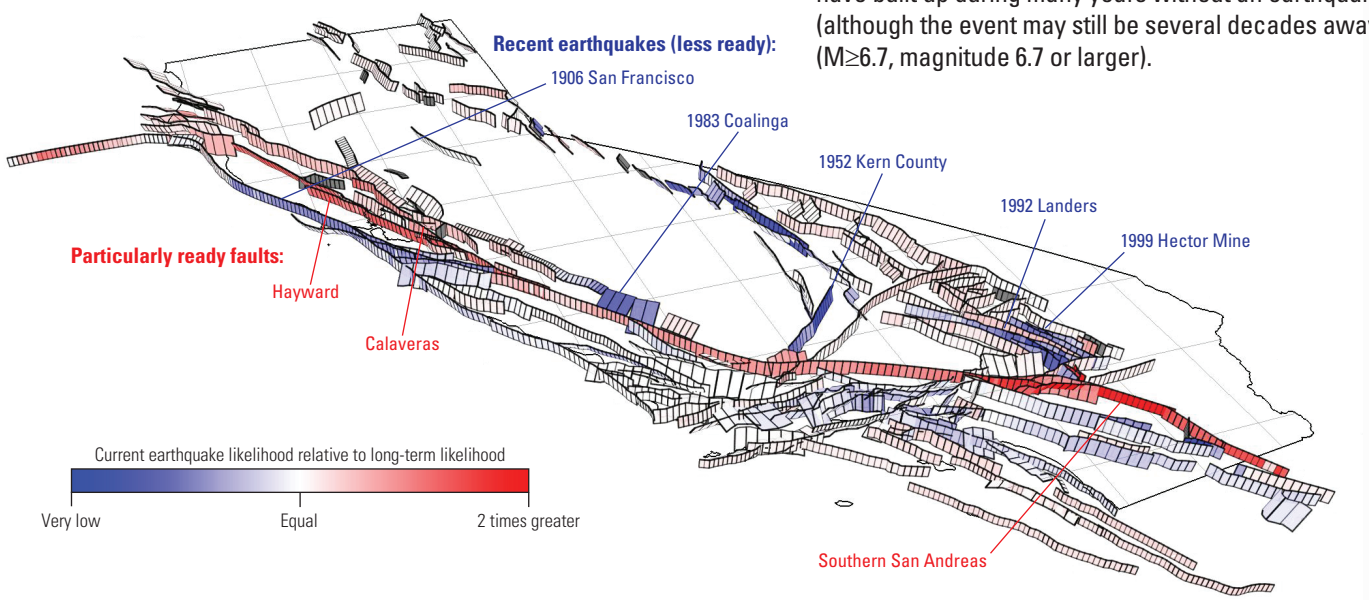


Figure 3. California earthquake likelihood in UCERF3 incorporates the concept that earthquake probabilities change with time according to elastic-rebound theory. Faults are less likely to rupture (less ready) when and where there has been a recent earthquake, and are more likely to rupture (more ready) where tectonic forces have built up during many years without an earthquake (although the event may still be several decades away) (M≥6.7, magnitude 6.7 or larger).

has become increasingly apparent that we are not dealing with a few well-separate faults, but with a vast interconnected fault system. In fact, it has become difficult to identify where some faults end and others begin, implying many more opportunities for multifault ruptures. As a consequence, UCERF3 now considers more than 250,000 different fault-based earthquakes, including multifault ruptures, whereas UCERF2 had about 10,000, and previous models had far fewer. Because we still lack a complete inventory of faults, UCERF3 (and UCERF2 before it) also includes the possibility of earthquakes on unrecognized faults elsewhere in the region.

Solving for the rate of all possible ruptures in the interconnected fault system represented a significant challenge. The UCERF3 methodological breakthrough, referred to as the "grand inversion," allowed us to not only solve for the rate of each earthquake rupture, but to also draw upon a broader range of observations in doing so. For example, the previous rate discrepancy at moderate-magnitudes was turned into part of the solution. That is, because the total plate-tectonic deformation is generally well known, any increase in the rate of larger, multifault ruptures must come with a consequent reduction in rates at lower magnitudes. The grand inversion manages the overall plate-tectonic, fault-system budget mathematically, adding whatever multifault ruptures are needed to eliminate the rate discrepancy at moderate magnitudes. So, not only does UCERF3 include the types of multifault ruptures seen in nature, but doing so has also eliminated the overprediction of moderate-sized events, implying the latter was simply a manifestation of the isolation and segmentation of faults in the previous models.

UCERF3 also includes the notion of fault "readiness," where earthquake likelihoods go down on faults that have recently ruptured, and build back up with time as tectonic stresses reaccumulate. Although this concept, known formally as Reid's elastic rebound theory (Reid, 1911), has been around for more than a century, applying it in a model that includes multifault ruptures also proved challenging. A new methodology was therefore developed, which also relaxes the requirement that the date-of-last event be known where applied. That is, we may not know when the most recent event occurred on many California faults, but we do know that it had to have been prior to 1875 (the year when reliable recordkeeping began). Being able to account for this "historic open interval" for events that precede 1875 allowed us to quantify fault readiness throughout the entire fault system (fig. 3), rather than being limited to only a subset of faults as in previous studies.

There are many uncertainties in both the data and scientific theories that go into UCERF3, and alternative values for each element can lead to a different forecast. Consequently, UCERF3 is not a single model, but rather a collection of 5,760 different viable models. The results presented in the next section represent an average of these forecasts. Calculating grand-inversion results for all the models required the use of super computers, as they would have taken more than 8 years on a single desktop computer.

What Are the Results, and How Do They Differ from Previous Estimates?

UCERF3 results for various regions and faults of interest are shown in the figures and tables here. How have expected earthquake rates changed from the previous model? Overall, the results confirm earlier findings (California is earthquake country), but with some important refinements in certain areas. Considering the entire region, the average time between magnitude 6.7 and larger earthquakes has gone from 1 every 4.8 years in UCERF2, to 1 about every 6.3 years in UCERF3, representing a 30 percent decrease in the new forecasted

Table 1. Average time between earthquakes in the various regions together with the likelihood of having one or more such earthquakes in the next 30 years (starting from 2014). Values listed in parentheses indicate the factor by which the rates and likelihoods have increased, or decreased, since the previous model (UCERF2). "Readiness" indicates the factor by which likelihoods are currently elevated, or lower, because of the length of time since the most recent large earthquakes (see text). These values include aftershocks. It is important to note that actual repeat times will exhibit a high degree of variability, and will almost never exactly equal the average listed here.

Greater California region

Magnitude (greater than or equal to)	Average repeat time (years)		30-year likelihood of one or more events		Readiness
5	0.12	(0.7)	100%	(1.0)	1.0
6	1.2	(0.9)	100%	(1.0)	1.0
6.7	6.3	(1.3)	>99%	(1.0)	1.0
7	13	(1.3)	93%	(1.0)	1.0
7.5	52	(1.0)	48%	(1.0)	1.1
8	494	(0.8)	7%	(1.5)	1.2

Southern California region

Magnitude (greater than or equal to)	Average repeat time (years)		30-year likelihood of one or more events		Readiness
5	0.24	(0.7)	100%	(1.0)	1.0
6	2.3	(0.9)	100%	(1.0)	1.0
6.7	12	(1.5)	93%	(1.0)	1.0
7	25	(1.4)	75%	(0.9)	1.1
7.5	87	(1.2)	36%	(0.9)	1.2
8	522	(0.4)	7%	(2.5)	1.3

Northern California region

Magnitude (greater than or equal to)	Average repeat time (years)		30-year likelihood of one or more events		Readiness
5	0.24	(0.7)	100%	(1.0)	1.0
6	2.4	(0.9)	100%	(1.0)	1.0
6.7	12	(1.2)	95%	(1.0)	1.0
7	25	(1.2)	76%	(1.0)	1.1
7.5	92	(0.9)	28%	(1.1)	1.0
8	645	(0.8)	5%	(1.4)	1.1

San Francisco region

Magnitude (greater than or equal to)	Average repeat time (years)		30-year likelihood of one or more events		Readiness
5	1.3	(0.7)	100%	(1.0)	1.0
6	8.9	(1.0)	98%	(1.0)	1.0
6.7	29	(1.1)	72%	(1.1)	1.1
7	48	(0.9)	51%	(1.3)	1.1
7.5	124	(0.7)	20%	(1.6)	0.9
8	825	(0.7)	4%	(1.9)	1.0

Los Angeles region

Magnitude (greater than or equal to)	Average repeat time (years)		30-year likelihood of one or more events		Readiness
5	1.4	(0.6)	100%	(1.0)	1.0
6	10	(1.1)	96%	(1.0)	1.0
6.7	40	(2.1)	60%	(0.8)	1.1
7	61	(2.0)	46%	(0.7)	1.2
7.5	109	(1.3)	31%	(0.9)	1.3
8	532	(0.4)	7%	(2.5)	1.3

rate (and note that most of these events occur in remote areas of the state). For magnitude 8 and larger, on the other hand, the rate has increased by 20 percent in UCERF3, with an expected repeat time of 494 years for UCERF3, down from 1 every 617 years in UCERF2. These changes are a direct and expected manifestation of including multifault ruptures in UCERF3. A more careful analysis of historical seismicity has also produced an increased rate for magnitude 5 and greater earthquakes, going from about 5.8 per year in UCERF2 to 8.3 per year in UCERF3. All of these trends are similar to those seen in various subregions of the state, with differences being slightly more dramatic for the Los Angeles area because that region has a large number of faults that can now host multifault ruptures.

Results are also expressed in terms of the likelihood of experiencing one or more earthquakes in the next 30 years, the duration of a typical home mortgage, and these values also take fault readiness into consideration (how long it has been since the most recent event). As in UCERF2, the likelihood for magnitude 6.7 and larger earthquakes somewhere in the entire region remains near certainty (greater than 99 percent). The likelihood is 7 percent for magnitude 8 and greater, a 50 percent increase over UCERF2, resulting from both the inclusion of multifault ruptures and the particular readiness of some large faults.

One particularly ready fault is the Southern San Andreas, which contributes to its continued status of being the most likely to host a large earthquake. Specifically, it has a 19 percent chance of having one or more events larger than magnitude 6.7 in the next 30 years near Mojave, Calif. The comparably low values for the Northern San Andreas, such as 6.4 percent near San Francisco, are partly because of the relatively recent 1906 earthquake on that fault. In fact, probabilities on two other Bay Area faults, the Hayward–Rodgers Creek and the Calaveras, currently rival or exceed those on the Northern San Andreas, in part because they are both relatively ready.

Compared to the previous model, UCERF2, the San Jacinto fault has a three-fold decrease in the likelihood of magnitude 6.7 or larger earthquakes. Much of this decrease is because of the inclusion of more multifault ruptures, as indicated by the factor of 57 increase in the likelihood of magnitude 8 and larger earthquakes. In other words, the fault has traded some moderate-sized events for rare larger ones.

The Calveras fault, on the other hand, has a three-fold increase in the likelihood of magnitude 6.7 or larger earthquakes. In UCERF2 most Calaveras events were well below magnitude 6.7, so the inclusion of multifault ruptures in UCERF3 has increased the frequency of earthquakes above magnitude 6.7.

We have only touched on a few of the more important changes between UCERF2 and UCERF3, and have highlighted only some of the influential factors. Many more are currently understood, and scientists will be further analyzing results and testing assumptions for years to come.

So what do these changes imply with respect to seismic hazard, the likelihood of ground shaking, as well as for seismic risk, the threat to the built environment with respect to fatalities and economic losses? The answer turns out to be entirely dependent on what you are concerned about. For example, increasing the likelihood of large multifault earthquakes, which consequently reduces the likelihood of moderate-sized events, may increase the risk to tall buildings or large bridges, but actually lower the risk to residential homes.

As a consequence, it is difficult to make generalizations about the hazard or risk implications of UCERF3 without first specifying both asset types and their locations. Conclusions will vary depending on whether you are designing a single family dwelling in Sacramento, retrofitting the San Francisco–Oakland Bay Bridge, considering the location of a nuclear power plant, laying pipeline across the San Andreas Fault, or considering aggregate losses over a large insurance portfolio. The practical implications will need to be considered on a case-by-case basis.

What Next?

UCERF3 can now be used to evaluate seismic hazard and risk in California. In fact, it has already been used for the 2014 update of the U.S. Geological Survey National Seismic Hazard Maps (http://earthquake.usgs.gov/hazards/), which in turn are used in building codes. The California Earthquake Authority, which is required by law to use the best available science, will use UCERF3 to evaluate insurance premiums charged to customers, as well as their own level of reinsurance. UCERF3 will be used in many other risk mitigation

Tabulated values represent the likelihood of having one or more earthquakes in the next 30 years (starting from 2014).

[At the points on the fault indicated by white circles. M≥6.7 means magnitude greater than or equal to 6.7, and likewise for the other two magnitude thresholds. %, percent. Values listed in parentheses indicate the factor by which the likelihoods have increased, or decreased, relative to the previous model (UCERF2), where "--" means the previous value was zero. "Readiness" indicates the factor by which probabilities are currently elevated, or lower, because of the length of time since the previous large earthquake]

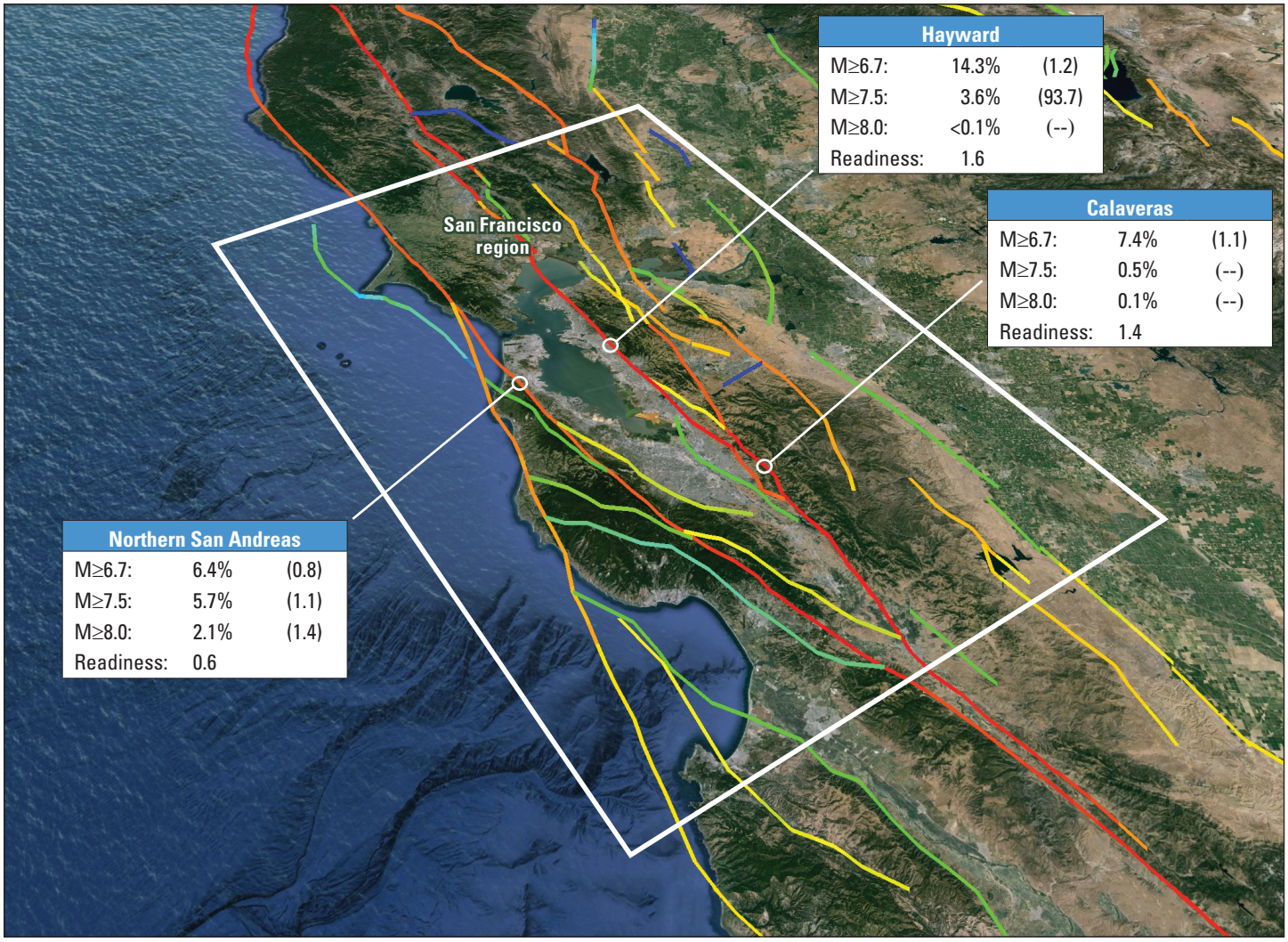


Figure 4. Likelihood of magnitude 6.7 or greater earthquakes in the next 30 years, from 2014, on the faults near San Francisco, Calif.

efforts in the years to come, including engineering design of buildings and lifelines, loss estimation for catastrophic bonds and other risk-linked securities, and emergency preparedness, all of which have the ultimate goal of increasing public safety and community resilience.

UCERF3 should also serve as a reminder that California is earthquake country, and residents should always be prepared. Simple safeguards include practicing "drop, cover, and hold on," securing items in your home and workplace that could fall during an earthquake, and storing seven-days worth of food and water. Homeowners can also consider structural retrofits, such as bolting the house to its foundation, as well as earthquake insurance options. For further guidance on how to prepare for, survive, and recover after big earthquakes, follow the Seven Steps to Earthquake Safety (http://www.earthquakecountry.org/sevensteps).

Although UCERF3 is a clear improvement over the previous model (UCERF2), it is still an approximation of the natural system. For example, it does not model the earthquake-triggering process that produces aftershocks, even though we know such events can be large and damaging. Through the National Earthquake Hazard Reduction Program (http://www.nehrp.gov), the U.S. Geological Survey and its partners will continue to conduct research aimed at improving our understanding of fault behavior and estimates of earthquake hazard in the future.

Tabulated values represent the likelihood of having one or more earthquakes in the next 30 years (starting from 2014).

[At the points on the fault indicated by white circles. M≥6.7 means magnitude greater than or equal to 6.7, and likewise for the other two magnitude thresholds. %, percent. Values listed in parentheses indicate the factor by which the likelihoods have increased, or decreased, relative to the previous model (UCERF2), where "--" means the previous value was zero. "Readiness" indicates the factor by which probabilities are currently elevated, or lower, because of the length of time since the previous large earthquake]

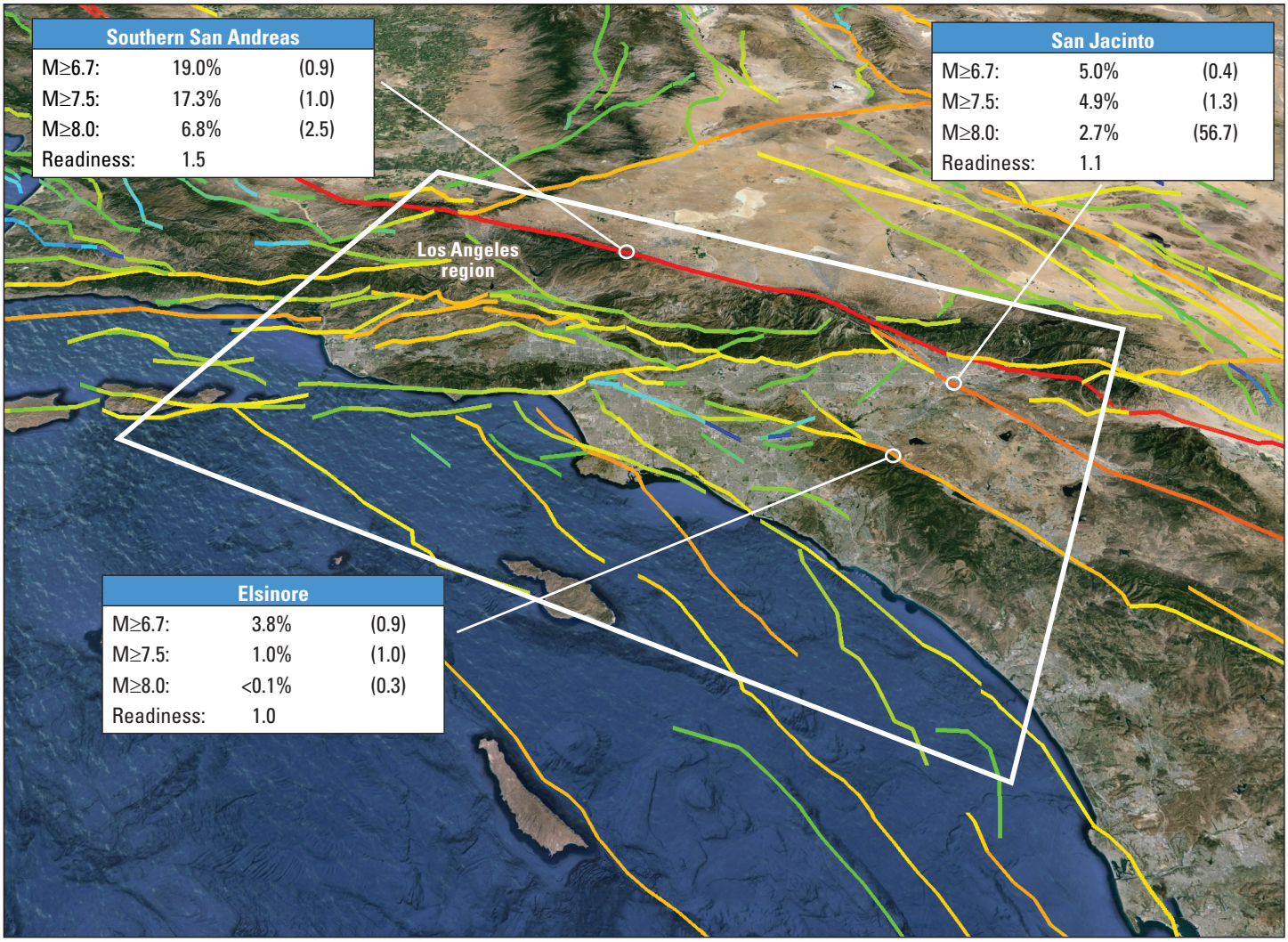


Figure 5. Likelihood of magnitude 6.7 or greater earthquakes in the next 30 years, from 2014, on the faults near Los Angeles, Calif.

References

Korzybski, A. 1931, A non-Aristotelian System and its necessity for rigour in mathematics and physics: presention at the American Mathematical Society, December 28, 1931, New Orleans, Louisiana, meeting of the American Association for the Advancement of Science. Reprinted in Science and Sanity, 1933, p. 747–61.

Reid, H.F., 1911, The elastic-rebound theory of earthquakes: University of California Publications, Bulletin of the Department of Geological Sciences v. 6, p. 413–444.

Working Group on California Earthquake Probabilities, 2007, Published as: Field, E.H., Dawson, T.E., Felzer, K.R., Frankel, A.D., Gupta, V., Jordan, T.H., Parsons, T., Petersen, M.D., Stein, R.S. Weldon, II, R.J., and Wills, C.J., 2009, Uniform California earthquake rupture forecast, Version 2 (UCERF 2): Bulletin of the Seismological Society of America, v. 99, p. 2053–2107, doi:10.1785/0120080049.

Working Group on California Earthquake Probabilities, in press, Published as: Field, E.H., Biasi, G.P., Bird, P., Dawson, T.E., Felzer, K.R. Jackson, D.D., Johnson, K.M., Jordan, T.H., Madden, C. Michael, A.J., Milner, K.R., Page, M.T., Parsons, T., Powers, P.M., Shaw, B.E., Thatcher, W.R., Weldon, R.J. II, , and Zeng, Y., 2015, Long-term, time-dependent probabilities for the third uniform California earthquake rupture forecast (UCERF3), Bulletin of the Seismological Society of America.

—*Authors: Edward H. Field and members of the 2014 WGCEP*

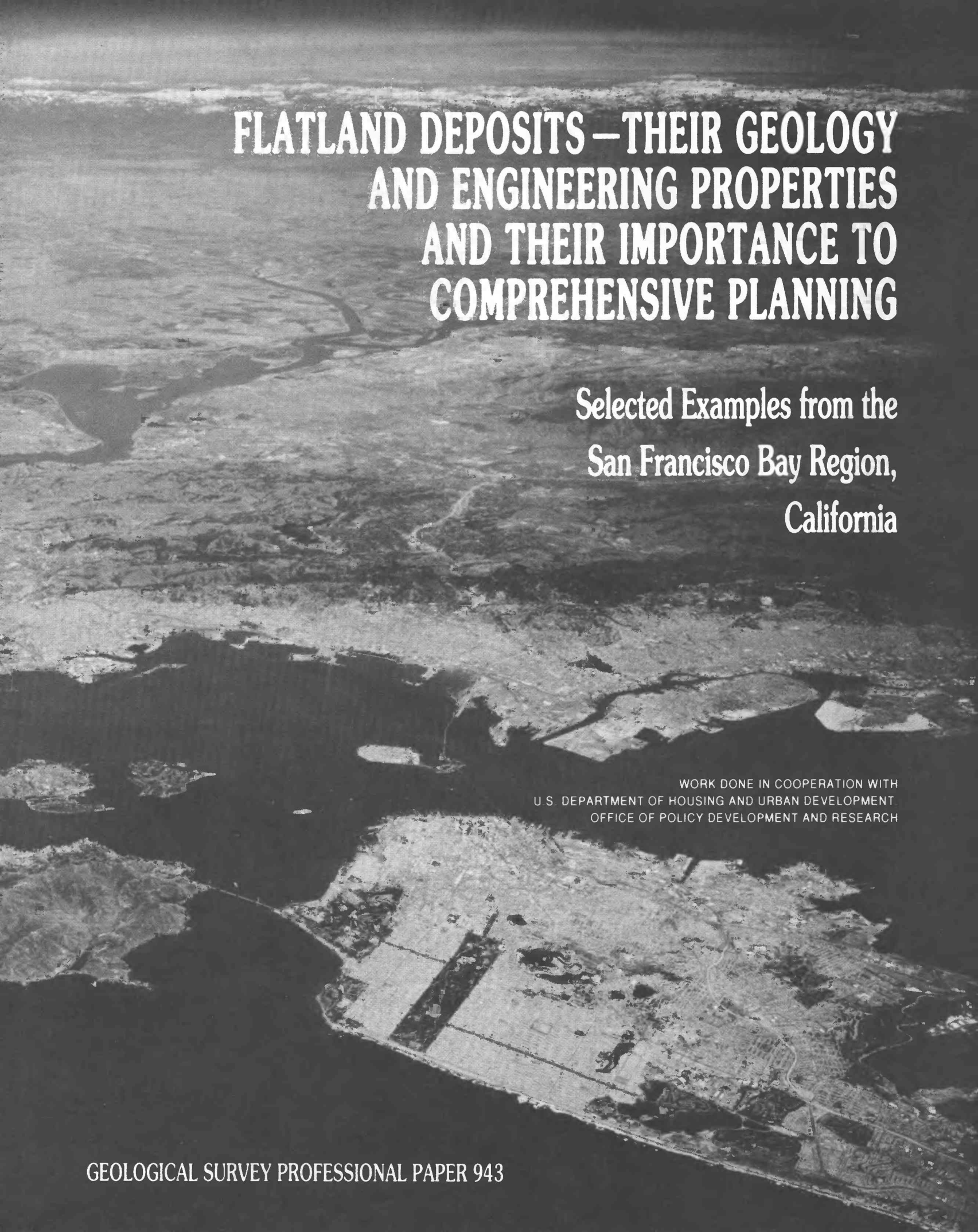
Cooperating organizations:
Southern California Earthquake Center (SCEC)
California Geological Survey (CGS)
California Earthquake Authority
U.S. Geological Survey

Additional Resources:

For general earthquake information contact:
1-888-ASK-USGS (1-888-275-8747)
http://earthquake.usgs.gov/
http://ask.usgs.gov
or
SCEC Education and Outreach: 213-740-3262

For UCERF3 information see:
http://www.WGCEP.org/UCERF3

For technical questions contact:
Edward (Ned) Field: field@usgs.gov



FLATLAND DEPOSITS—THEIR GEOLOGY AND ENGINEERING PROPERTIES AND THEIR IMPORTANCE TO COMPREHENSIVE PLANNING

Selected Examples from the San Francisco Bay Region, California

WORK DONE IN COOPERATION WITH
U.S. DEPARTMENT OF HOUSING AND URBAN DEVELOPMENT
OFFICE OF POLICY DEVELOPMENT AND RESEARCH

GEOLOGICAL SURVEY PROFESSIONAL PAPER 943

Flatland deposits of the San Francisco Bay Region, California—their geology and engineering properties, and their importance to comprehensive planning

By E. J. HELLEY *and* K. R. LAJOIE
U.S. GEOLOGICAL SURVEY, *and* W. E. SPANGLE *and* M. L. BLAIR,
WILLIAM SPANGLE & ASSOCIATES

GEOLOGICAL SURVEY PROFESSIONAL PAPER 943

Jointly supported by the U.S. Geological Survey and the Department of Housing and Urban Development, Office of Policy Development and Research, as a part of a program to develop and apply earth-science information in support of land-use planning and decisionmaking

A series of closely related earth-science studies that define the nature and severity of earthquake hazards associated with geologic conditions

UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 1979

UNITED STATES DEPARTMENT OF THE INTERIOR

MANUEL LUJAN, JR., *Secretary*

GEOLOGICAL SURVEY

Dallas L. Peck, *Director*

First printing 1979
Second printing 1980
Third printing 1991

Library of Congress Catalog in Publication Data

Main entry under title:
Flatland deposits of the San Francisco Bay region, California.
(Geological Survey Professional Paper 943)
Bibliography: p. 86-88.
CONTENTS: Helley, E. J. and Lajoie, K. R. Their geology and engineering properties.—Spangle, W. E. and Blair, M. L. Their importance to comprehensive planning.
Supt. of Docs. no.: I 19:16
1. Sediments (Geology)–California–San Francisco Bay region. 2. Natural disasters–California San Francisco Bay region. I. Helley, Edward J. 11. Series: United States. Geological Survey. Professional Paper 943.
QE471.2.F56 551.3'04'097946 77-608184

For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402

Stock Number 024-001-03170-1

FOREWORD

This report is a product of the San Francisco Bay Region Environment and Resources Planning Study, an experimental program designed to facilitate the use of earth-science information in regional planning and decisionmaking. The study is jointly supported by the U.S. Geological Survey, Department of the Interior, and the Office of Policy Development and Research, Department of Housing and Urban Development. The Association of Bay Area Governments participates in the study and provides a liaison and communication link with other regional planning agencies and with county and local governments.

Although the study focuses on the nine-county, 7,400-square-mile (19,000-square-kilometers) San Francisco Bay region, it bears on an issue that is of national concern. This issue—how best to accommodate orderly development and growth while conserving our natural resource base, insuring public health and safety, and minimizing degradation of our natural and man-made environment—is difficult and complex. The complexity, however, can be greatly reduced if we understand the natural characteristics of the land, the processes that shape it, its resource potential, and its natural hazards. These subjects are chiefly within the domain of the earth sciences: geology, geophysics, hydrology, and the soil sciences. Appropriate earth-science information, if available, can be rationally applied in guiding growth and development, but the existence of the information does not assure its effective use in the day-to-day decisions that shape development. Planners, elected officials, and the public rarely have the training or experience needed to recognize the significance of basic earth-science information, and many of the conventional methods of communicating earth-science information are ill suited to their needs.

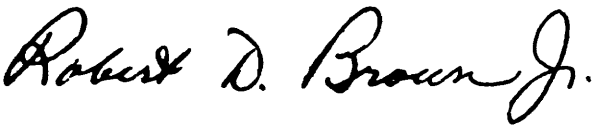
It is hoped that the study will aid the planning and decisionmaking community by (1) identifying important problems that are rooted in the earth sciences and related to growth and development in the bay region; (2) providing the earth-science information that is needed to solve these problems; (3) interpreting and publishing findings in forms understandable to and usable by nonscientists; (4) establishing new avenues of communication between scientists and users, and (5) exploring alternate ways of applying earth-science information in planning and decisionmaking.

Since the study was started in 1970, it has produced more than 100 reports and maps. These cover a wide range of topics: reduction of flood and earthquake hazards, unstable slopes, engineering characteristics of hillside and lowland areas, mineral and water resources management, disposal of solid and liquid waste, erosion and sedimentation problems, bay-water circulation patterns, and others. The methods used in the study and the results it has produced have elicited broad interest, and a wide range of applications, from planners, government officials, industry, universities, and the general public.

This report on flatland deposits and their land-use significance examines the low-lying areas of the San Francisco Bay region where urban centers are numerous and the population is dense. These areas of low relief are also likely to be favored sites for future growth, for they are easily reached by existing roads and railroads, and their relatively level surface is adapted to a variety of intensive uses of the land. But the lowlands are not

uniform. They include valley floors and terraces, plains, low alluvial slopes, marshlands, and marine terraces. These landforms result from a number of different geologic processes, they are underlain by deposits with different physical and chemical properties, and they respond differently to the impact of use.

This report evaluates the different flatland deposits, both in terms of their natural properties and in terms of the geologic processes that they record. It also discusses how earth-science knowledge of the deposits and the processes that formed them may be incorporated into planning for better use of the land. These two closely related topics are addressed in separate sections of the report. The first section identifies the different kinds of deposits that underlie flatlands of the bay region, describes their properties and the processes that formed them, and demonstrates how this knowledge can be used to predict the consequences of changing land use. The second section of the report shows how planners and decisionmakers working within the conventional framework of comprehensive planning can use interpreted earth-science information to assess alternative uses of land.



R. D. Brown, Jr.
Project Director
San Francisco Bay Region Study

CONTENTS

Page

Foreword ---------- III
Definitions of terms ---------- VII
Abstract ---------- 1
Introduction by William E. Spangle, Martha L. Blair, Edward J. Helley, and Kenneth R. Lajoie ---------- 1
Problems and purposes ---------- 1
Planning and decisionmaking ---------- 3
Agencies for regional land-use planning ---------- 4
Comprehensive planning agencies ---------- 5
Functional planning agencies ---------- 5
Agencies with permit authority ---------- 6
Regulatory agencies ---------- 6
Single-purpose planning and operating districts 6
Intergovernmental relations ---------- 7
Regional setting ---------- 7
Geographic setting ---------- 7
Climate ---------- 7
Drainage ---------- 12
Geology and engineering properties of the flatland deposits by Edward J. Helley and Kenneth R. Lajoie ---------- 14
Geologic history ---------- 14
Geologic map of flatland areas ---------- 20
Holocene deposits (10,000 years old) ---------- 21
Bay mud ---------- 21
Beach and dune sand deposits ---------- 22
Alluvium ---------- 22
Pleistocene deposits (10,000-1.8 million years old) ---------- 24
Alluvium ---------- 24
Marine terrace deposits ---------- 25
Geologic mapping techniques ---------- 27
Physical properties of geologic units ---------- 31
Seismic properties ---------- 33
Potential problems in flatlands regions ---------- 33
Water-related problems ---------- 33
Flooding ---------- 39
Stream channel changes ---------- 42
Salt-water intrusion ---------- 42
Subsidence ---------- 45

Page

Geology and engineering properties of the flatland deposits—Continued
Potential problems in flatlands regions—Continued
Water-related problems—Continued
Settlement ---------- 49
Shrink-swell ---------- 50
Seismic hazards ---------- 51
Seismic response ---------- 51
Seismic amplification ---------- 52
Liquefaction potential ---------- 53
Resources and potentials ---------- 61
Water resources ---------- 61
Soil ---------- 62
Mineral resources ---------- 63
Sand and gravel ---------- 64
Clay ---------- 65
Salines ---------- 68
Shell ---------- 68
Peat ---------- 68
Importance of flatland geology to comprehensive planning by William E. Spangle and Martha L. Blair ---------- 68
Description of land-capability studies ---------- 69
Importance of flatland deposits in regional studies ---------- 71
Applying information on flatland deposits ---------- 72
Defining the focus of the study ---------- 72
Determining the natural characteristics affecting land capability ---------- 72
Gathering, analyzing, and presenting the information ---------- 73
Evaluating relative capability of land units ---------- 74
Use of land-capability studies ---------- 74
Planning response to flatland issues ---------- 76
Planning for the baylands ---------- 76
The urban-agricultural conflict ---------- 81
Planning for hazardous areas ---------- 81
Seismic hazards—a special problem ---------- 82
Santa Clara County bayland study ---------- 82
Summary ---------- 85
References cited ---------- 86

ILLUSTRATIONS

[Plates are in pocket]

PLATES 1-3. Geologic maps of the flatland deposits of the San Francisco Bay region.
1. Northwestern part.
2. Northeastern part.
3. Southern part.

Page

FIGURE 1. Map showing the nine counties in the San Francisco Bay region ---------- 2
2. Maps of San Francisco Bay region showing developed areas and flat lowland areas ---------- 3
3. Diagram of the land-use planning process ---------- 4
4. Map of California showing physiographic provinces and location of San Francisco Bay region ---------- 8

Page

FIGURE 5. Map of San Francisco Bay region showing the mountainous uplands, the flat alluviated lowlands, and the bay and its marshes ---- 9
6. Diagram showing annual temperature and precipitation variations in San Francisco ---- 10
7. Map showing precipitation in the San Francisco Bay region ---- 11
8. Map showing area of interior California that drains through San Francisco Bay ---- 13
9. Map of San Francisco Bay region showing major drainage divides and basins ---- 14
10. Diagram showing geologic time in perspective ---- 16
11. Generalized geologic map of San Francisco Bay region ---- 17
12. Map showing shorelines of San Francisco Bay and Pacific Ocean during Holocene transgression ---- 19
13. Diagram of Holocene processes along the bay plains ---- 20
14. Diagram showing erosional and depositional features along the coast ---- 21
15. Topographic map of Palo Alto area showing geomorphic features of alluvial plain ---- 28
16. Map showing soil units in Palo Alto area ---- 30
17. Map showing younger and older alluvium in Palo Alto area ---- 32
18. Map showing rock units in the Palo Alto area ---- 34
19. Block diagram showing facies relations in younger alluvial deposits ---- 35
20. Diagram of highway test-boring log ---- 36
21. Diagram showing ranges in dry density of geologic units ---- 37
22. Diagram showing ranges in natural moisture content of geologic units ---- 37
23. Diagram showing ranges in permeability of geologic units ---- 38
24. Diagram showing penetration resistance of geologic units ---- 38
25. Stratigraphic column showing geologic units and graphs showing P- and S-wave velocities as a function of depth at Ravenswood Point, San Mateo County ---- 39
26. Block diagram showing stratigraphic relations and seismic velocities near the margin of San Francisco Bay ---- 40
27. Block diagram showing potential water problems in the alluvial plain bordering San Francisco Bay ---- 41
28. Map showing flood-prone areas in the San Francisco Bay basin ---- 42
29. Diagram showing four ways that salt-water intrusion can occur ---- 43
30. Map showing areas of salt-water intrusion in the bay region ---- 44
31. Map showing areas of subsidence due to ground-water withdrawal, peat oxidation, and gas extraction ---- 46
32. Map showing subsidence in Santa Clara Valley from 1934 to 1967 ---- 47
33. Graph showing amount of subsidence of bench mark BMP7 due to lowering of water level in San Jose ---- 48
34. Graph showing amount of subsidence in delta area owing to oxidation of peat ---- 49
35. Diagrammatic sections showing examples of settlement ---- 50
36. Map showing settlement of the land surface on San Francisco waterfront ---- 51
37. Photograph of house in San Francisco showing settlement ---- 52
38. Photograph of desiccation cracks in clay-rich sediments ---- 53
39. Block diagram showing potential seismic hazards on the alluvial plain bordering San Francisco Bay ---- 54
40. Diagram illustrating seismic amplification in bedrock alluvium, and bay mud from nuclear test blast data ---- 55
41. Seismograms showing seismic amplification data from Ravenswood site ---- 55
42. Schematic cross section of southwestern San Francisco Bay and tabular description of physical properties of the units ---- 56
43. Map showing estimated relative intensities of ground shaking in the south San Francisco Bay region from earthquakes on the San Andreas and Hayward faults ---- 57
44. Simplified geologic map of Dunedin, New Zealand ---- 58
45. Map showing density of damage claims resulting from the February 1974 earthquake, Dunedin, New Zealand ---- 59
46. Map showing liquefaction potential, southern San Francisco Bay region ---- 60
47. Map showing high- and low-infiltration areas, San Francisco Bay region ---- 63
48. Map showing areas of high potential for ground water recharge, southern Santa Clara County ---- 64
49. Photograph showing soil capability classes ---- 65
50. Diagram showing distribution of water and soil resources in the flatland deposits ---- 66
51. Map of bay region showing mineral resources in flatland areas ---- 67
52. Map of part of bay region showing areas with high, moderate, and low capability of urban residential development ---- 75
53. Map showing reduction in area of natural tidal marsh around San Francisco Bay between 1850 and 1975 ---- 78
54. Map showing risk zones for land-use planning, Santa Clara County Baylands ---- 84

TABLES

Page

TABLE 1. Factors and conditions controlling liquefaction-induced ground failure ---- 33
2. Summary of liquefaction-potential analysis using standard penetration data ---- 61
3. Factors and conditions controlling liquefaction ---- 61
4. Factors affecting porosity and permeability of sedimentary deposits ---- 62

Page

TABLE 5. Characteristics of flatland materials affecting capability for urban residential development ---- 72
6. Capability weighting and scoring system for urban residential development---- 73
7. Capability rating of geologic units for urban residential development ---- 74
8. Capability rating of geologic units for selected uses ---- 76
9. Regional planning implications of capability rating for urban residential development ---- 77
10. Projected losses due to geologic problems in California, 1970–2000---- 82
11. A scale of acceptable risks---- 83
12. Risk zones for settlement and ground failure---- 83
13. Land and building uses for various risk zones ---- 85

DEFINITION OF TERMS

For the convenience of readers unfamiliar with some of the geologic terms used in this report, the following glossary has been prepared. We hope it will save a number of trips to the dictionary and make the text easier to understand.

Alluviation. The process of building up of sediments by a stream at places where stream velocity is decreased. The coarsest particles are the first to settle and the finest muds the last.

Anticyclone. An atmospheric high-pressure system in which the wind blows spirally outward in a clockwise direction in the Northern Hemisphere.

Aquiclude. A relatively imprevious rock layer that forms the upper or lower boundary of an aquifer but does not transmit enough water to supply wells or springs.

Aquifer. A permeable layer of rock that contains enough ground water to yield significant quantities of water to wells and springs.

Berm. A low bench or narrow terrace on the back shore of a beach formed of material thrown up by storm waves.

Colluvium. Any loose mass of soil or rock fragments that moves downslope largely by the force of gravity. Usually it is thicker at the base of the slope.

Diatom. A microscopic single-celled plant that secretes siliceous cell walls in a great variety of forms.

Eolian. Deposits laid down by the wind, landforms eroded by the wind, or structures such as ripple marks made by the wind.

Facies. A rock unit distinguished from others by appearance or composition as a result of environment of deposition.

Geomorphic. Pertaining to the form of the surface features of the earth. Specifically, geomorphology is the analysis of landforms and their mode of origin.

Holocene. The most recent epoch of geologic time, extending from 10,000 years ago to the present time.

Indurated. Rock or soil compacted by pressure, cementation, and heat.

Interfluvial. The land lying between streams.

Isohyet. A line connecting points of equal precipitation.

Isoseismal line. A line connecting points on the Earth's surface at which earthquake intensity is the same.

Lithified. The consolidation of a loose sediment into a solid rock.

Lithostatic load. The vertical load at a point in the Earth's crust equal to the load that would be exerted by a column of the overlying rock or soil.

Littoral drift. Material (such as sand, gravel, and shell fragments) that is moved along the coast by an ocean current.

Plate tectonics. An Earth model in which a small number (10–25) of large, broad, thick plates of the Earth's surface believed to "float" on an underlayer and move more or less independently, grinding against each other like ice floes in a river. The plates are propelled from the rear by sea-floor spreading. The continents form part of the plates and move with them like blocks of wood in an ice floe.

Pleistocene. An epoch of geologic time extending from 10,000 years ago to 1.8 million years ago; it includes the last Ice Age.

Pliocene. The epoch of geologic time before the Pleistocene. Its age covers the span of 1.8 to 7 million years ago.

Pore pressures. The pressure exerted by the fluid that fills the pore spaces between the particles in a rock layer.

P wave. A type of earthquake wave that moves by alternating compression and expansion of material in the direction of movement. The P stands for primary because it is the fastest of the earthquake waves and so arrives before the secondary or S wave.

Quaternary. A period of geologic time thought to cover the past 1.8 million years. It consists of two epochs—the Pleistocene and Holocene.

Radiometric age. An age determined by measuring the disintegration rate of radioactive elements. The age may be calculated by measuring a short-life element like carbon-14, or a long-life element plus its decay product such as potassium-40/argon-40.

Sea-floor spreading. A theory that the oceanic crust is forming by upwelling and cooling of lava along the mid-oceanic ridges and is moving away from the ridges at the rate of 1–10 centimeters per year. This movement is thought to provide the source of power for the movement of large "plates" of the Earth's crust. (See "plate tectonics.")

Seismic impedance (acoustic impedance). The product of seismic S-wave velocity and bulk density.

Seismic velocity. The rate of propagation of an elastic wave. The velocity depends upon the type of wave and the elastic properties and density of the Earth material through which it travels.

Shear wave, S wave. A type of earthquake wave that moves by a shearing of material, so that there is movement perpendicular to the direction of propagation. S stands for secondary because it travels slower than the P or primary body waves.

Soil horizon. A layer of soil distinguished from adjacent layers by such characteristics as structure, color, texture, or chemical composition. Soil horizons are generally designated by capital letters, for example, A horizon or B horizon.

Soil profile. A vertical section of a soil that shows all its layers and the material from which it was derived.

Subduction. The process of one crustal block moving beneath another—by folding, faulting, or both.

Tectonics. A study of the origin, relations, and evolution of structural features of the Earth's crust, such as folding and faulting of the rocks.

Tsunami. A sea wave produced by any large-scale, short-duration disturbance of the ocean floor, principally by a shallow submarine earthquake. Tsunamis are characterized by great speed and may cause considerable damage along an exposed coast thousand of miles from the source.

FLATLAND DEPOSITS OF THE SAN FRANCISCO BAY REGION, CALIFORNIA— THEIR GEOLOGY AND ENGINEERING PROPERTIES, AND THEIR IMPORTANCE TO COMPREHENSIVE PLANNING

By E. J. HELLEY and K. R. LAJOIE

ABSTRACT

Geologic maps of the deposits underlying the flatlands (slope less than 15 percent) of the San Francisco Bay region provide urban and regional planners and decisionmakers with earth-science information regarding geologic hazards and resources. The flatlands are particularly suitable for development because the low relief permits simple, relatively low cost construction, but parts of the flatlands possess unusual geologic characteristics that must be taken into account if development and the use of resources are to be effectively managed.

To examine the flatland characteristics systematically, 13 geologic units are mapped in the area surrounding San Francisco Bay, in the outlying valleys, and in the coastal zone. The geologic units are studied and mapped by unconventional methods. These include the use of 19th-century maps and coastal charts, and pre-1940 aerial photography; studies of environments of deposition, soil, and stratigraphy; and age determinations from radiometric methods, paleontology, and archaeology. Among the geologic units that can be recognized and mapped are the estuarine (bay) muds and marsh deposits; and alluvial-fan, channel, flood-basin, levee, dune, and beach deposits. The 13 geologic units shown on the map that accompanies the report range in age from oldest Pleistocene (1.8 million years) to deposits that are still forming today.

The engineering properties of these units are determined by analyzing unpublished reports by private consultants, the geologic and engineering literature, bore-hole logs for highway and bridge construction, and U.S. Geological Survey field studies. The engineering properties are shown to be systematically related to the age of the geologic units. These properties include bulk density, moisture content, penetration resistance, seismic wave velocities, and liquefaction potential. The depositional processes and age of each unit give a basis for predicting potential geologic hazards as well as natural resources. Most potential hazards are related to water or to earthquakes. Water-related hazards include flooding, rapid channel changes, salt-water intrusion, subsidence, ground settlement, and shrinking and swelling. Seismic hazards include ground-motion amplification and liquefaction with possible ground failure. The young estuarine muds and flood-basin deposits are most susceptible to seismic hazards.

Natural resources are also evaluated for each unit. The agricultural potential of the soils is probably most important because this vital resource is generally lost forever after urbanization. The flatlands are also a source for sand and gravel, clay, peat, shells, and salts.

The hazards and resource potential are identified for each unit so that regional planners will have sound information on which to base their decisions regarding land use.

How this information can be evaluated and applied is shown in a hypothetical land-capability study. Each geologic unit is rated for relative capability for agriculture, urban residential development, ground-water recharge, and sand and gravel extraction. The study shows that bay mud has low capability for all uses considered, that relatively few units have high capability for agriculture or ground-water recharge, and that most units have high or moderate capability for urban residential development. The ratings bring into focus potential land-use conflicts that require resolution through evaluating economic, political, social, and other environmental information. Land-capability studies can assure that natural factors are given full consideration in the planning process and direct attention to areas and problems needing further investigation before land-development decisions are made.

Three examples of planning response to particular flatland potential problems are (1) the policies and permit procedures of the San Francisco Bay Conservation and Development Commission under which development proposals for construction on fill over bay mud are reviewed by a board including earth-science and engineering professionals, (2) policies and project-review criteria of the Association of Bay Area Governments emphasizing the regional importance of prime agricultural land, and (3) the geologic and soils report requirements of Santa Clara County, which are related to mapped risk zones in the baylands. These examples show how geologic studies can be effectively used in land-use planning to foster safe, economical, and environmentally sound land-use decisions.

INTRODUCTION

By William E. Spangle, Martha L. Blair, Edward J. Helley and Kenneth R. Lajoie

PROBLEMS AND PURPOSES

The San Francisco Bay region consists of the nine counties surrounding San Francisco Bay (fig. 1)—the largest estuary on the California coast. The area is characterized by diversity in topography, natural resources, and climate. It is richly endowed with outstanding scenic and recreational resources; a mild climate; large open-space areas; large areas of flat, easily developed land; fertile soils; good water supplies; extensive inland waterways; and fine harbors. These favorable natural features have attracted a large population which has produced a vigorous and diversified social and economic system. The area is one of the most attractive urban-suburban complexes in the United States.

FIGURE 1.—The nine counties in the San Francisco Bay Region.

The region, however, is not without its environmental problems. Many natural constraints to land use in the bay region were ignored or were not recognized in the period of rapid population growth since World War II. As a result, valuable and irreplaceable natural resources such as prime agricultural land were destroyed, houses and public facilities were built on landslides and active faults, overdraft of ground-water aquifers caused severe subsidence in some areas, and development took place on active flood plains. Recognition in the late 1960's that many of these problems relate to geologic factors led to the formation of the San Francisco Bay Region Study jointly funded by the U.S. Geological Survey and the Department of Housing and Urban Development. This study was designed to provide some of the basic geologic data needed to develop guidelines for the use of the land and natural resources of the San Francisco Bay region.

Most of the residential, agricultural, industrial, and commercial development in the bay region is in the nearly flat lowland areas surrounding the bay and extending into the outlying mountainous areas as narrow valleys (fig. 2). In effect, these flat low-

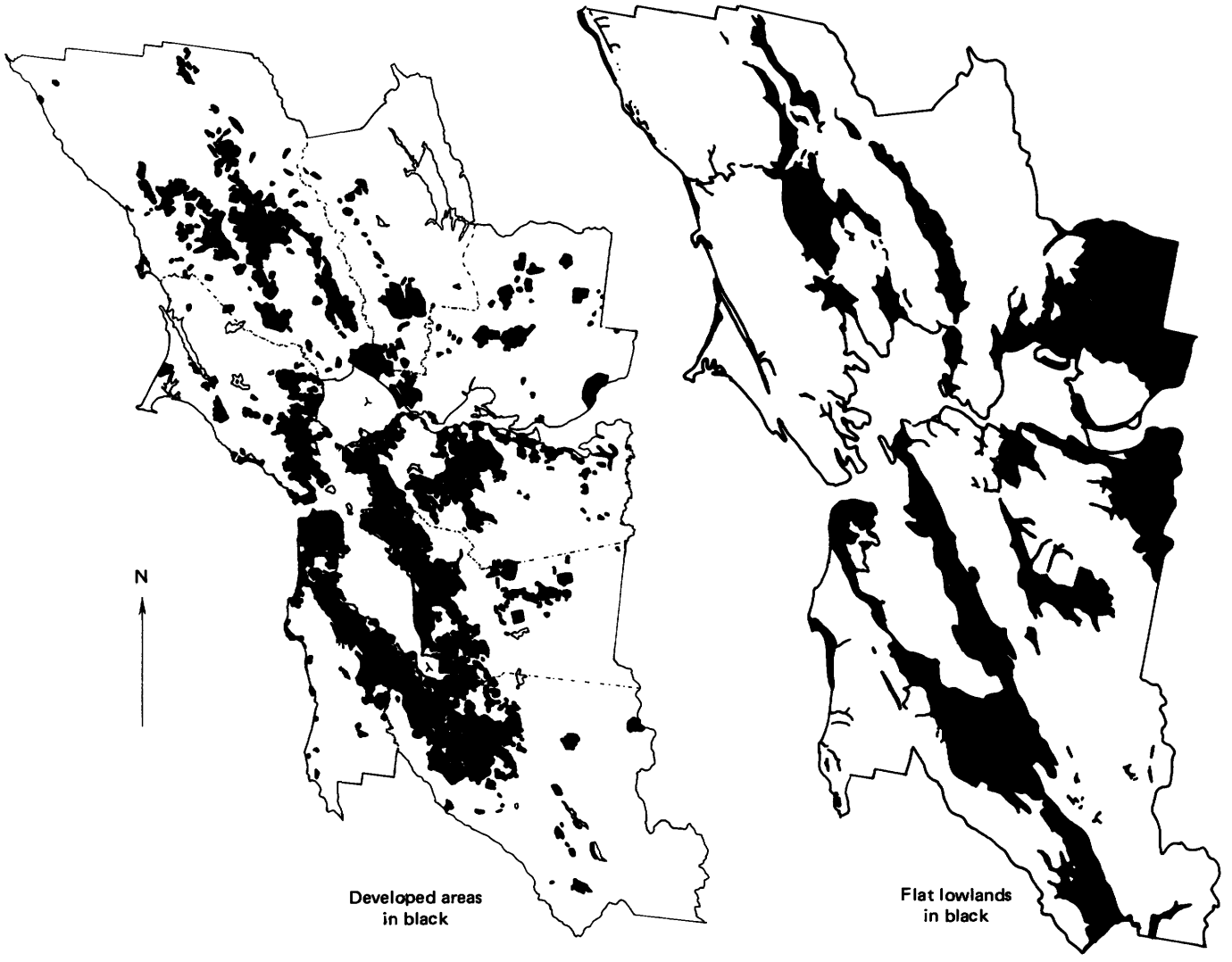


FIGURE 2.—The developed areas and flat lowland areas in the San Francisco Bay region. Developed areas consist of low-, medium-, and high-density residential, commercial, industrial, military, and transportation facilities as of 1965. Data from Association of Bay Area Governments, 1966.

lands are themselves an important natural resource of the bay region. Most future urban development can be expected to occur in these flatlands. The purpose of this report is twofold: (1) to identify the geologic units and processes of these lowland areas, placing particular emphasis on the opportunities and constraints associated with the deposits that underlie these areas, and (2) to show how information concerning the natural characteristics of flatland areas can be used in regional planning to influence future land-use decisions.

PLANNING AND DECISIONMAKING

The information needed in regional planning and the extent to which it can affect decisions depend on the nature of the planning and decisionmaking process, the powers and objectives of the agencies involved in planning, and the natural features and processes of the planning area. These aspects of the San Francisco Bay region provide the basis for the interpretation and application of geologic information in regional planning.

Planning is the process of devising and carrying out a course of action to reach an identified objective. As an organized governmental activity, planning seeks to improve the decisions of public bodies and administrators. Comprehensive planning treats the long-term development of an area considering all major determinants of growth and change—economic, political, social, and physical.

A land-use plan is a key component of a comprehensive plan providing a link between more general goals and policies and the pattern of land develop-

ment. A land-use plan includes objectives, policies, and proposals for the type, pattern, and intensity of land use. A functional plan describes needed facilities and operations for a specific function of government such as transportation, water development, flood control, or emergency response; it is more specific than a comprehensive plan and usually has a shorter range. Any plan, when adopted by the governing body of an agency, is official public policy. This report is primarily concerned with land-use planning and decisionmaking carried out by regional agencies.

The process of developing comprehensive, land-use, and functional plans generally consists of six steps: identifying problems and defining goals and objectives, collecting and interpreting data, formulating plans, evaluating impacts, reviewing and adopting plans, and implementing plans. These steps, shown in figure 3, are interrelated. Plan formulation often indicates the need for additional information, additional information may alter the concept of the objectives and problems, and plan implementation may reveal the need for more additional information or modification of the plan.

The steps in the planning process consitute a systematic approach to informed decisionmaking applicable to most governmental activities. The product of the process is a logical and internally consistent plan or set of plans and programs to guide public and private decisions. The planning process is ongoing, producing refinements, revisions, and new plans and implementing programs as additional information is obtained, new issues and problems raised, or changes in public attitudes recognized. Public participation is essential throughout the planning process. Success in implementing a plan depends on widespread public support, which can be gained only if all major segments of the public participate in the planning process.

Decisions occur throughout the process, ranging from the decision to engage in a planning effort to the final approval of a plan and adoption of implementing regulations, programs, and procedures. Elected public officials have final responsibility for most key policy decisions, although persons in nonelective positions actually make many important day-to-day decisions.

The process shown is generally applicable regardless of jurisdictional level, subject area, or size of planning area. However, the actual content of the plans varies widely depending on the responsibility, authority, and financial position of the planning agency; the diversity of the planning area; scope of the planning effort; and availability of data. For example, regional councils of governments (COGs) are likely to emphasize developing procedures and criteria for use in reviewing major projects and plans. This is beacause the COGs' primary power derives from federally mandated review processes. Local agencies are more likely to emphasize objectives, policies, and criteria to provide a basis for land-use and development regulation—traditionally a local responsibility.

AGENCIES FOR REGIONAL LAND-USE PLANNING

In the San Francisco Bay region, planning and decisionmaking authority at the regional level is

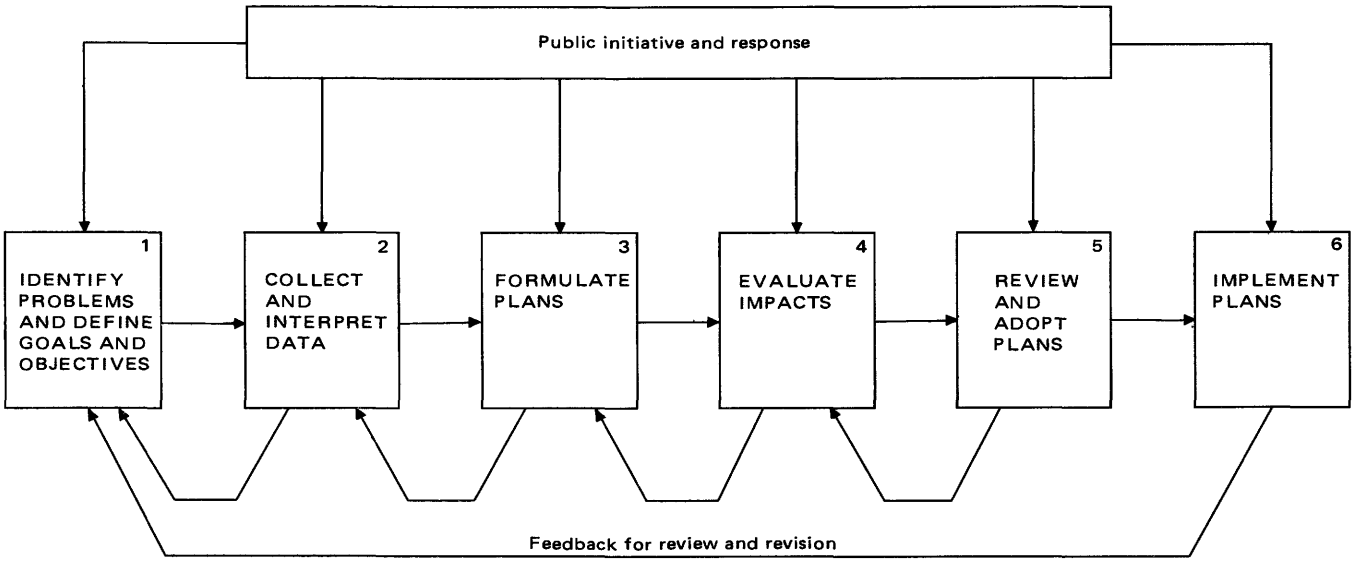


FIGURE 3.—The land-use planning process.

diffused among more than 20 agencies with different but sometimes overlaping responsibilities and jurisdictional boundaries. The agencies with duties or powers affecting land use fall into the following five basic categories:

- Comprehensive planning agencies.
- Functional planning agencies.
- Agencies with permit authority.
- Regulatory agencies.
- Single-purpose planning and operating districts.

COMPREHENSIVE PLANNING AGENCIES

The Association of Bay Area Governments (ABAG) is responsible for areawide comprehensive planning. Established in 1961 to develop plans and policies pertinent to regionwide problems, ABAG is a voluntary association of local governments. Present voting membership includes 7 counties and 85 cities out of a potential voting membership of 9 counties and 92 cities. However, all 9 counties are included within the ABAG planning area.

ABAG's adopted regional plan consists of the *Regional Plan 1970-1990* (1970), the *Regional Airport Systems Study Final Plan* (1972), *Regional Open Space Plan, Phase II* (1972), *Regional Ocean Coastline Plan* (1973), plus goals and policies adopted from time to time by the General Assembly or Executive Committee (Memorandum to staff from Revan A. F. Tranter, Executive Director, ABAG, November 11, 1974). An important aspect of ABAG's planning activity is developing procedures, standards, and criteria for identifying and reviewing regionally significant projects and plans. Geologic information is needed by ABAG to carry out all of its planning functions.

ABAG's primary power to implement its plans and policies derives from its designation by the Federal government as the areawide clearinghouse agency for the San Francisco Bay region. In this capacity, ABAG reviews local requests for Federal funds available from about 150 Federal programs, including among others local applications for Community Development Block Grants and Comprehensive Planning Assistance Grants authorized by the Housing and Community Development Act of 1974. As a clearinghouse agency, ABAG also reviews proposed Federal projects and federally required Environmental Impact Statements. ABAG's review is advisory. However, because the funding agency must explain in writing a decision to override a negative finding by ABAG and because many projects are usually competing for limited funds, ABAG's recommendations are usually heeded. ABAG may also review state-required Environmental Impact Reports and any project it deems to be regionally significant. In addition, ABAG can directly participate in planning programs with other public agencies through joint memoranda of agreement. As a voluntary association with advisory functions, ABAG's powers of plan implementation ultimately depend on its ability, through well-conceived plans, development and dissemination of information, and the art of persuasion, to influence the decisions of other public agencies—regional, Federal, State, and local.

FUNCTIONAL PLANNING AGENCIES

The Metropolitan Transportation Commission (MTC) and Bay Area Comprehensive Health Planning Council (BACHPC) have specific mandates to engage in areawide functional planning with respect to transportation, health facilities, and waste-water treatment, respectively. The planning and project-review responsibilities, and other duties these agencies may be authorized to perform, are normally coordinated with ABAG activities. Each agency reviews local plans and projects for conformance with its functional plan.

MTC was established to coordinate the development of regional transportation facilities. It is charged with preparing and adopting a Regional Transportation Plan including proposals for major highways, mass transit, transbay bridges, airports, and harbors. It must also develop a transportation improvement program and a financial program for carrying out the program. The adopted Regional Transportation Plan is to be the bay area component of a statewide transportation plan required by Assembly Bill 69 (1972) Metropolitan Transportation Commission, 1975.

MTC has stronger project review powers than the other functional agencies. MTC's approval is required for certain projects, including transbay bridges, public multi-county transit systems on exclusive rights of way, construction of State highways, and all applications from local governments or districts for State or Federal funds for any kind of transportation facility. In addition to reviewing projects, MTC administers, for the bay area, the public transit funds acquired from State and local sales taxes on gasoline. MTC needs geologic information in planning the location of transportation facilities and reviewing transportation proposals.

BACHPC is a voluntary federation of nine county health-planning councils. It is recognized by State

and Federal authorities as the agency to undertake and coordinate comprehensive health planning. The agency was organized to prepare a regional health plan to evaluate proposals for construction of new health facilities. BACHPC's primary power is the review of requests for Federal and State funds. The comments are advisory, but since requests for funds usually exceed funds available, the BACHPC review comments can be determining. BACHPC needs to consider geology, particularly seismic hazards, in locating and designing medical facilities.

AGENCIES WITH PERMIT AUTHORITY

The San Francisco Bay Conservation and Development Commission (BCDC) and the California Coastal Zone Conservation Commission (CCZCC) are the major agencies having permit authority. BCDC was created by the State Legislature to prepare a comprehensive plan for San Francisco Bay and its shores and to control development within its area of jurisdiction. The plan was adopted by the State Legislature, and BCDC became a permanent agency charged with carrying out the plan. The adopted plan has legal status and guides the review of projects. BCDC shares authority over land-use decisions with the cities and counties, which retain normal land-use and building-permit controls. However, with certain minor exceptions, a permit from BCDC is required for all projects within its area of jurisdiction. Thus, in effect, it holds veto power over any project proposal in conflict with the San Francisco Bay Plan. Geologic information was extensively used by BCDC in preparing its plan and is almost always needed for project review.

In 1972, California voters adopted, by initiative, legislation to create the California Coastal Zone Conservation Commission and subordinate regional commissions.

The CCZCC, working with six regional commissions, is charged with preparing a plan for the future of the California coastal zone. While the plan was being prepared, the commissions controlled all development, through a permit process, to insure consistency with the objectives of the established legislation and the emerging plan policies. The plan was presented to the Governor and legislature in December 1975 for adoption and implementation. In 1976, the California Coastal Act was enacted, establishing the policies and governmental mechanism for ensuring wise use of the State's coastal areas. Coastal areas of the bay region are represented by two commissions: Central (San Mateo County) and North Central (San Francisco, Marin, and Sonoma Counties). CCZCC used geologic information in preparing the coastal plan and, if maintained as a permanent organization, will continue to need geologic data.

REGULATORY AGENCIES

Regional agencies with a primary purpose of establishing, enforcing, and administrating regulations are the Bay Area Air Pollution Control District (BAAPCD) and the San Francisco Bay Regional Water Quality Control Board (RWQCB). The BAAPCD is responsible for establishing and carrying out a program to reduce air contaminants from both stationary and moving sources, and the RWQCB is responsible for formulating and adopting a water-quality control plan. However, the major influence of each agency on land-use decisions derives from its authority to set and enforce standards. For example, the RWQCB has issued moratoriums on sewer hook-ups in certain localities to prevent deterioration of water quality. In addition, any project that may have an effect on water quality must receive a permit from the board before it can be undertaken. Similarly, the BAAPCD, with jurisdiction over the nine counties, except for parts of Solano and Sonoma Counties, is required to consider the effects of land-use decisions on air quality. The BAAPCD has little potential need for geologic information, but the RWQCB can use such information to help determine the effect of proposed projects on water quality.

SINGLE-PURPOSE PLANNING OPERATING DISTRICTS

A number of agencies typically are given taxing powers and the responsibility to plan, develop, construct, operate, and maintain particular facilities or services. Bay Area Rapid Transit District, East Bay Regional Park District, Golden Gate Bridge High-

way and Transportation District, and East Bay Municipal Utility District are examples of such agencies. These agencies use geologic information primarily in locating and designing regional facilities.

INTERGOVERNMENTAL RELATIONS

The diffusion of planning responsibility and regulatory powers among so many regional agencies works against development of a coordinated, comprehensive approach to the solution of regional land-use and environmental problems. This diffusion is compounded by the authority and responsibility lodged with governmental agencies at the other jurisdictional levels. The operations of regional agencies affect and are affected by the planning and decisionmaking of government agencies at Federal, State, and local levels.

Federal and State agencies often preempt or limit regional decisionmaking by imposing requirements for funds, criteria for programs, shared responsibility for specific functions such as transportation, and regulations concerning, for example, environmental quality or the content of local plans.

Regional and, to an increasing extent, local governmental agencies are highly dependent on Federal and State funds to carry out their responsibilities. This means that plans and programs developed at the regional and local level are often framed with an eye not only to locally expressed objectives and concerns but also to Federal and State program-funding requirements. Thus, individual governmental decisions become part of the network of decisions made by other agencies at different jurisdictional levels over a period of time.

Land-use decisions are made within this context of complex inter-governmental relations. The effective use of geologic information in planning by the various regional agencies often depends on complementary decisions of other regional, Federal, State and local agencies. All the regional agencies described above engage in, or have some impact on, land-use planning and decisionmaking. Many make use of geologic information in developing plans, establishing criteria, reviewing projects, locating and designing facilities, or enforcing regulations. The information on the geologic characteristics, problems, and potentials of flatland areas presented in this report can assist these regional agencies to plan and act with greater awareness of the physical environment.

REGIONAL SETTING

GEOGRAPHIC SETTING

The San Francisco Bay region lies between lat 36° and 39° N. and extends across the lowest and narrowest segment of the Coast Ranges in central California and into the west edge of the Great Valley of California (fig. 4). This region covers an area of 7,461 square miles (19,320 km^2) consisting of northwest trending mountain ranges, broad basins, and narrow valleys generally paralleling major geologic structures and the coastline of central California.

About 65 percent (4,920 mi^2, 12,740 km^2) consists of rounded hills and rugged mountain uplands with many ridge crests rising above 1,000 feet (300 m) and a few peaks rising above 4,000 feet (1200 m) (fig. 5). Almost 11 percent (784 mi^2, 2,030 km^2) consists of the open water and tidal marshlands of the bay itself that lie at or close to sea level. The remaining 24 percent (1,757 mi^2, 4,550 km^2) consists of the relatively flat lowland areas (generally less than 200 feet (60 m) above sea level) that constitute the broad alluvial plain surrounding the bay, the broad to narrow valley bottoms extending from the bay plain into the surrounding hills, and the narrow elevated marine terraces cut into the mountains along the Pacific Coast.

CLIMATE

The San Francisco Bay region has a mediterranean climate with mild wet winters and warm dry summers (fig. 6). This type of climate is common on western continental coasts between lat 30° and 50° N. where coastal ocean currents moderate the effects of seasonal changes in temperature.

The climate along the coast is marked by moderate and even temperatures, heavy persistent summer fog, and winds from the west-northwest. In contrast, inland areas have a wider range of temperature and have less wind. Temperatures are influenced by elevation and local topography. Higher summer temperatures and lower winter temperatures occur in low areas isolated by mountainous terrain. This kind of climate is also true of areas far distant from the bay and its temperature-moderating waters. Precipi-

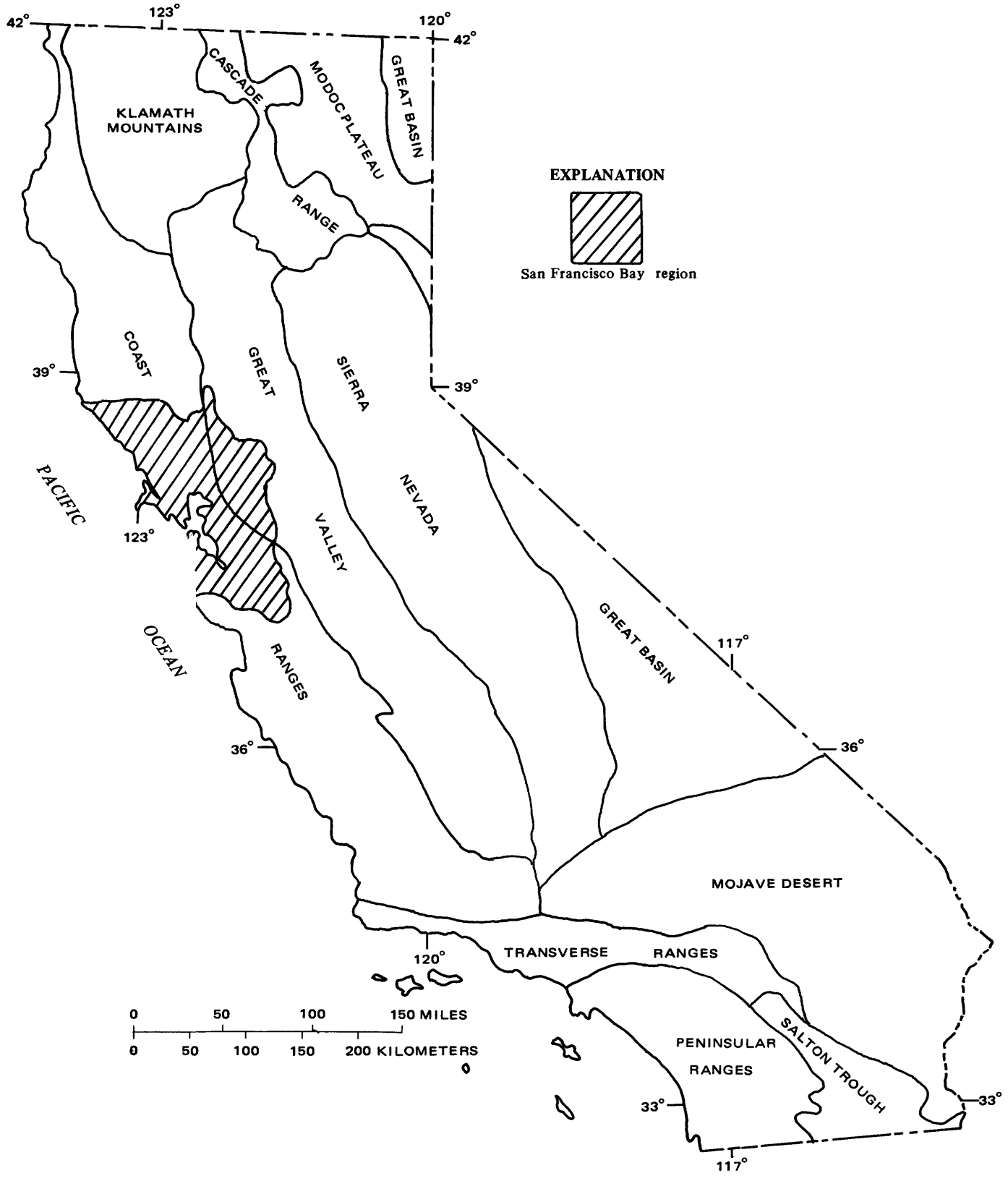


FIGURE 4.—Physiographic provinces of California and location of San Francisco Bay region (California Division of Mines and Geology, 1966, p. 17).

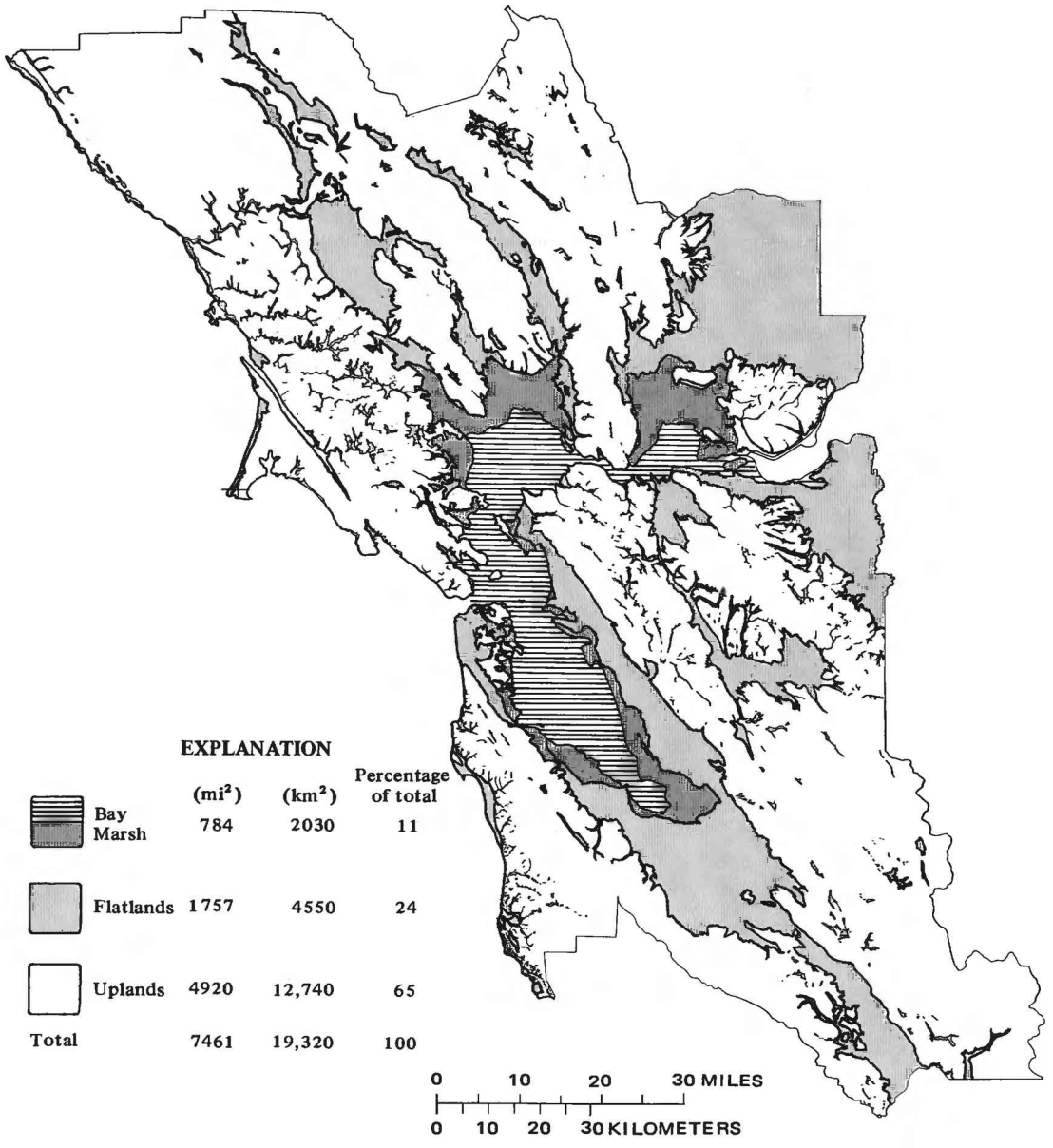


FIGURE 5.—The San Francisco Bay region showing mountainous uplands, the flat alluviated lowlands, and the bay and its tidal marshes.

tation is distinctly seasonal, most falling between November and March, very little between June and September. The seasonal distribution of precipitation is largely controlled by the location of the anticyclonic cell (high-pressure system) that is normally found off the California coast, particularly in the summer. Winter precipitation occurs when this anticyclone is absent or far south of its normal position, which blocks storm systems from the Gulf of Alaska. Almost all precipitation is in the form of rain and what little snow falls usually soon melts.

Average annual precipitation ranges from 10-20 inches (25-50 cm) in the dry interior valleys to 40-60 inches (100-150 cm) and locally to 80 inches (200 cm) in the high coastal mountains (fig. 7). Precipitation is heaviest on the western slopes of the Coast Ranges and decreases, in general, from north to south. This pleasant mild climate provides for a long growing season as well as making an attractive place for humans to live.

The native vegetation in the bay region north through Sonoma County and south through Santa Clara County is dominated by plants adapted to mild climatic conditions including a summer drought. The bay area is actually a meeting ground for many plant species from the north Pacific Coast that reach their southern limit in the bay region and other plants from southern California that reach their northern limit here. The native plants evolved here in their own ecological niches, which we refer to as biotic

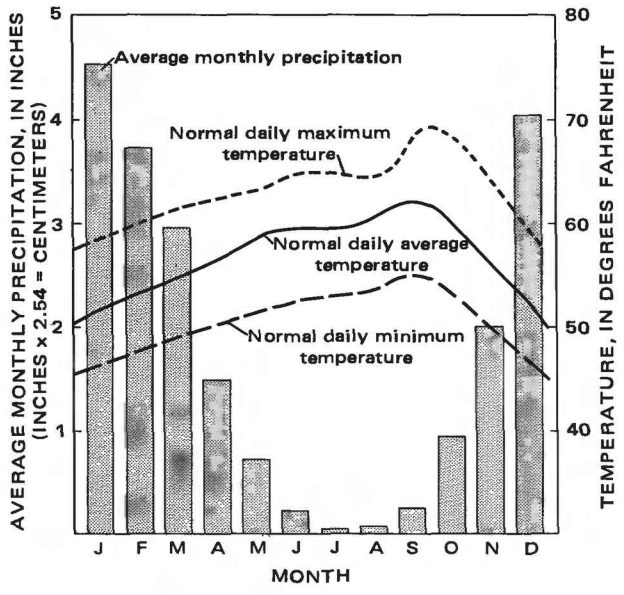


FIGURE 6.—Annual temperature and precipitation variations in San Francisco.

communities. These plant communities are bay and salt marsh, freshwater marsh, the open coast, chaparral, grasslands, broad-leaved forest, and coniferous forest. The flatland deposits underlie almost all but the last two communities. However, the broadleaved and coniferous forests do cover stream terrace deposits in the outer valleys. The native plant communities are summarized below from Metcalf (1959) and Smith (1968).

Community	*Characteristic vegetation*
Bay and salt marsh	Salt grass (*Distichilis spicata*)
	Cordgrass (*Spartina foliosa*)
	Pickle-weed (*Salicornia, spp.*)
	Marsh rosemary (*Limonium commune*)
	Marsh Grindelia (*Grindelia cuneifolia*)
	Sea bite (*Suaeda californica*)
Freshwater marsh	Common tule (*Scirpus acutus, S. robustus,* and *S. communis*)
	California bulrush (*Scirpus californicus*)
	Cat-tail (*Typha latifolia*)
	Sedge (*Carex senta*)
Open coast	Surf grass (*Phyllospadix torreyi* and *P. scouleri*)
	Tree lupine (*Lupinus arboreus*)
	Sea rocket (*Cakile edentula*)
	Blue grass (*Poa douglasi*)
	Sand verbena (*Abronia sp.*)
	Beach grass (*Ammonphila arendria*)
Chaparral	Chamise (*Adenostoma fasciculatum*)
	Scrub oak (*Quercus dumosa*)
	Buckbrush (*Ceanothus cuneatus*)
	Coffee berry (*Rhamnus californica*)
	Leather oak (*Quercus durata*)
	Interior live oak (*Quercus wislizeni*)
	Coast live oak (*Quercus agrifolia*)
	Manzanita (*Arctostaphylos canescens*)
	Wild lilac (*Ceanothus sp.*)
Grasslands	Blue bunch grass (*Festuca idahoensis*)
	California oat grass (*Danthonia californica*)
	Foothill sedge (*Carex tumulicola*)
	Soft chess (*Bromus hordeaceus*)
	Red brome (*Bromus rubens*)
	Wild oats (*Avena fatua*)
	Coyote bush (*Baccharis pilularis*)
	Coast live oak (*Quercus agrifolia*)
	California buckeye (*Aesculus californica*)
	California laurel (*Umbellularia californica*)

Before discussing the broadleaf and coniferous communities, it is worth noting that the native trees of the bay area can be divided into three groups primarily on the basis of their leaf characteristics. These are the conifers, broadleaf evergreens, and broadleaf deciduous trees. Conifers are cone-bearing evergreen trees distinguished by their simple needlelike or scalelike leaves. Broadleaf evergreens are those trees that keep all or most of their leaves, usually leathery, throughout the year. Broadleaf deciduous trees are those that lose their leaves in winter. Their leaves are usually thinner and less leathery than the broadleaf evergreen (Williams and Monroe, 1967).

Community	*Characteristic vegetation*
Broadleaf forest	Sycamore (*Platanus racemosa*)
Riparian woodlands	Willow (*Salix* sp.)
	Bigleaf Maple (*Acer macrophyllum*)

Community	*Characteristic vegetation*
Riparian woodlands—Continued	Oregon ash (*Fraximus latifolia*)
	California buckeye (*Aesculus californica*)
	California laurel (*Umbellularia californica*)
Ripirian woodlands—Continued	Creek dogwood (*Cornus californica*)
	Poison oak (*Rhus diversiloba*)
	Hoary nettle (*Urtica holosericar*)

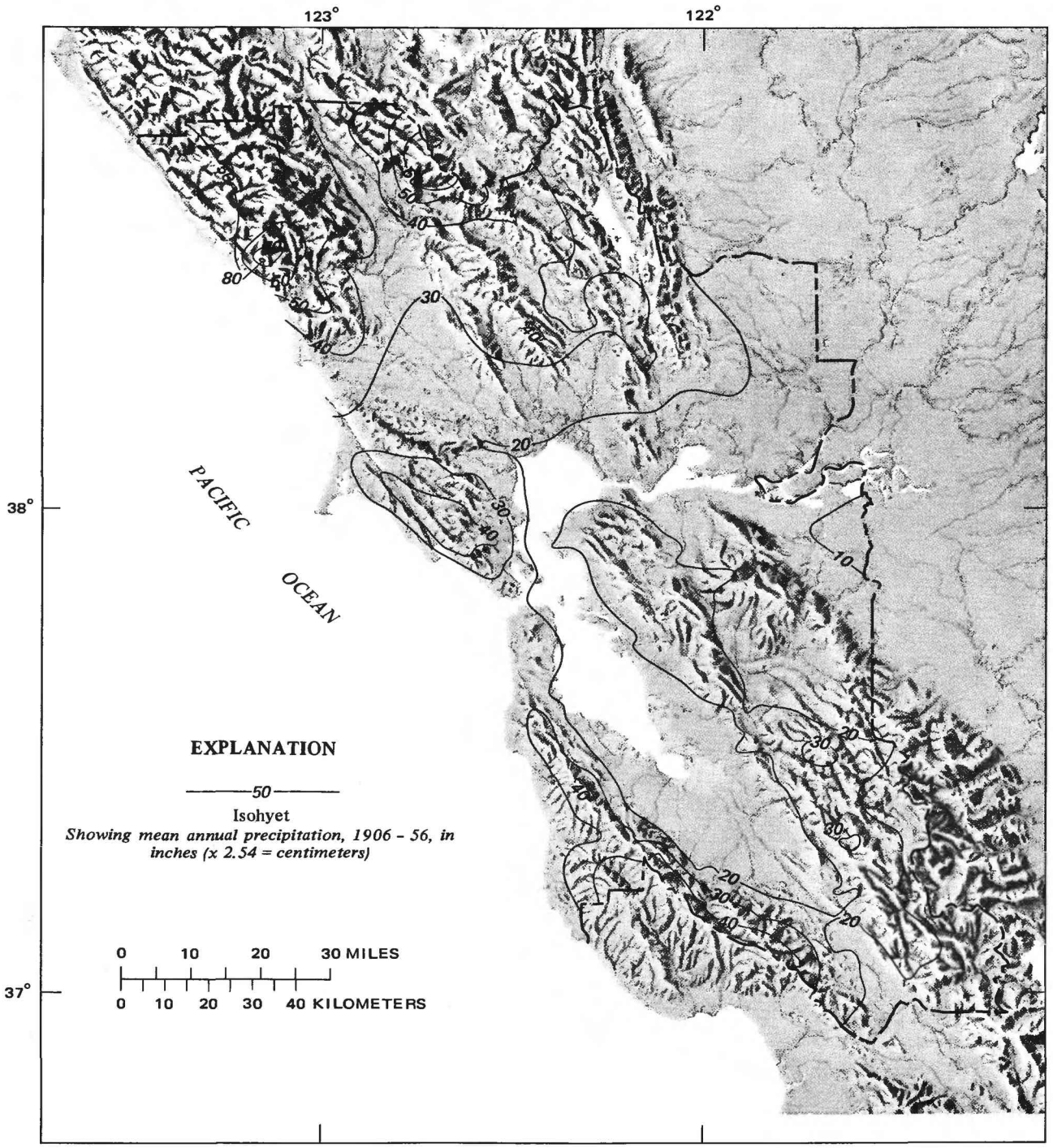


FIGURE 7.—Precipitation distribution in San Francisco Bay region. After Rantz (1971).

Community	*Characteristic vegetation*
Oak woodlands	Live oak (*Quercus agrifolia*)
	California buckeye (*Aesculus californica*)
	California laurel (*Umbellularia californica*)
	Black oak (*Quercus kelloggi*)
	Blue oak (*Quercus douglasi*)
	Oregon oak (*Quercus garryanna*)
	Interior live oak (*Quercus wislizeni*)
	Madrone (*Arbutus menziesii*)
	Poison oak (*Rhus diversiloba*)
	Manzanita (*Arctostaphylos* sp.)
	Coyote bush (*Baccharis pilularis*)
	Chamise (*Adenostoma fasciculatum*)
	Lupines (*Lupinus* sp.)
Coniferous forest	Coast redwood (*Sequoia sempervirens*)
	Douglas fir (*Pseudotsuga menziesii*)
	Monterey cypress (*Cupressus macrocarpa*)
	Monterey pine (*Pinus radiata*)
	Knobcone pine (*Pinus attenuata*)
	Bishop pine (*Pinus muricata*)
	Wax myrtle (*Myrica californica*)
	Redwood sorrel (*Oxalis oregona*)
	Ponderosa pine (*Pinus ponderosa*)
	Thimble berry (*Rubus parviflora*)
	California sword fern (*Polystichum munitum*)
	Firs (*Abies* sp.)
	Spruce (*Picea* sp.)
	Western yew (*Taxus brevifolia*)
	Incense cedar (*Libocedrus decurrens*)

The mild climatic conditions result in relatively moderate rock-weathering and erosional conditions which give a characteristic rounded aspect to much of the upland landscape. Weathered rock material is not removed rapidly from the hilly uplands, so bedrock outcrops are few and decomposed rock debris mantles most hillslopes. Soil creep caused largely by seasonal shrinking and swelling of expansive clays in the mantle of weathered rock debris is a dominant erosional process that tends to form smooth, rounded hills. Landsliding, induced in large measure by heavy winter rains, is another dominant erosional process and commonly forms steep, irregular slopes on exposed hillsides and in deep narrow canyons. The weathered rock debris that accumulates in gulley and canyon bottoms is eroded and transported to the alluvial lowlands mainly by winter floods. In the recent geologic past, when climatic conditions were cooler and moister, the rates and relative importance of various weathering and erosional processes were probably slightly different from those of today.

The moderate and stable climatic conditions result in more than 300 argicultural growing days per year over much of the area, but the summer drought prevents summer crop cultivation without irrigation. Local ground-water supplies are usually insufficient for intensive irrigation, so water impoundments and imports are necessary for summer cultivation.

The total argicultural, domestic, and industrial demands for water are far greater than local supplies. Consequently, water imports, primarily from the Sierra Nevada, are necessary for immediate use and recharge of ground-water aquifers in much of the region.

DRAINAGE

The Sacramento and San Joaquin Rivers, which drain most of the Great Valley of interior California (about 27 percent of the state), coalesce in a broad marshy delta east of the bay region and empty into the Pacific Ocean through Suisun Bay, San Pablo Bay, and the Golden Gate (fig. 8). Almost all the fresh water entering the estuary is derived from this interior drainage area, which is about 50 times larger than the local drainage area emptying directly into the San Francisco Bay estuary (McCulloch and others, 1970).

The San Francisco Bay region itself is drained by a network of ephemeral streams and small rivers (fig. 9). Only the broad valleys in the central 50 percent of the region drain directly into the bay. About 25 percent of the region drains northward and westward into the Pacific Ocean, 20 percent drains eastward into the Great Valley, then into the bay through the delta, and the remaining 5 percent drains southward into Monterey Bay.

The streams that drain these basins transport weathered rock debris from the upland areas to the lowlands where it is deposited to form flat alluvial plains and estuarine mudflats. The two large rivers draining the Great Valley bring debris into the bay region from as far away as the Sierra Nevada and Klamath Mountains (fig. 3). Most of the coarse gravel and sand carried by these rivers is deposited in the Great Valley. (Gilbert, 1917) Much of the fine-grained

silt and clay carried in suspension is transported into San Pablo Bay, into San Francisco Bay, and even directly into the Pacific Ocean through the Golden Gate. Estuarine currents produced by tidal action distribute this debris throughout the bay and into southern San Francisco Bay where it settles to the bottom during slack water periods and forms the fine-grained, water-saturated deposit called "bay mud."

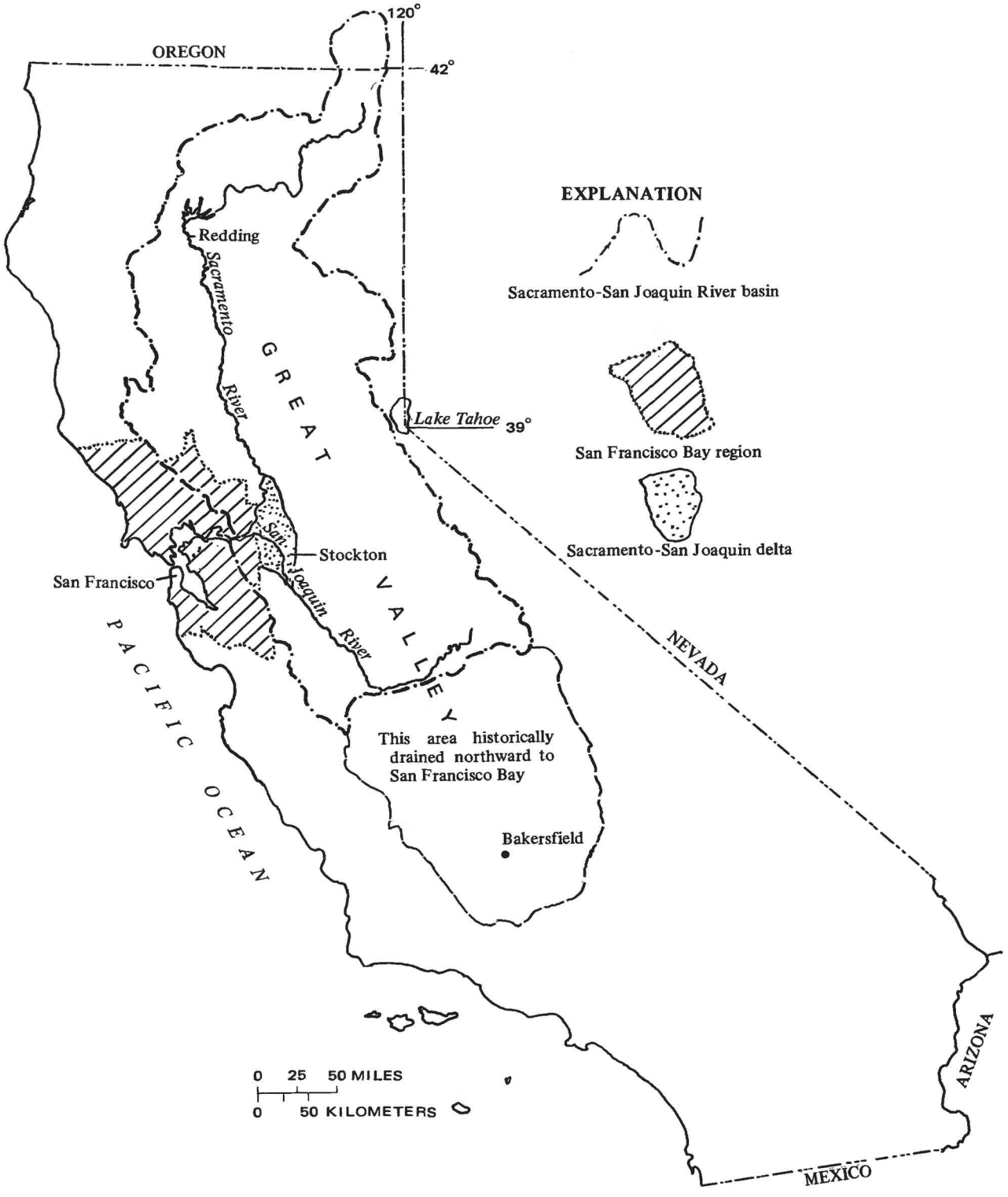


FIGURE 8.—Area of interior California that drains through San Francisco Bay.

Most of the debris forming the sedimentary deposits, particularly the alluvial deposits, is derived locally, however, and is transported only short distances from the upland to immediately adjacent lowlands. These sediments generally consist of broken rock debris (gravel, sand, silt, and clay) eroded, transported, and deposited by streams to form alluvial fans on broad lowlands and stream terraces in narrow valleys. The mineralogic and lithologic composition of these sediments is variable and is governed by the composition of the rocks exposed in source areas, weathering and depositional processes, and post-depositional alteration. Much of the alluvial material in the narrow valleys and on the upper part of alluvial fans is merely in temporary residence, however, and will be eventually reworked, broken down, and transported to lower elevations where it will become a permanent part of the thick sedimentary deposits filling the slowly subsiding basins.

GEOLOGY AND ENGINEERING PROPERTIES OF THE FLATLAND DEPOSITS

By EDWARD J. HELLEY and KENNETH R. LAJOIE

GEOLOGIC HISTORY

The known geologic history of the San Francisco Bay region is only about one-fortieth as long as the

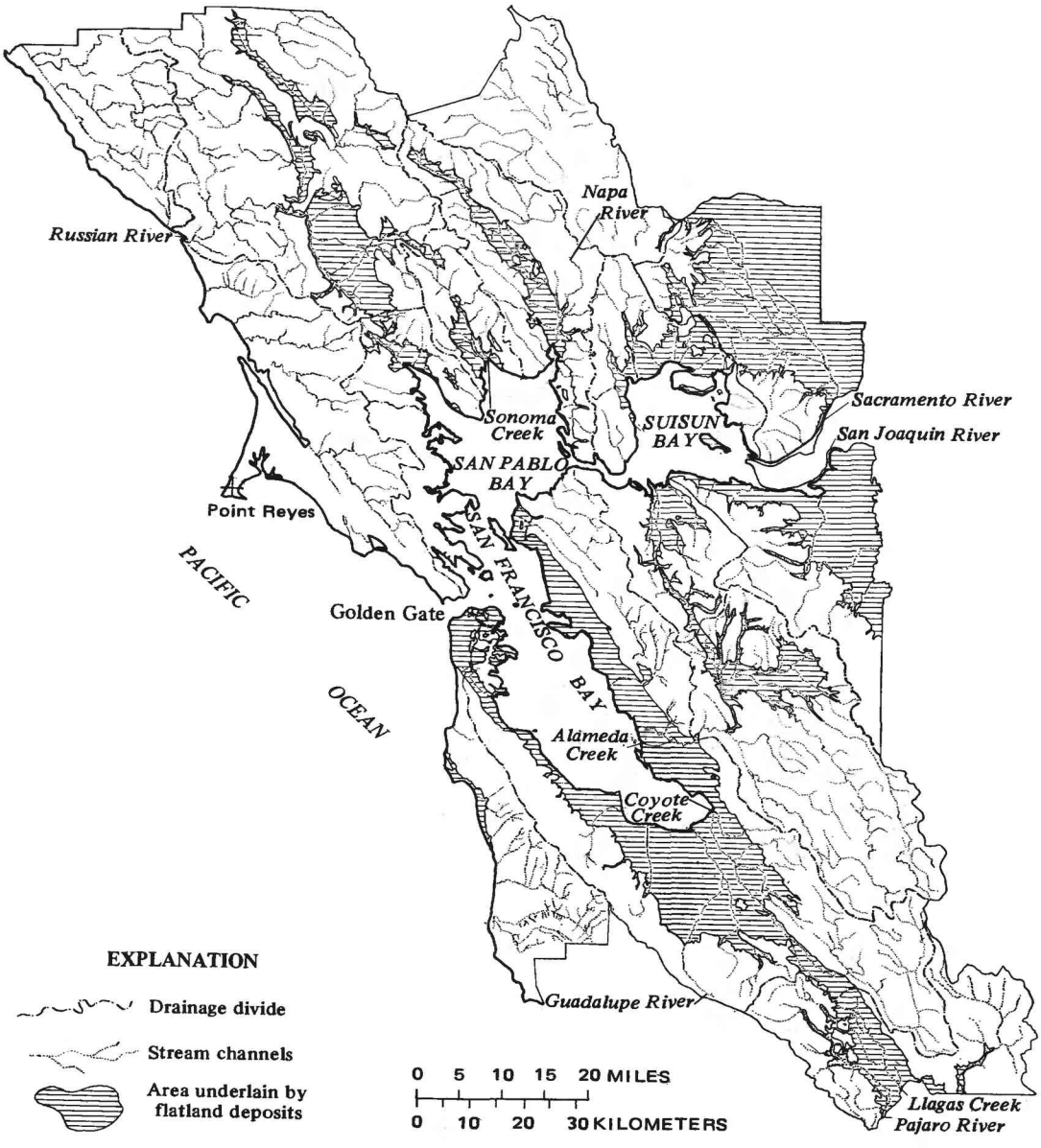


FIGURE 9.—Major drainage divides and basins, San Francisco Bay region.

earth as a whole. The oldest known rocks on earth are about 3.8 billion years old, whereas the oldest exposed in the bay region are only 100 million years old. In turn, the oldest deposits considered in detail in this report are only about one-half million years old, and the geologic history we consider in detail is less than one two-hundreth that of the bay region as a whole. The youngest deposits are still forming today. Therefore, the geologic materials exposed at the surface in the flat lowland region, though formed of debris eroded from much older rocks in the surrounding uplands, are extremely young in geologic terms and most of the geologic processes that formed them are still active today and are of concern in land-use planning.

Figure 10 gives a perspective of geologic time from the origin of the earth to the present. Figure 11 shows the types of rocks that occur in the bay region together with their geologic age.

The following paragraphs are a brief summary of the history and character of the older bedrock formations of the bay region from which the deposits that concern us were derived. The history we infer for the oldest of these deposits depends largely on modern concepts of sea-floor spreading and plate tectonics. For a more complete review of plate tectonics, see Oxburgh, 1974.

Between 100 and 65 million years ago, during the closing phases of the Mesozoic Era, great quantities of basaltic lava flows, red siliceous ooze, and muddy sand and mud accumulated in irregularly interbedded layers on an ocean floor west of what is now California. During this same time, an equally large quantity of mud, sand, and gravel accumulated in regular beds on the floor of a deep trench along what was then the margin of the North American Continent and is now the site of the Great Valley and eastern Coast Ranges. The ocean-floor sequence was lithified to hard sandstone, chert, and greenstone (metamorphosed basalt), partly crushed, and thoroughly mixed as the sea-floor on which it rested was dragged beneath the edge of the continent by subduction. This sequence is now known as the Franciscan Formation. The regularly bedded sequence on top of the surface of underthrusting was not so intensely disturbed, although it too was lithified to relatively hard sandstone, shale, and conglomerate. These rocks are now known as the Great Valley sequence. At the time of underthrusting, masses of gabbro and rock that later formed serpentine, originally parts of the Earth's mantle and lower crust, were incorporated into the Franciscan Formation and along the base of the Great Valley sequence. East of the San Andreas fault these rocks now make up most of the high mountains and uplands and underlie all other deposits at depth.

Granitic rocks, which solidified from molten magma about 90 million years ago in the area now occupied by southern California, were subsequently moved northwestward along the San Andreas fault to a position opposite San Francisco Bay. They now underlie at depth all land areas and the continental shelf west of the fault and are exposed at the surface on Montara Mountain, on the Point Reyes peninsula, the Farallon Islands, and Bodega Head.

During most of the Cenozoic Era (the last 65 million years), the crustal blocks that are now the San Francisco Bay region appear to have been divided into smaller sinking areas, that formed basins and embayments, interspersed with areas of uplift that formed highland areas. Sand, clay, and gravel eroded from the highlands or brought in from the east were deposited beneath the sea or on alluvial plains above sea level in the subsided basins and were interbedded with accumulations of diatom ooze and locally of volcanic rocks. The positions of basins and uplifts shifted from time to time, and areas that had been basins of accumulation were uplifted and vice versa. During periods of crustal movement, the sedimentary accumulations were lithified into sandstone, shale, conglomerate, and chert and were tilted, folded, and faulted. In general, they did not become as hard as the Mesozoic rocks, the younger rocks are less deformed and less lithified than the older rocks.

When a former basin of accumulation was uplifted to form a highland, its Cenozoic cover was eroded (in part, at least) to fill nearby newly formed basins, and the Mesozoic basement was re-exposed. Remnants of the Cenozoic rocks are found today mainly beneath the floors of existing basins, but they also make up two important highlands of the bay region, the Santa Cruz Mountains west of the San Andreas fault, and the Berkeley Hills-Mt. Diablo area.

Volcanic rocks are found in the Santa Cruz Mountains and Berkeley Hills and make up several mountain ranges north of San Pablo Bay in Sonoma, Napa, and Solano Counties.

The alternation of highland and basin is still going on, for the Berkeley Hills was a lowland as recently as 6 million years ago, and is now a major highland, and the San Francisco Bay valley, which was probably a highland at that time, is apparently now slowly subsiding.

The geography of the bay region was significantly different 2–3 million years ago from what it is today; for example, Mt. Diablo and the Carquinez Straits did not exist (Sarna-Wojcicki, 1971). The bay as we know it did not exist, and the interior of California probably did not drain to the Pacific Ocean through this region until about 1 million years ago. Geologic

evidence throughout coastal California indicates that the terrane west of the San Andreas fault has been moving northwestward relative to the terrane east of the fault at a rate of about 1–2 inches (2.5–5.0 cm) per year for the past several million years as a result of displacement along the fault. Therefore, the Point Reyes peninsula probably lay south of the present Golden Gate within the past several million years and actually may have blocked it within the past 1–3 million years. Throughout this time the ancestral bay basin was subsiding and filling with sediments that today are highly folded and faulted (Hall, 1966). These partly indurated sediments are now exposed only in discontinuous outcrops around the margins of the lowland basins (fig. 11). During this time the bay, when it existed, was connected with the ocean through passages far different from the present Golden Gate.

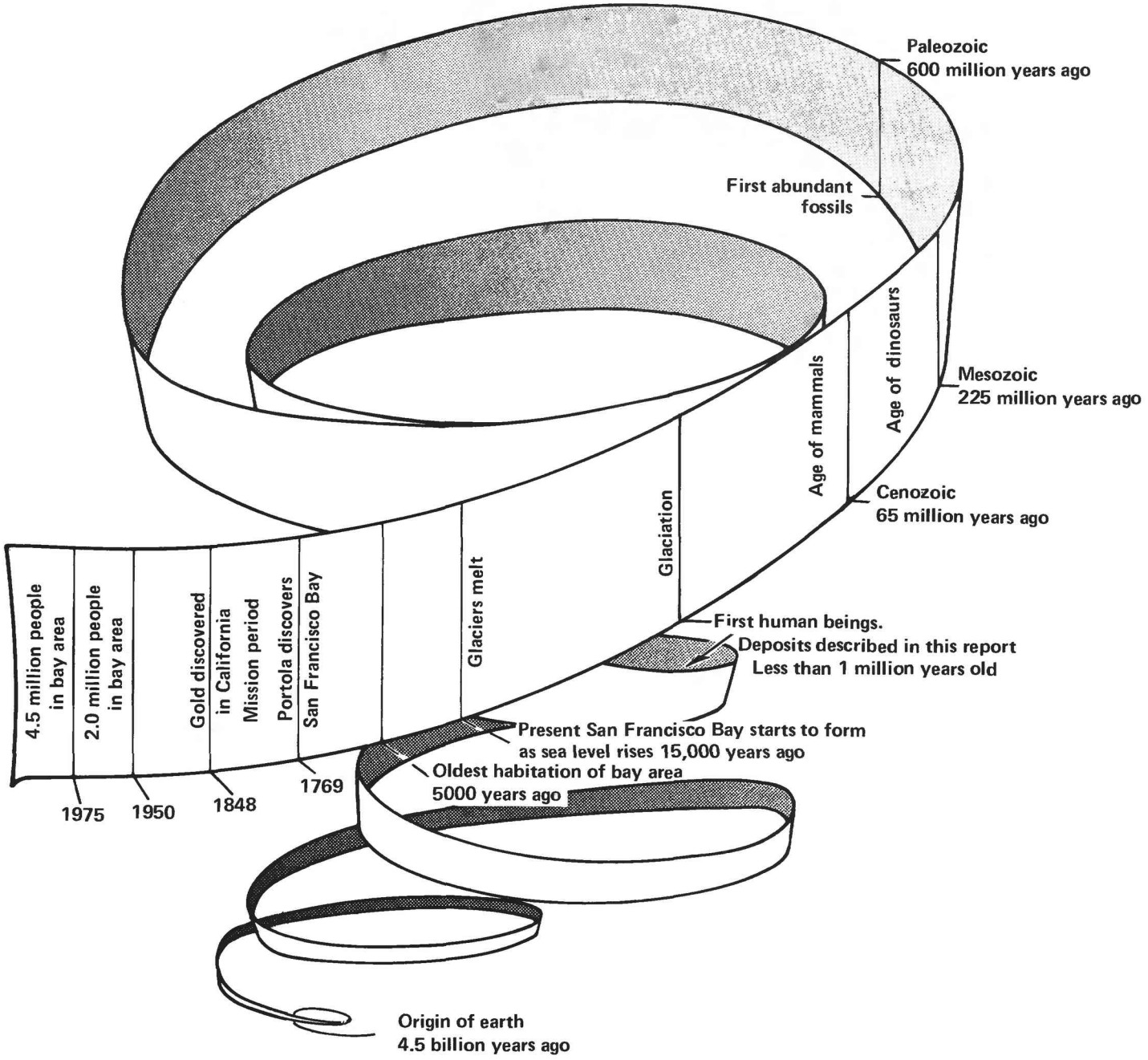


FIGURE 10.—Geologic time in perspective.

In addition to tectonic effects, major changes in sea level caused by worldwide climatic fluctuations over the past million years or so have left their geologic imprint on the bay region. When the climate was colder than it is today, sea level was lower because large volumes of ocean water were stored on the continents in glaciers. During these periods there was no bay and the ocean shoreline was located as far west as the Farallon Islands. When the climate was relatively warm, as it is today, sea level was close to its present position because the glaciers partially melted and the water they contained returned to the

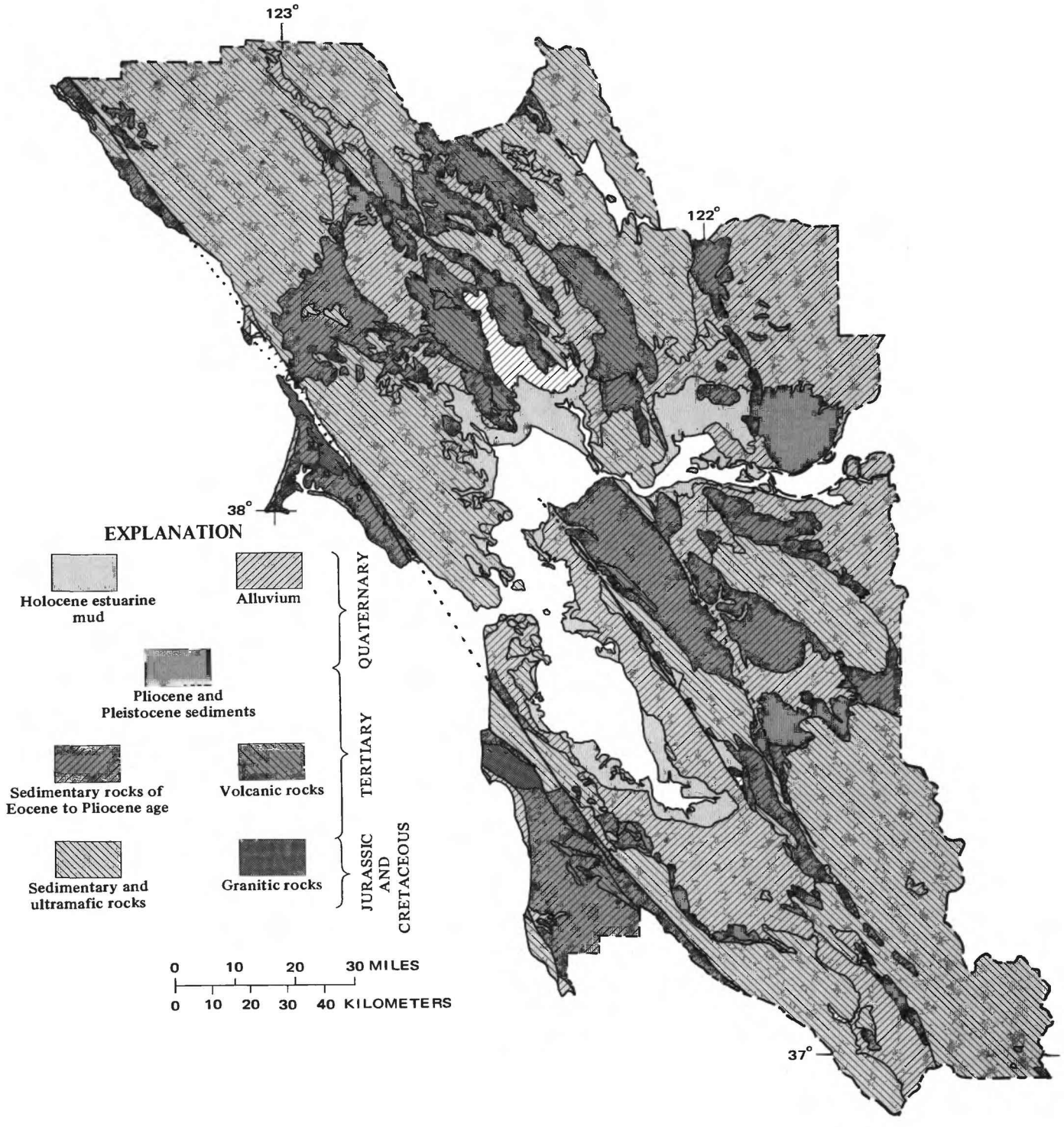


FIGURE 11.—Generalized geologic map of San Francisco Bay region. Modified from Schlocker, 1971.

oceans. During warm periods, the bay basin was partially flooded, as it is today, and the ocean shoreline was located approximately in its present position. During each of these major sea-level highstands, estuarine sediments were deposited in the bay and wave erosion cut a nearly flat marine terrace into the coastal mountains. A vertical succession of as many as six of these terraces capped by a thin veneer of marine sediments occurs along the coast indicating general uplift of the coastal mountains 400–600 feet (120–180 m) during the past ½–1 million years. The youngest marine terrace, which is the lowest and usually the best preserved, probably formed during the last major highstand of sea level between 120,000 and 70,000 years ago. Uplift and deformation of these marine terraces by faulting and folding clearly record the tectonic activity that has affected the coastal region in the fairly recent geologic past. The deformation was quite irregular—some areas were uplifted and others depressed.

During the last Pleistocene glacial advances between about 70,000 and 10,000 years ago, sea level stood as much as 300–400 feet (90–120 m) below its present elevation (fig. 12). The streams presently draining into the bay were merely tributaries of a large river flowing through the bay region from the Great Valley and across the broad coastal plain between the narrow canyon that is now the Golden Gate and the Farallon Islands. Camels, bison, mammoths, sloths, and horses roamed the broad inland valleys whose nearly flat floors, now partly occupied by the bay, were covered by fresh-water marshes and open coniferous woodlands consisting mainly of Douglas-fir (*Pseudostuga menziesii*) and incense-cedar (*Libocedrus decurrens*), two species tolerant of cooler climates.

Because the coastline lay so much farther west, it is reasonable to believe that Sequoia were not abundant, for today they are found only within 30 miles (49 km) of the coastal fog belt. Perhaps the lack of oak is indicative of a wetter climate, at least one without a summer drought.

About 15,000 years ago, sea level began to rise as glaciers in the northern latitudes began to melt. Subsequent changes in sea level in the San Francisco Bay area are recorded by tidal-marsh deposits located at the base of Holocene estuarine sediments. These marsh sediments accumulated near sea level when it was lower than today, so their radiocarbon ages closely approximate the ages of sea levels in the past. The local record of Holocene sea-level changes indicates that the rising sea entered the Golden Gate 10,000–11,000 years ago. The newly formed bay then spread across land areas as rapidly as 100 feet (30 m) per year; it reached the vicinity of the Dumbarton Bridge about 8,000 years ago. Subsequent shoreline changes have been more gradual because of a decrease in the rate of sea-level rise since about 5,000–6,000 years ago. The ocean reached its present level at about this time and so should have San Francisco Bay (fig. 12). However, the active tectonic nature of the bay region strongly suggests that the bay waters are still expanding, especially in the southern part of the bay. As sea level rose throughout this interval, the base levels of the streams in the bay region were raised slightly, the younger alluvial sediments were deposited on the flood plains around the growing bay, and the younger bay mud was deposited beneath the rising water. All these younger deposits exposed on the alluvial apron around the bay plain and the extensive valleys of the region are less than 5,000 years old. These deposits are also found buried beneath the transgressive bay muds, and here they are older but still less than 9,300 years old.

In most areas along the coast, the post-Pleistocene rise in sea level inundated the lower parts of the deeply incised valleys of the large coastal streams and caused them partially to fill with sediment. The lower course of the Russian River is a fine example.

The bedrock of the Russian River valley lies at least 125 feet (38 m) below sea level near the river mouth and at least 80 feet (24 m) below sea level near Guerneville, about 12 miles (19 km) upstream (Higgins, 1952).

The modern depositional processes operating on the lowlands are mainly the result of the region's mediterranean climate and active tectonic setting. The interaction between easily eroded bedrock and the heavy winter rains causes large seasonal fluctuations in the sediment loads carried by streams from the uplands down to the bay. During times of high surface-water runoff, sediments are supplied from slopewash, landslides, and gullying, then carried by shifting alluvial channels to the marshlands and bay. Some material is deposited on the alluvial plain, especially when streams overtop their banks and spread their sediment-laden waters over the low plains and basins. The finest grained sediment reaches the bay and is moved by tidal currents and waves. It may be deposited as fine estuarine mud or be eroded and transported out of the bay through the Golden Gate. The modern depositional and erosional processes operating along the bay are summarized in figure 13.

Along the coast, the depositional and erosional processes are controlled less by the climate than by wind and wave action. Sediment is supplied to the coastline by streams and rivers but much is also derived by erosion of sea cliffs. Littoral drift moves

the sediment along the coast where some is lost to deeper water, some is blown off the beaches to form dunes, and the rest remains as beach material. Just as with the sediments on the alluvial plain surrounding San Francisco Bay, the finer grained sediments like clay and silt are carried farther from their source. When sediment ceases to be supplied to the coast, the supply of sand for beach material decreases, but the

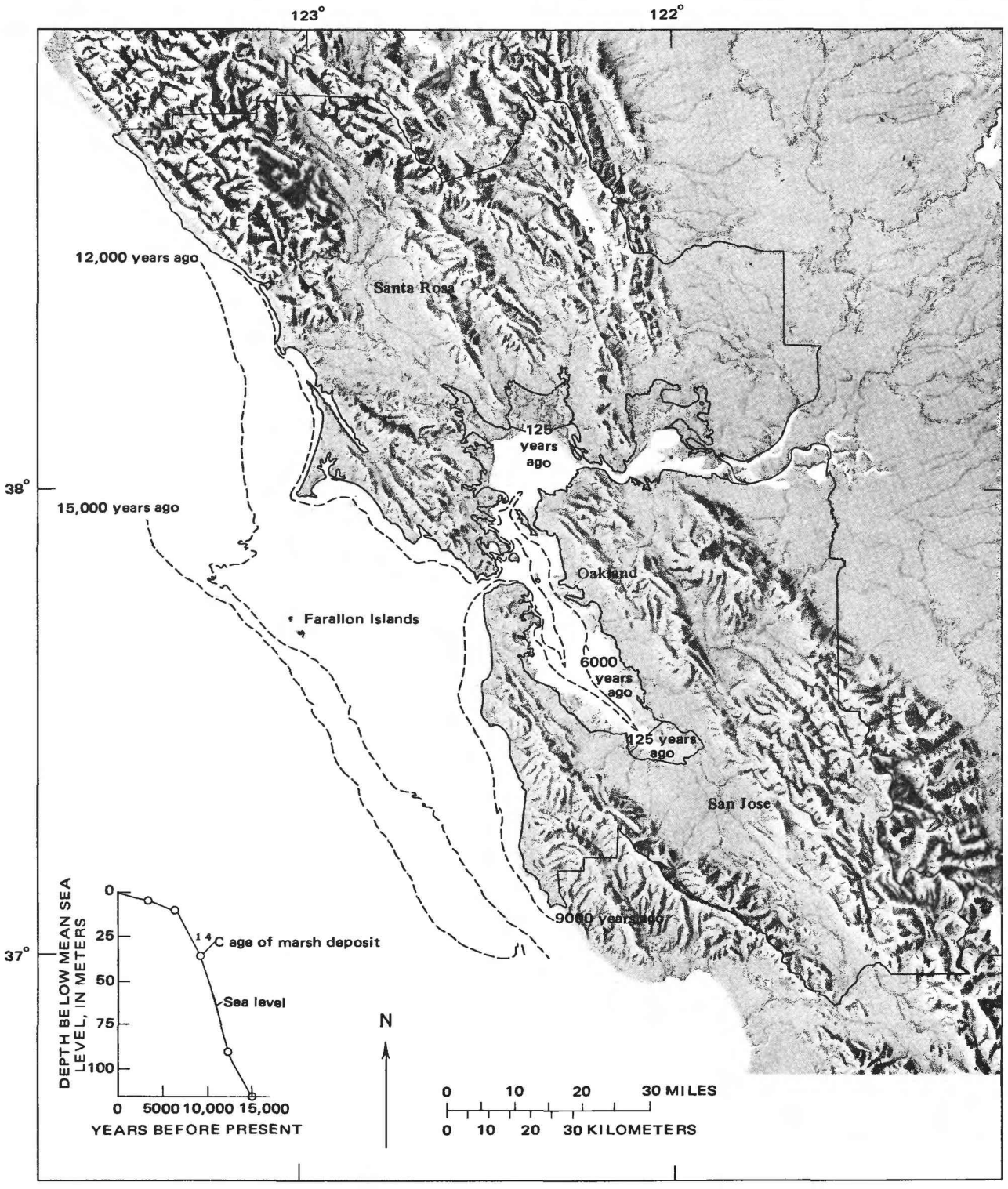


FIGURE 12.—Shorelines of San Francisco Bay and Pacific Ocean during Holocene transgression.

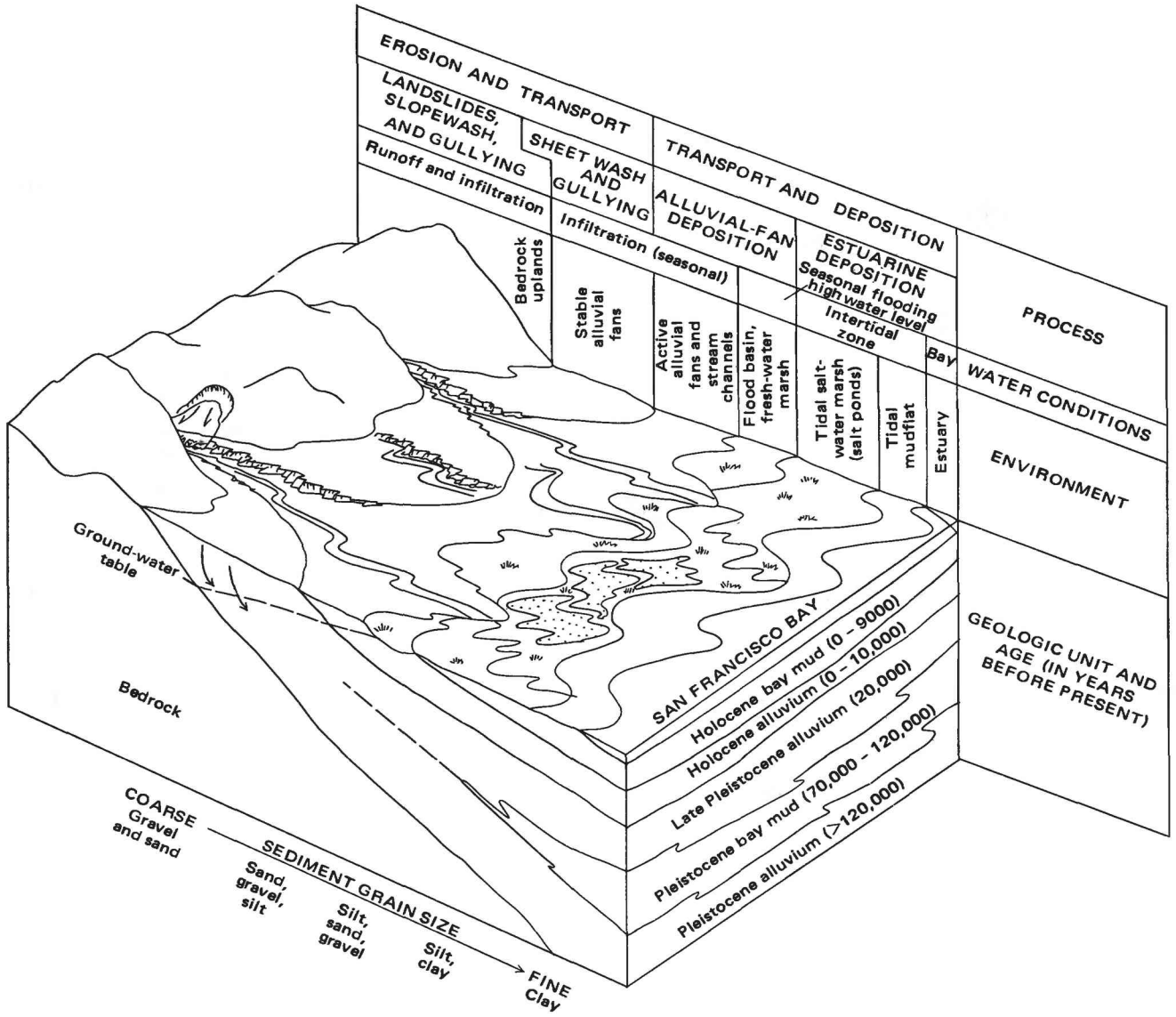


FIGURE 13.—Diagram of modern depositional and erosional processes along the bay plains.

littoral drift and wind erosion continue, and the beaches can disappear. During winter months most beaches are smallest, and bedrock may be exposed where strong wave action during storms has removed the sand. The reverse is true during summer months when most beaches are largest. A summary of coastal processes is shown in figure 14.

GEOLOGIC MAP OF FLATLAND AREAS

The map units that appear on plates 1, 2, and 3 are described according to geologic age from oldest to youngest. Most of the information used for establishing an absolute chronology and for correlating sedimentary deposits in the bay region was obtained from published and unpublished geologic, archeologic, and engineering reports. These diverse and readily available sources provided the data for constructing an initial working model and determined where subsequent dating information was needed. Many of the samples dated specifically for this study were obtained from the numerous drill cores collected as much as 25 years ago for engineering foundation studies of various proposed or existing trans-bay bridges. Extensive use of radiocarbon dating was made when appropriate sample material was already available or was discovered during the course of fieldwork.

In addition to each map unit listed by age the following geologic characteristics are discussed: physical description and lithology, thickness, age, distribution and stratigraphy, origin of deposit, and

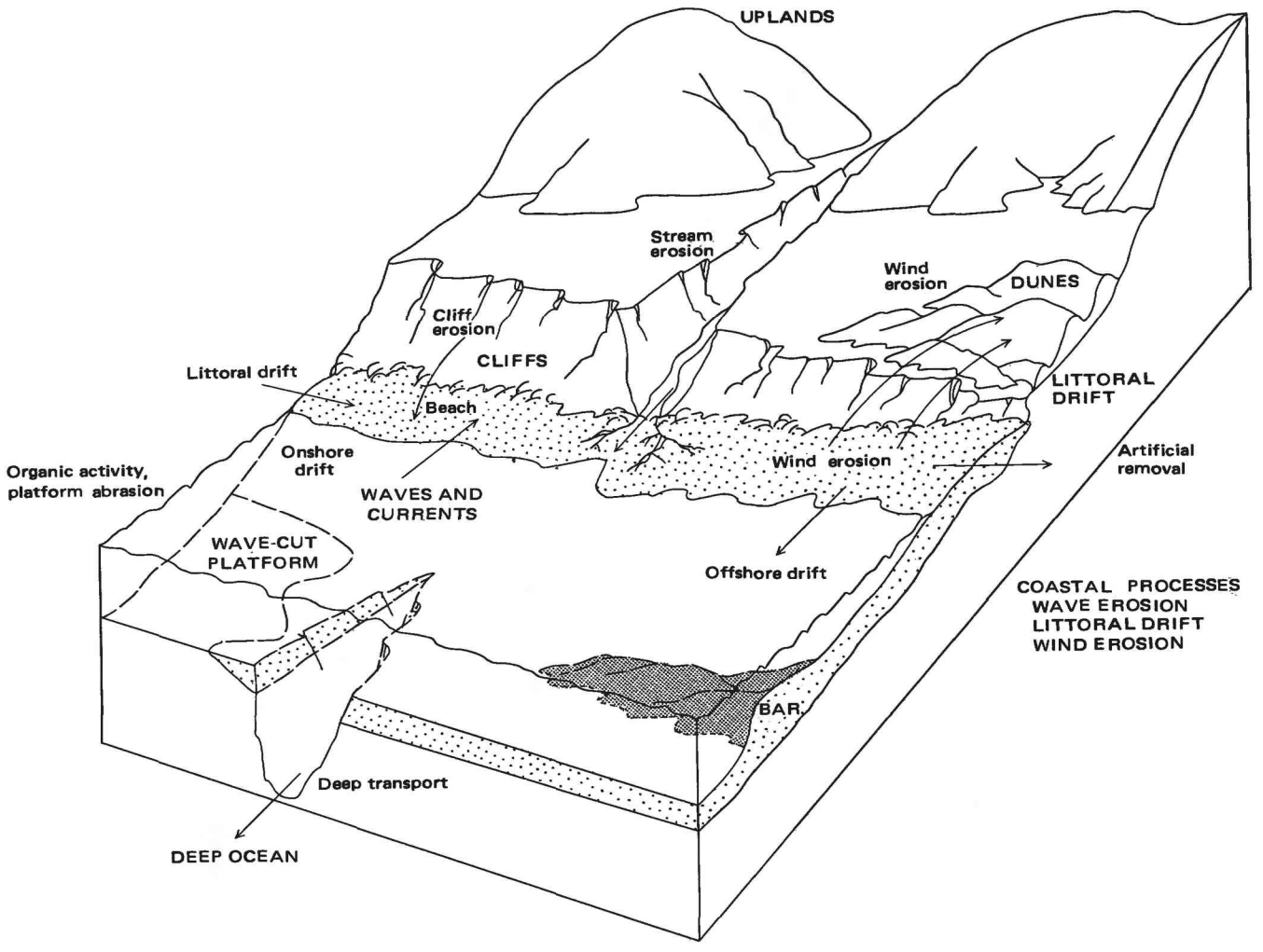


FIGURE 14.—Summary of coastal processes.

topographic form and relation to modern drainage. Since the amount of information known about each characteristic varies widely, some units can be described in much greater detail than others. The data are tabulated here for convenience.

HOLOCENE DEPOSITS (LESS THAN 10,000 YEARS OLD)

Estuarine deposits, Bay mud (Qhbm)

Physical description and lithology

Unconsolidated, water-saturated, dark, plastic clay and silty clay rich in organic material. Locally contains lenses and stringers of well-sorted silt and sand as well as beds of peat.

Locally contains fresh- and brackish-water gastropod and pelecypod shells and beds of peat.

See Pestrong (1972) for more detailed information on composition and physical properties of bay mud.

Thickness much as 120 feet (37 m) beneath the bay. Thins to less than 1 foot (0.3 m) around the margins of the bay. Probably less than 10 feet (3 m) thick in small coastal lagoons and estuaries.

Age

Presently forming. Oldest dated deposits in bay basin, 9,600 years old (Atwater and others, 1976).

Locally contain Holocene molluscan fossils. Upper part contains molluscan species introduced by man in past 100 years.

Distribution and stratigraphy

Underlies the waters of San Francisco Bay and small coastal lagoons and estuaries. Found generally below 8 feet (2.5 m) above mean sea level. Interfingers with Holocene alluvial de-

posits along the margins of the bay and in the lowest parts of broad valleys along the Pacific Coast and also overlies undifferentiated young alluvial deposits and older alluvium. Forms flat marshlands with low levees adjacent to tidal sloughs and gently sloping mudflats exposed only during low tides. Much of the area of exposure shown is used as salt-water evaporating ponds and much is covered by a thin veneer of artificial fill. See Nichols and Wright (1971) for more detailed information on distribution of young bay mud.

Origin of deposit

Between mean sea level and high tide line (+8 ft, 2.5 m). Deposited primarily in brackish- to salt-water marshes along the margins of the bay and in coastal lagoons. Below mean sea level deposited on tidally exposed mudflats and beneath the shallow waters of the bay.

Beach and dune sand deposits (Qhs)

Physical description and lithology

Loose well-sorted fine- to medium-grained sand. Includes some small deposits stabilized by vegetation. Mineral composition is variable and generally reflects local bedrock lithologies.

Locally may contain lenses of gravel or clay rich in organic material. Some dune deposits contain aboriginal artifacts and kitchen middens.

Thickness

The thickness of beach sand varies seasonally. Heavy surf strips sand from beaches and deposits it in shallow water offshore during the winter. Milder surf pushes the sand back onto the beaches during the summer. Dune sand thickness varies constantly but may locally exceed 25 feet (8 m).

Age

Presently forming. Large dune fields on Franklin Point, Año Nuevo Point, Point Reyes, Toms Point, and Bodega Head. Probably initially formed about 5,000 years ago when sea level attained its present elevation.

Distribution and statigraphy

Beach sand is found intermittently along the Pacific Coast close to sea level. The largest, most permanent deposits occur in sheltered coves and embankments such as Half Moon Bay, Bodega Bay, and Point Reyes peninsula. Dune sand occurs locally above beaches but is most extensive on headlands, such as Bodega Head, Point Reyes, Franklin Point, and Año Nuevo Point. Beach sand overlies bedrock except where it overlies marine terrace deposits. Dune sand generally overlies marine terrace deposits.

Origin of deposit

Beach sand is generally derived locally by wave abrasion of sea cliffs and by stream erosion in adjacent hills. Wave action winnows silt and clay from rock debris supplied to the beaches and leaves a residuum of clean, well-sorted sand. Dune sand is derived from beaches by the wind.

Human activity, such as damming streams and stabilizing sea cliffs and beaches, may have locally disrupted sand supply.

Topographic form and relation to modern drainage

Beach sand forms seasonally and changes configuration from broad, flat, gently sloping beaches to steep beaches with high berms. Dune sand forms low mounds in small deposits but forms parabolic dunes (U-shaped in the direction of the wind) and longitudinal dunes (linear ridges oriented parallel to the wind direction) in the large deposits at Point Reyes, Bodega Head, Franklin Point, and Año Nuevo Point.

Fine-grained alluvium (Qhaf)

Physical description and lithology

Unconsolidated, plastic, moderately to poorly sorted silt and clay rich in organic material. Seasonally saturated. Irregularly bedded.

Locally contains fresh-water gastropod and pelecypod shells, aboriginal artifacts, and skeletal remains.

Thickness

Generally less than 10 feet (3 m) thick.

Age

Presently forming where basins are not artificially drained or filled. Oldest deposits, along bay plain, are probably 5,000 to 7,000 years old.

Locally contains Holocene molluscan fossils.

Distribution and stratigraphy

Found in poorly drained, nearly horizontal basins between active and abandoned stream levees at the outer margins of alluvial fans adjacent to San Francisco Bay and in the lower parts of broad coastal valleys. Interfingers with and grades into coarser grained stream deposits toward higher elevations and with finer grained salt-water marsh deposits toward lower elevations. Overlies older alluvial fan and stream terrace deposits on the bay margin and bedrock along the coast.

Origin of deposit

Deposited from standing floodwaters that periodically inundate low interfluvial basin areas and locally form seasonal fresh-water marshes.

Presently being formed but depositional processes severely disrupted by modern cultural activity.

Topographic form and relation to modern drainage

Forms flat floodbasins between stream levees at or near sea level.

Presently being deposited by modern streams but recent cultural activity has disrupted formative processes.

Potential resources and uses

Agricultural soils developed on these deposits provide good to fair farming if well drained.

Potential geologic hazards and problems

Shrink-swell problems; periodic flooding; poorly drained, seasonal standing water due to high water table; potentially liquefiable where local shallow sand beds exist and are saturated.

Poor to fair foundation conditions because of the shrinking and swelling and poor drainage.

Low shear strength, high seasonal water content, and potentially liquefiable layers near the surface suggest strong ground-motion amplification during earthquakes and the possibility of ground failure.

Fine-grained salt-affected alluvium (Qhafs)

Physical description and lithology

Unconsolidated, plastic, moderately to poorly sorted, silt and clay rich in organic material. Seasonally saturated. Irregularly bedded; carbonate nodules and mottled weathering profile common.

Contains fresh-water gastropod and pelecypod shells; locally contains aboriginal artifacts and skeletal remains.

Thickness

Generally less than 10 feet (3 m).

Age

Presently forming where basins are not artificially drained or filled. Oldest deposits along bay margin, probably 5,000 to 7,000 years old.

Distribution and stratigraphy

Exposed along margins of south San Francisco Bay from latitudes of San Mateo and Hayward southward only. Interfingers with and grades into coarser grained stream deposits toward higher elevations and with finer grained salt-water marsh deposits toward lower elevations.

Origin of deposit

Similar to fine-grained alluvium.

Topographic form and relation to modern drainage

Similar to fine-grained alluvium.

Medium-grained alluvium (Qham)

Physical description and lithology

Unconsolidated, moderately sorted, moderately permeable fine sand, silt, and clayey silt with occasional thin beds of coarse sand. Well bedded.

Contains minor amounts of organic matter including fresh-water gastropod and pelecypod shells; locally contains aboriginal artifacts and skeletal remains.

Thickness

Thickness ranges from 0 to about 12 feet (4 m). Generally thickest in levees along streams and where deposits interfinger with and grade into coarse-grained younger alluvial fan deposits.

Distribution and stratigraphy

In some narrow canyons as valley fills and stream terraces. Interfingers with and grades into coarse-grained deposits along streams in broad valleys and on flood plains in broad valleys and on the outer edges of large alluvial fans on the broad alluvial plain marginal to San Francisco Bay. Interfingers with and grades into finer grained

basin deposits in the lower parts of broad coastal valleys and in the interfluvial basins adjacent to San Francisco Bay. Overlies bedrock in narrow valleys; overlies older alluvial fan deposits on the alluvial plain marginal to the bay and older alluvial fan deposits and marine terrace deposits on the lower marine terraces along the Pacific Coast.

Origin of deposit

Origin similar to younger alluvial fan deposits but deposited farther from source, therefore finer grained than coarse-grained alluvium. Local bedrock characteristics may control grain size in narrow canyons.

Age

Presently being formed but depositional processes disrupted severely by recent human activity.

Topographic form and relation to modern drainage

Forms flat flood plains in some narrow valleys. Forms active levees and flood plains in broad valleys and at the outer margins of large alluvial plain marginal to San Francisco Bay.

Presently being deposited by modern streams, but recent cultural activity has disrupted formative processes.

Coarse-grained alluvium (Qhac)

Physical description and lithology

Unconsolidated, moderately sorted, permeable sand and silt with coarse sand and gravel becoming abundant toward fan heads and in narrow canyons. Well bedded.

Locally contains aboriginal artifacts and skeletal remains.

Thickness

Thickness ranges from less than 10 feet (3 m) to as much as 50 feet (15 m). Thickest deposits in valley bottoms and at the heads of alluvial fans.

Age

Presently forming. Oldest deposits probably 5,000 to 7,000 years old.

Distribution and stratigraphy

On active stream terraces and as valley fills in narrow canyons where it interfingers with and grades into colluvium along the walls and at the heads of the canyons. Found along streams in the lower parts of broad valleys and at the heads of alluvial fans where streams flow from narrow bedrock canyons onto alluvial plains marginal to the bay or onto low marine terraces along the Pacific Coast. Interfingers with and grades into medium-grained alluvium on flood plains, in broad valleys, and at the outer edges of alluvial fans. Overlies bedrock at fan heads and in valleys; overlies late Pleistocene alluvial fan deposits and the Colma Formation on the alluvial plain marginal to the bay; overlies late Pleistocene alluvium and marine terrace deposits on the lower marine terraces along the Pacific Coast.

Origin of deposit

Fragmented and transported material derived from bedrock uplands and older unconsolidated sediments deposited by flowing water on active stream levees and flood plains primarily during floods. When streams overflow their banks during floods, the coarsest debris is deposited close to stream channel to form natural levees. The factors that initiated the cycle of deposition represented by the younger sedimentary deposits are probably related to the climatic and base-level changes associated with the drastic rise in sea level between 15,000 and 5,000 years ago.

Depositional processes disrupted severely by recent human activity.

Topographic form and relation to modern drainage

Forms flat flood plains and terraces in narrow valleys. Forms well-drained levees and flat flood plains in broad valleys. Forms well-drained small alluvial fans where small streams flow from narrow bedrock valleys onto marine terraces. Forms well-drained stream levees and flat flood plains near the heads of large alluvial fans on the alluvial plain marginal to San Francisco Bay.

PLEISTOCENE DEPOSITS (1.8 MILLION–10,000 YEARS OLD)

Early Pleistocene alluvium (Qpea)

Physical description and lithology

Moderately consolidated, deeply weathered, poorly sorted, irregularly interbedded clay, silt, sand, and gravel.

Lithology is variable and dependent on local source rocks; for example, deposits in the north bay generally indicate the Sonoma Volcanics as a source.

Thickness

Maximum thickness unknown but at least 150 feet (46 m) thick and probably reaches a maximum thickness of 500 feet (150 m) under south San Francisco Bay.

Age

About 70,000 years and older. Maximum age unknown but probably between 70,000 and 1.8 million years old.

Distribution and stratigraphy

Exposed primarily along the highest parts of narrow valleys outside the immediate San Francisco Bay valley, such as along Dry Creek north of Healdsburg, the Santa Rosa Plain south of the Russian River, and west of Napa in Redwood Valley. These deposits generally represent the highly dissected remnants of alluvial terrace deposits. The rivers and streams that laid them down were probably similar to those that deposited the late Pleistocene alluvium. The early Pleistocene deposits generally overlie bedrock; some deeply dissected channels within them are filled with younger deposits.

Origin of deposit

Deposited from flowing water on stream terraces and alluvial fans. Similar in origin to late Pleistocene alluvium. Greater age is indicated by the deeper dissection and erosion of the soil profiles. As with the late Pleistocene alluvial deposits, these earlier ones may have been laid down during a lower stand of sea level.

Topographic form and relation to modern drainage

Forms very old highly dissected alluvial terrace deposits. Farther removed from the streams that deposited them and related, in fact, only by being in the same valley.

The fluvial regime that deposited these sediments was probably similar to the one that deposited the late Pleistocene alluvium.

Marine and Continental deposits (Qpmc)

Physical description and lithology

In the northwest and central parts of the exposed area, the Colma consists of pale-colored, loose or friable, well-sorted, fine- to medium-grained sand with subordinate gravel, sandy silt, and clay. In the southeast part of area, it consists mostly of sand and silty clay. See Bonilla (1965) for more complete description.

Thickness

Maximum thickness about 200 feet (60 m) (Bonilla, 1965).

Age

Exact age unknown but may be one-half to one million years old.

Distribution and stratigraphy

Occurs in a narrow zone between Burlingame on the southeast, through Colma Valley to Daly City on the northwest. Overlies bedrock. Locally overlain by younger deposits. Probably correlates with oldest marine terrace deposits in the southern part of San Mateo County.

Origin of deposit

Deposited in shallow marine and continental environment. The Colma was probably deposited at or near present sea level and has been subsequently uplifted and tilted to the east by tectonic forces. The site of Colma Valley was a shallow marine passageway connecting the ocean with an ancestral bay during the time the Colma Formation was deposited. The ancient site of Colma Valley was probably very much like the Golden Gate is today.

Topographic form and relation to modern drainage

Forms southeasterly tilted floor of Colma Valley. Modern streams dissecting original flat surface have formed low rolling hills.

Late Pleistocene and Holocene alluvial deposits partially fill the lower part of small valleys eroded into the Colma Formation.

Undifferentiated bedrock

No mapping was attempted for the older consolidated rock units such as the Franciscan assemblage or Great Valley sequence.

MARINE TERRACE DEPOSITS (QPMT)

Physical description and lithology

Weakly consolidated, slightly weathered sand and gravel. Usually consists of an undifferentiated lower part of shallow-water marine sediments and an upper part of alluvium and colluvium. Lower part commonly consists of conglomeratic sand or fine- to medium-grained micaceous sand overlain by horizontally bedded and cross-bedded medium- to coarse-grained sand. Upper part generally consists of poorly sorted, irregularly bedded sand and gravelly sand.

Lower part of deposits on youngest terrace contains shallow-water molluscan shells and occasional marine mammal skeletal remains.

Thickness

As much as 70 feet (20 m) thick in the Half Moon Bay area but generally less than 30 feet (10 m) thick.

Age

Deposits on the lowest and most extensive marine terrace are probably 70,000 to 120,000 years old. The deposits on the highest terraces may be one-half to one million years old and may correlate with the Colma Formation in the northern part of San Mateo County.

Lower part of younger (lowest) terrace deposits contain late Pleistocene marine molluscan fauna.

Distribution and stratigraphy

Occurs on flat, gently sloping, wave-eroded platforms along Pacific Coast between sea level and 500 feet above sea level. Overlies bedrock. Locally overlain by alluvial deposits and by sand dunes. Some of the deposits on the highest terraces in the southern part of the coast may correlate with the Colma Formation in the northern part of San Mateo County.

Origin of deposit

Lower marine part deposited in shallow, nearshore marine environment. Upper continental part deposited as alluvium and (or) colluvium by streams and (or) mudflows. Marine terraces and their deposits formed during periodic high stands of sea level. All terraces were probably formed at or near present sea level but have been subsequently uplifted, tilted, and folded by tectonic forces.

Topographic form and relation to modern drainage

Forms flat, gently tilted and warped terraces along the Pacific Coast. Lateral continuity of terraces has been destroyed by faulting, folding, wave erosion (cliff retreat) and steam dissection. Terraces have generally elevated above sea level and are not part of the modern terrace erosion cycle, which was initiated about 5,000 years ago when sea level reached its present elevation.

Late Pleistocene alluvium (Qpa)

Physical description and lithology

Weakly consolidated, slightly weathered, poorly sorted, irregular interbedded clay, silt, sand, and gravel. Grades progressively from coarse-grained stream deposits on abandoned terraces in bedrock canyons and at the heads of old alluvial fans into fine-grained alluvial fan and fresh-water marsh deposits near the present shore of the bay.

Contains local accumulations of fresh-water gastropods and pelecypods and continental vertebrate fauna including camel, bison, horse, sloth, and mammoth.

Thickness

Maximum thickness unknown, but at least 150 feet (46 m) thick. Maximum thickness of entire sedimentary pile beneath south San Francisco Bay is probably between 1,000 and 2,000 feet (300–600 m).

Age

About 10,000 years old and older. Maximum age unknown but probably between 35,000 and 70,000 years old.

Locally contain late Pleistocene (Rancholabrean) vertebrate and invertebrate fossil faunas.

Distribution and stratigraphy

Exposed primarily along the highest part of the broad alluvial plain marginal to the bay. Along the northern bay margin and along the Pacific Coast occurs on abandoned flood plains deeply incised by channels that are partly filled by younger alluvial deposits. Along the southern bay margin overlapped by younger deposits. Inter-

fingers with and grades into older basin deposits near and under the bay. Overlies bedrock and marine terrace deposits along the Pacific Coast. Overlies bedrock, the Colma Formation, and deformed older sedimentary deposits (bedrock) on alluvial plain marginal to the bay.

Origin of deposit

Deposited from flowing water in stream channels, on stream terraces, and on alluvial fans. Similar in origin to younger alluvial fan deposits; greater age is indicated by slight consolidation and better soil profile development than on younger deposits. The upper part of this unit in the bay basin was deposited by streams graded to lower stands of sea level; the bay did not exist during period of deposition.

Topographic form and relation to modern drainage

Forms old, slightly dissected alluvial fans with subdued levees and stream channels. Forms dissected, abandoned flood plains in bedrock canyons and on coastal marine terraces. Incised by modern streams in canyons and at the heads of old alluvial fans.

The fluvial regime that deposited these sediments was very similar to the recent one that deposited the younger alluvial deposits.

Beach(?) and dune sand deposits (Merritt Sand) (Qps)

Physical description and lithology

Loose, well-sorted, fine- to medium-grained sand with subordinate silt.

Thickness

Maximum thickness near Oakland of about 50 feet (15 m).

Age

Overlies peaty mud older than 40,000 years (radiocarbon-dated), therefore oldest deposits at least 40,000 years old but may include younger deposits.

Distribution and stratigraphy

Exposed at northeast end of south San Francisco Bay near southwest Oakland, in Alameda, and on Bay Farm Island. Recognized in borehole logs to extend under San Francisco Bay southwestward to the latitude of the San Mateo-Hayward Bridge. Also extends westward intermittently across the bay and may correlate in part with dune deposits in San Francisco.

Origin of deposit

Probably derived chiefly by wind eroding and transporting stream sediments during lower stands of sea level that occurred more than 40,000 years ago but probably less than 100,000 years ago. May have been modified by beach or shoreline processes as sea level rose.

Topographic form and relation to modern drainage

The distribution and shape suggest that the present form is little modified and is probably primary. The large prong-like dunes are oriented parallel to the ancient northwest wind direction.

GEOLOGIC MAPPING TECHNIQUES

One of the main purposes of the current geologic study of the San Francisco Bay region has been to differentiate the alluvial and estuarine deposits underlying the gently sloping (less than 15 percent) sedimentary plain between the bay and the surrounding hills. Specificially, attempts were made to relate deposits to the processes that were responsible for their origin. Shortcuts and innovative mapping techniques have been used because approximately 7,500 square miles (19,425 km^2) was mapped in only 3 years. The alluvial units are defined by various geologic criteria such as depositional environment, geomorphic expression, soil-profile development, age, induration, compaction, and texture. The distribution of the units is determined primarily from topographic maps, published soil series maps, and aerial photographs. Figures 15, 16, 17, and 18 illustrate the evolution of such a geologic map for a small area near Palo Alto. The late Quaternary deposits of the entire region are mapped on plates 1, 2, and 3. This mapping differs from a soil series map in that it considers greater thicknesses than the upper few feet and is largely based on the process by which the deposit was laid down. For example, floodbasin deposits are shown separately from alluvial fans.

On the basis of relative soil-profile development, the 18 alluvial soil series described in the Soil Conservation Service (1968) report on the region (fig. 16) fall into two distinct groups that reflect some basic differences in the deposits on which they are developed. The soil units with strongly developed weathering profiles constitute one group, and those with weakly

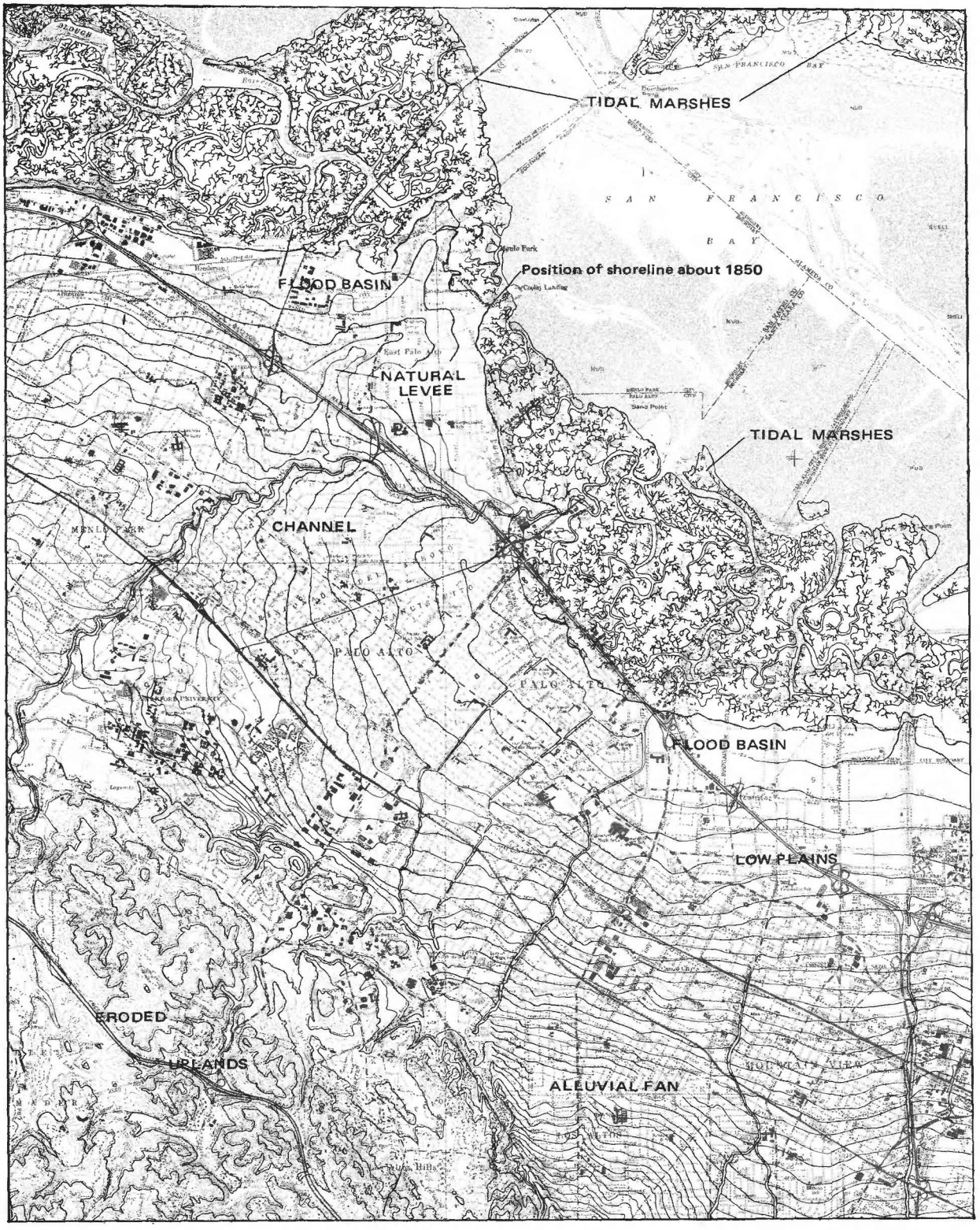


FIGURE 15.—Alluvial deposits related to geologic processes in the Palo Alto area. The enhanced contour lines (derived from USGS 7.5-minute Mountain View and Palo Alto quadrangles) reveal the fluvial geomorphic features, alluvial fans, natural stream levees, and floodbasins on the broad alluvial plain between the bay marshlands and the irregular bedrock uplands. Distribution of former tidal marshland from Nichols and Wright (1971).

to moderately developed weathering profiles constitute the other. Soil profiles are developed by physical and chemical weathering processes at the surface of the Earth; therefore, well-developed soil profiles generally indicate that the materials on which they are formed have been exposed to either intense weathering conditions or moderate weathering conditions for a considerable length of time. The alluvial deposits on which the strongly developed weathering profiles occur were inferred to be significantly older than the deposits on which the weakly to moderately developed profiles occur because the weathering conditons in the bay region are relatively uniform. These two groups of deposits, therefore, simply indicate younger and older alluvial deposits. (fig. 17).

The younger deposits make up the alluvial fans being formed under the existing regime. The streams forming these young fans are graded to present sea level. These younger deposits and the bay mud into which they grade are informally referred to as Holocene deposits (fig. 18). The older alluvial deposits, now partly covered by the Holocene deposits, make up alluvial fans formed by these same streams when they were graded to lower stands of sea level during the late Pleistocene (prior to about 10,000 years ago). These older deposits are informally referred to as late Pleistocene alluvium (fig. 18).

The Holocene alluvium is differentiated further into depositional units called facies (fig. 18) on the basis of textural characteristics (that is, gravel, sand, silt, and clay) obtained primarily from published soil reports and unpublished engineering foundation reports, and the depositional environment (such as stream levees and floodbasins) determined from geomorphic expression as shown on topographic maps and aerial photographs. These facies grade from coarse-grained gravel and sand deposits, which form prominent stream levees at the highest part of the alluvial fans, into medium-grained sand and silt deposits, which form broad flood plains and subdued levees along the lower margins of the alluvial fans. These stream deposits grade into and interfinger with fine-grained silt and clay deposits, which form the flat floor of floodbasins between stream levees on the outer margins of the alluvial fans directly adjacent to the bay marshlands. These fine-grained basin deposits and some of the medium-grained levee deposits interfinger with and grade into the bay mud—the carbonaceous silty clay that was deposited in the marshes and on the mudflats of San Francisco Bay during Holocene time (roughly the past 10,000 years).

This gradation from coarse-grained to fine-grained sediment in the Holocene alluvium is a natural consequence of very recent stream erosion, transportation, and deposition. The coarsest rock debris eroded from the bedrock uplands is deposited near the base of the hills where the rapidly flowing streams enter the broad, gently sloping alluvial plain. Only the finer grained debris is carried by the ever-slackening water to the lower parts of the alluvial fans and eventually into the bay itself where it is deposited as bay mud. The landward extent of the saturated, plastic bay mud underlying the former marshes and tidal mudflats of San Francisco Bay (fig. 15) was established from early (ca. 1850) U.S. Coast and Geodetic Survey hydrographic charts (Nichols and Wright, 1971) rather than from direct field observation, because human activity over the past 50 years has obscured its original distribution.

Long exposure to erosion and weathering processes has altered the original geomorphic expression and physical character of the late Pleistocene alluvial deposits, thus they have not been separated into depositional facies similar to those of the Holocene alluvial deposits in this study.

In the areas of the bay region where detailed soils data are not available, the alluvial deposits have been differentiated by using only the geomorphic and genetic criteria derived from aerial photographs and extrapolated from areas where detailed soils data provide the main and most reliable means of recognition. Fossils, archeological remains, and radiometric ages corroborate the relative ages and correlations based on these limited data. The upper part of the late Pleistocene alluvial deposits contains a Rancholabrean fossil vertebrate fauna consisting mainly of extinct species (for example, camel, horse, bison, mammoth, and ground sloth), whereas the Holocene alluvial deposits contain a fossil fauna completely modern in aspect (for example, deer and elk).

The upper part of the late Pleistocene alluvium contains fossil wood and fresh-water molluscan shells that yield radiocarbon dates of about 22,000 years ago. Holocene alluvial deposits contain fossil wood, shells, and archeological remains that yield radiocarbon dates of about 5,000 years or less. Peat and shell deposits in the bay mud yield radiocarbon dates that range from about 9,600 years at the base of the unit in the lowest parts of the basin to modern age at the top of the unit. These ages from the bay mud date the latest marine transgression into the basin—a transgression that agrees very well with the post-Pleistocene rise in sea level established from worldwide data (Milliman and Emery, 1968). In general, the partial flooding of the basin resulting from this rise in sea level raised the base level of the local

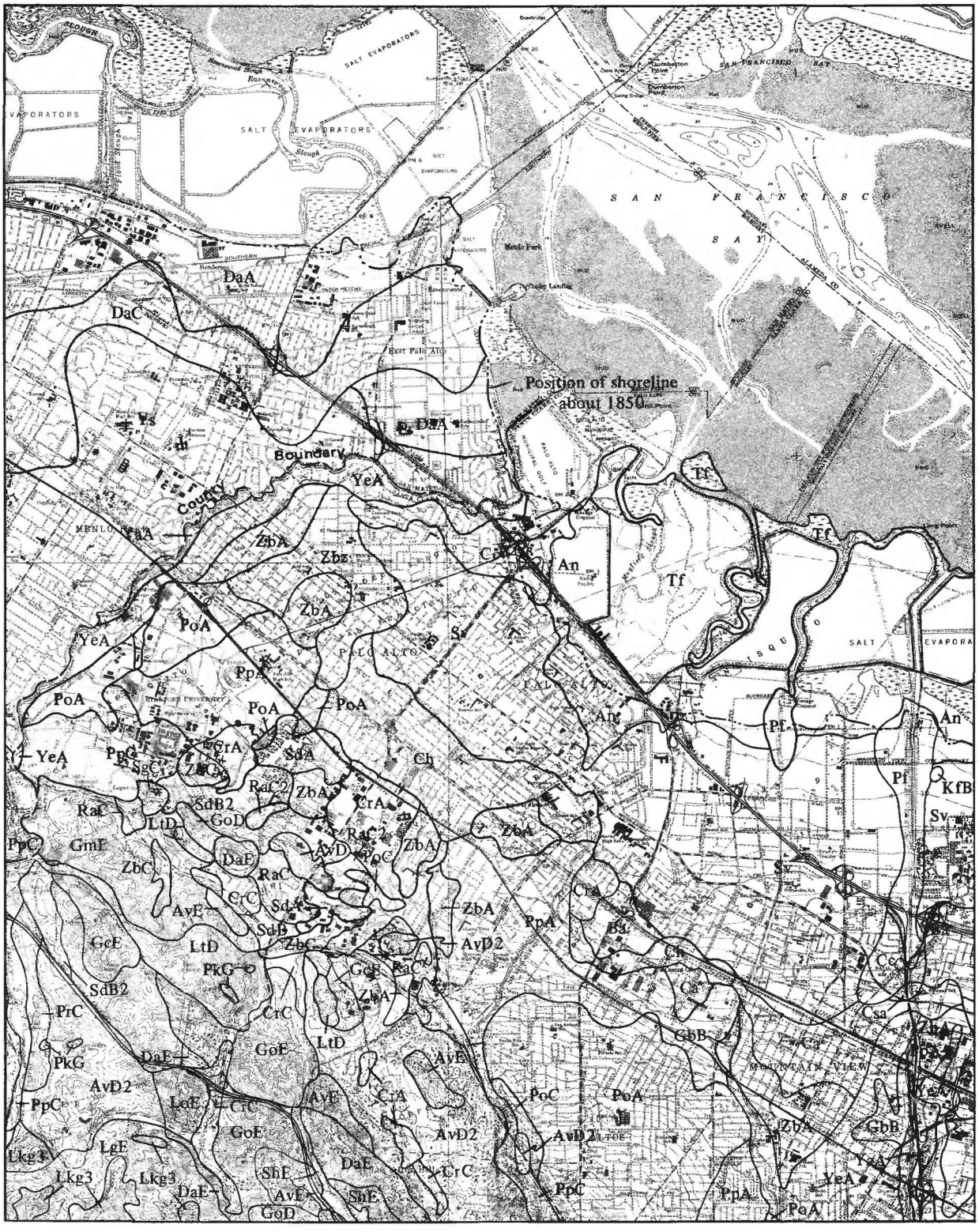


FIGURE 16.—Soil units in Palo Alto area. Soil units are defined primarily on the basis of profile development, texture, and slope. Soil profile development is controlled by many factors including time, climate, parent material, slope, and biological activity. In this area where weathering conditions and parent material are relatively uniform, the time factor is clearly expressed by relative soil-profile development, which can therefore be used as a means of differentiating alluvial deposits on the basis of relative age. The symbols shown on the map refer to the names of local soil series.

EXPLANATION

Soil Series in the Palo Alto area*

Alluvial soil series with weakly to moderately developed weathering profiles:

An	Alviso clay
Ba	Bayshore clay
Ca	Campbell silty clay loam
Cc	Campbell silty clay loam, clay substrate
Ch	Clear Lake clay, drained
CrA	Cropley clay; 0- to 2-percent slopes
CrC	Cropley clay; 2- to 9-percent slopes
Csa	Cropley clay loam; 0- to 2-percent slopes
GbB	Garretson gravelly loam; 0- to 5-percent slopes
Pf	Pacheco loams, clay substrate
Sv	Sunnyvale silty clay, drained
YaA	Yolo loam; 0- to 2-percent slopes
YeA	Yolo silty clay loam; 0- to 2-percent slopes
Ys	Yolo loam; no slope given, taken from older survey
ZbA	Zamora silty clay loam; 1- to 3-percent slopes
ZbC	Zamora clay loam; 2- to 9-percent slopes
Zbz	Zamora clay loam; 0- to 2-percent slopes

Alluvial soil series with strongly developed weathering profiles:

PoA	Pleasanton loam; 0- to 2-percent slopes
PoC	Pleasanton clay loam; 0- to 2-percent slopes
PpA	Pleasanton gravelly loam; 0- to 2-percent slopes
PpC	Pleasanton gravelly clay loam; 2- to 9-percent slopes
RaC	Rincon clay loam; 0- to 2-percent slopes
RaC2	Rincon clay loam; 2- to 9-percent slopes
SdA	San Ysidro loam; 0- to 2-percent slopes
SdB	San Ysidro loam; 2- to 9-percent slopes
SdB2	San Ysidro loam; 2- to 9-percent slopes, eroded

Upland soil series (nonalluvial soils):

AvD	Azule silty clay laom; 2- to 9-percent slopes
AvD2	Azule silty clay loam; 9- to 15-percent slopes
AvE	Azule silty clay loam; 15- to 30-percent slopes
DaA	Diablo clay; 0- to 2-percent slopes
DaC	Diablo clay; 2- to 9-percent slopes
DaE	Diablo clay; 15- to 30-percent slopes
GcE	Gaviota loam; 15- to 30-percent slopes
GoD	Gilroy clay loam; 5- to 15-percent slopes
GoE	Gilroy clay loam; 15- to 30-percent slopes
GmE	Gaviota-Los Gatos complex; 15- to 30-percent slopes
LgE	Los Gatos clay loam
LoE	Los Osos clay loam; 15- to 30-percent slopes
Lkg3	Los Gatos and Maymen complex; 50- to 75-percent slopes
LtD	Los Trancos stony clay; 15- to 30-percent slopes
PrC	Positas-Saratoga loam; 2- to 9-percent slopes
ShE	Soper gravelly loam
SgC	Saratoga-Positas loam; 2- to 9-percent slopes

Miscellaneous map symbols:

KfB	Kitchen middens, archeological site
PkG	Gravel pits
Tf	Tidal mudflats

*From U.S. Soil Conservation Service (1968)

FIGURE 16.—Continued.

streams and began the present depositional cycle represented by the Holocene alluvial deposits. The fact that the Holocene alluvial deposits around the margins of the bay are graded to the present sea level is used as one means of identifying these deposits and adds credence to the relative ages and correlations based on other criteria. The stratigraphic relations of the various alluvial facies are shown in figure 19 for the plain bordering San Francisco Bay.

PHYSICAL PROPERTIES OF GEOLOGIC UNITS

Physical properties of the various geologic units such as texture, thickness, bulk density, induration, and seismic velocity are needed to assess their potential for becoming geologic hazards. These properties were compiled or interpreted from readily available sources (fig. 20) and were augmented by direct measurement where no data existed or where verification of existing data was needed. This information also was used to differentiate units where soil series were ambiguous or had not been mapped.

Very few data are available on the total thickness of the unconsolidated and semiconsolidated deposits filling the bay basin. A few deep drill holes and several seismic profiles (Hazelwood, 1974) indicate that these sediments are probably more than 1,970 feet (600 m) thick in the San Jose Area and decrease irregularly to 200–300 feet (60–90 m) to the north near San Francisco.

The thickness of the younger units is fairly well known from numerous shallow bore holes described in engineering reports (fig. 20) and from shallow seismic surveys where bore-hole data are lacking. The Holocene alluvium (fig. 18) generally ranges in thickness from about 50 feet (15 m) near the heads of alluvial fans to about 10 feet (3 m) near the margins of the bay. The Holocene bay mud ranges in thickness from 0 to as much as 120 feet (36 m).

The thickness of the late Pleistocene alluvium (fig. 18) is not precisely known because its base is not distinctly defined in the thick sedimentary section beneath the bay and the surrounding alluvial plain. Where the base of the late Pleistocene alluvium can be seen on stream terraces in narrow valleys, these sediments are about 10 feet (3 m) thick. They are probably as much as 130 feet (40 m) thick beneath the bay where they overlie an old estuarine mud identified by marine fossils brought up in a drill sample. Still older Pleistocene alluvial deposits probably underlie these deeply buried estuarine muds, but their total thickness is not known. In the southern bay area, these deposits may grade downward into the Pliocene and early Pleistocene alluvial deposits or may lie unconformably on them.

Published soils maps and unpublished engineering reports from highway departments and engineering consultants are the main source of data on the physical properties of the various geologic units. Each unit generally has a distinctive range of values for properties such as grain size, sorting, bulk density, compaction, induration, and moisture content. This relation is true partly because some of the units, in particular the three facies of Holocene alluvium, are defined and delineated by using physical properties

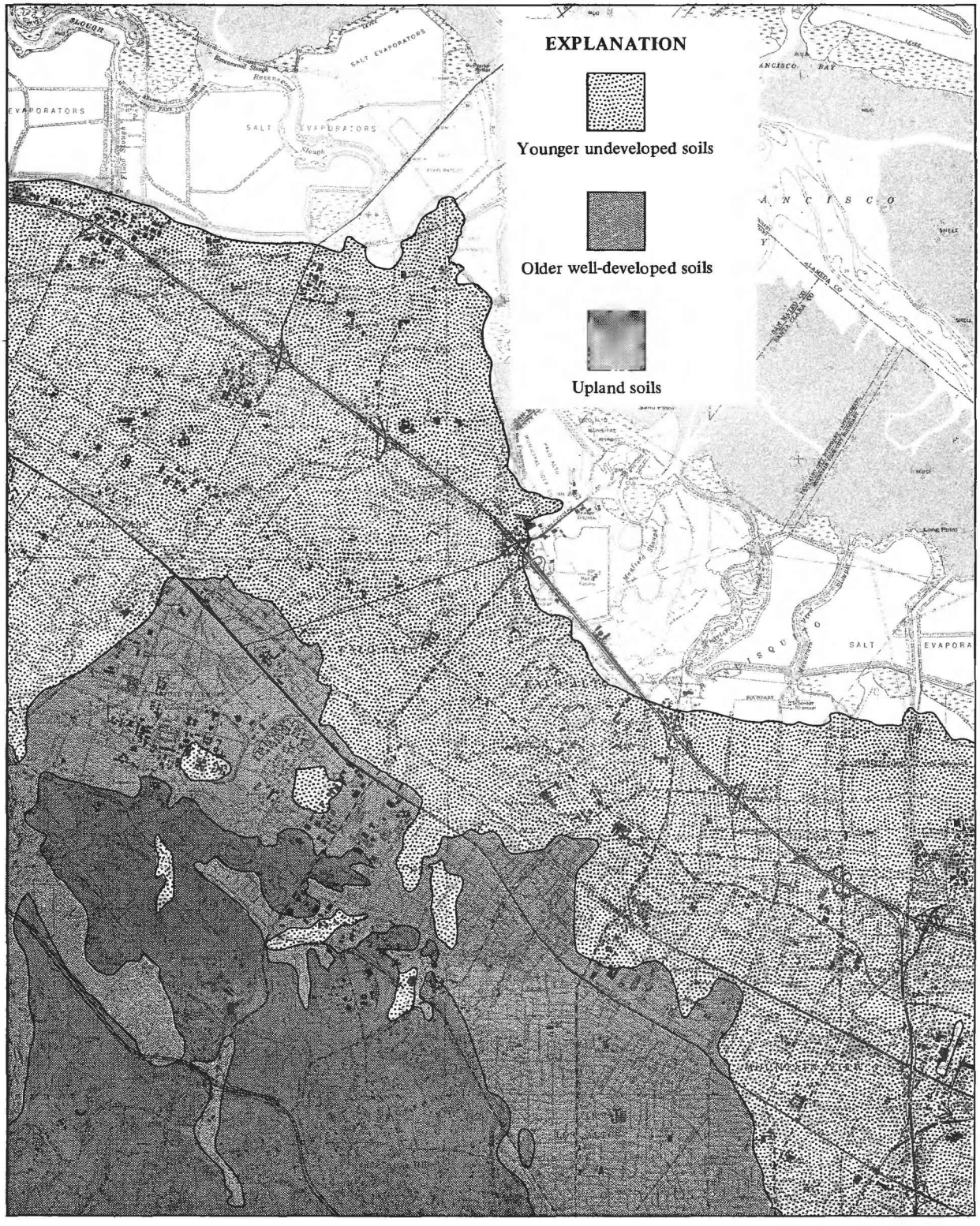


FIGURE 17.—Distribution of younger and older alluvial deposits in the Palo Alto area as determined primarily from relative soil-profile development of soil series as mapped by Soil Conservation Service (fig.15). Alluvial deposits on which weak to moderate weathering profiles are developed were initially inferred to be younger than alluvial deposits on which strong weathering profiles are developed. Radiocarbon and fossil data have confirmed this relative age classification. The younger alluvial deposits contain modern vertebrate and invertebrate fossils and organic remains that yield radiocarbon ages of about 5,000 years ago and younger. The older alluvial deposits locally contain extinct late Pleistocene vertebrate fossils such as camel, sloth, bison, and mastodon, and organic remains that yield radiocarbon ages of about 20,000 years.

such as grain size and induration.

The primary physical properties such as grain size and sorting are controlled by the depositional environment, whereas the secondary properties such as induration, compaction, and bulk density generally increase with age of the geologic units. This variation of the secondary physical properties with age is indicated by the increasing penetration resistance from the Holocene deposits to the various bedrock units. The very low penetration resistance of the bay mud is attributable to its extremely high water content, fine grain size, and loose packing, which reflect its youthful age. Older, deeply buried estuarine muds would have higher penetration resistances due to loss of water during compaction. Penetrometer resistance can be used to estimate relative densities which, with data on grain size, sorting, and moisture content, can be used to evaluate liquefaction potential in shallow, unconsolidated deposits. Liquefaction of unconsolidated materials may or may not cause ground failure; the conditions that determine whether or not ground failure is likely to occur are given in table 1.

Figures 21–24 illustrate the range of some physical properties of the geologic map units. These properties were compiled and interpreted from readily available sources, such as bridge and highway data and private engineering reports, and were augmented by direct measurement where no data existed or where verification of existing data was needed. Numerical values were excluded because statistical validity could not be determined for so vast an area. These diagrams, then, are to be interpreted only as a general guide to the physical properties and should not be substituted for on-site investigation.

TABLE 1.—*Factors and conditions controlling liquefaction—induced ground failure*

Factor affecting liquefied material	Condition conducive to ground failure	Condition not conducive to ground failure
Lateral confinement	Not confined Along stream banks Near cliff faces	Confined laterally Depression such as a floodbasin Flat plain
Slope	Gentle to steep slopes Alluvial fans to hillslopes	Horizontal to gentle slopes Flat alluvial surfaces Flat floors of floodbasins
Loading	Nonuniform loading Differential thickness of overlying material	Uniform loading Uniform thickness of overlying material

SEISMIC PROPERTIES

The relation between seismic behavior and specific physical properties is still not well known. Seismic properties of the various units are described in terms of their response to seismically induced energy rather than in terms of any inherent physical characteristic. Experience has shown, however, that low-density, water-saturated, soft sediments tend to amplify some components of seismic energy. Consequently, more shaking will occur in areas underlain by these sediments. Because of the amplification of bedrock motion, great damage may be expected (depending on the nature of the structure) where these soft sediments are thickest. Areas with different shaking characteristics can be determined from studying good geologic maps. Distinctions can commonly be made on the basis of firmness and geologic age (Borcherdt, Joyner, Warrick and Gibbs, 1975). Figure 25 shows the change in P (compressional) and S (shear) wave velocities as a function of depth (also age) at Ravenswood Point, San Mateo County.

The stratigraphic relations and seismic velocities (P-wave and S-wave) of the various deposits are shown in a block diagram for part of south San Francisco Bay (fig. 26). This area was chosen because reliable information on depth to bedrock as well as reliable velocity data were available.

POTENTIAL PROBLEMS IN FLATLAND REGIONS

The geologic units shown on the regional flatlands map (pl. 1) have characteristics that constrain or favor particular uses of the land. Some potential problems and opportunities can be quite accurately identified from the map. Others can be only broadly inferred; definition requires additional, more specific information.

WATER-RELATED PROBLEMS

The flatland deposits are traversed by the many streams that formed them. These water courses, big and small, can flood, overtopping their banks and inundating lowlands. High ground-water conditions usually exist during the winter rainy season and can cause problems in low-lying basins and marshes fringing the bay that are underlain by units such as bay mud, fine-grained alluvium, and fine-grained salt-affected alluvium.

During the summer drought, ground water supplies are usually heavily used for irrigation. Overdraft of the ground water has led to both land subsidence and salt water encroachment. A general summary of the water-related processes is shown in figure 27. The diagram shows the kinds of problems that may be associated with the different flatland deposits from the foot of the bedrock uplands down to the tidal mudflats. Surface water obviously plays a significant role in distributing the sedimentary materials, which in turn can control the ground water characteristics.

FIGURE 18.—Rock units in the Palo Alto area.

FIGURE 18 EXPLANATION
ROCK UNITS IN THE PALO ALTO AREA

Description of Map Units

Holocene deposits (less than 10,000 years old):

Estuarine deposits (0–9,000 years old):

Qhbm Bay mud. Water-saturated estuarine mud; predominantly clay and silty clay underlying marshlands and tidal mudflats of San Francisco Bay. Contains a few lenses of well-sorted fine sand and silt and a few shelly and peaty layers. Interfingers with and grades into fine-grained and medium-grained alluvium; generally overlies early Holocene alluvium or late Pleistocene alluvium 0–120 ft (0–40 m) thick.

Alluvial deposits (0–5,000 years old):

Qhaf Fine-grained alluvium. Plastic, poorly sorted carbonaceous clay and silty clay in poorly drained interfluvial basins marginal to bay marshlands. Locally contains thin beds of well-sorted silt, sand, and fine gravel; contains modern vertebrate fossils and fresh-water gastropod and pelecypod shells. Interfingers with and grades into bay mud and medium-grained alluvium; overlies late Pleistocene alluvium. Generally less than 15 feet (5 m) thick.

Qhafs Salt affected fine-grained alluvium; same as Qhaf but containing high concentration of salt.

Qham Medium-grained alluvium. Loose, moderately drained, moderately sorted sand forming alluvial plains and stream levees. Locally contains beds of well-sorted clay, silt, and gravel; contains modern vertebrate fossils and fresh-water gastropod and pelecypod shells. Intermediate in character and lateral extent between fine-grained and coarse-grained alluvium with which it interfingers; generally overlies late Pleistocene alluvium. Generally less than 21 feet (7 m) thick.

Qhac Coarse-grained alluvium. Loose well-drained, moderately sorted, permeable sand and gravel forming stream levees and flood plains on higher parts of alluvial fans; gravel becomes dominant toward fan heads. Locally contains beds of well-sorted silt, sand, and gravel; contains modern vertebrate fossils and fresh-water pelecypod and gastropod shells. Thickness ranges from as much as 50 feet (15 m) at fan heads to 20 feet (6 m) where these deposits interfinger with and grade into medium-grained alluvium; overlies late Pleistocene alluvium and bedrock.

Pleistocene deposits (10,000–3,000,000 years old):

Qpa Late Pleistocene alluvium (10,000–70,000? years old). Weathered, slightly consolidated and indurated alluvial fan deposits consisting primarily of gravel and sand with some silt. Less permeable than Holocene alluvium. Locally contains fresh-water pelecypod and gastropod shells and extinct late Pleistocene vertebrate fossils. Overlain by Holocene deposits on lower parts of alluvial plain; incised by channels that are partly filled with Holocene alluvium on higher parts of alluvial plain. Maximum thickness unknown but at least 150 feet (45 m) near margins of present bay where these deposits overlie deeply buried Pleistocene estuarine deposits.

Bedrock:

Qpea Early Pleistocene and Pliocene alluvium. Tectonically deformed alluvial-fan deposits with local minor amounts of shallow-water marine deposits. Weakly to moderately indurated gravel, sand, and silt with subordinate amounts of lacustrine silt and clay; local thin tuff beds; contains late Pliocene and early Pleistocene vertebrate fossils. Underlies late Pleistocene alluvium; overlies or in fault contact with Franciscan Formation. Consists of the Santa Clara Formation in southwest bay area.

Br Undifferentiated Tertiary bedrock. Well-indurated sandstone, shale, and volcanic rocks. In map area underlies or is in fault contact with Pliocene and early Pleistocene alluvium.

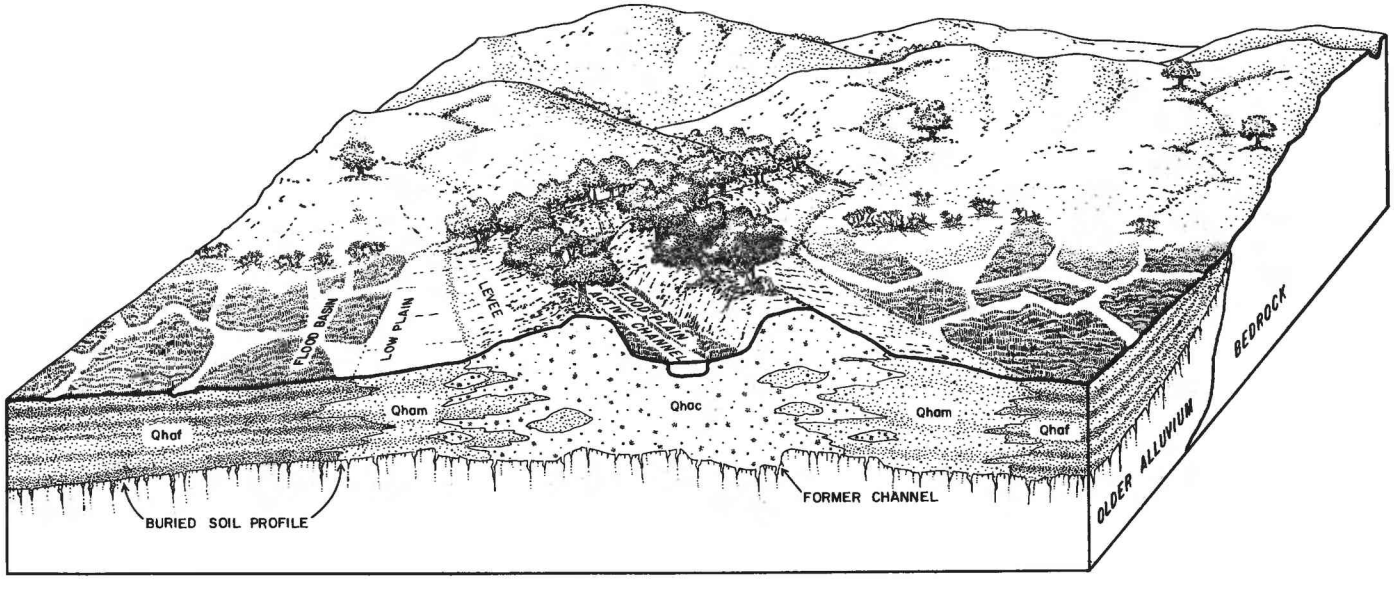


FIGURE 19.—Facies relations in younger alluvial deposits.

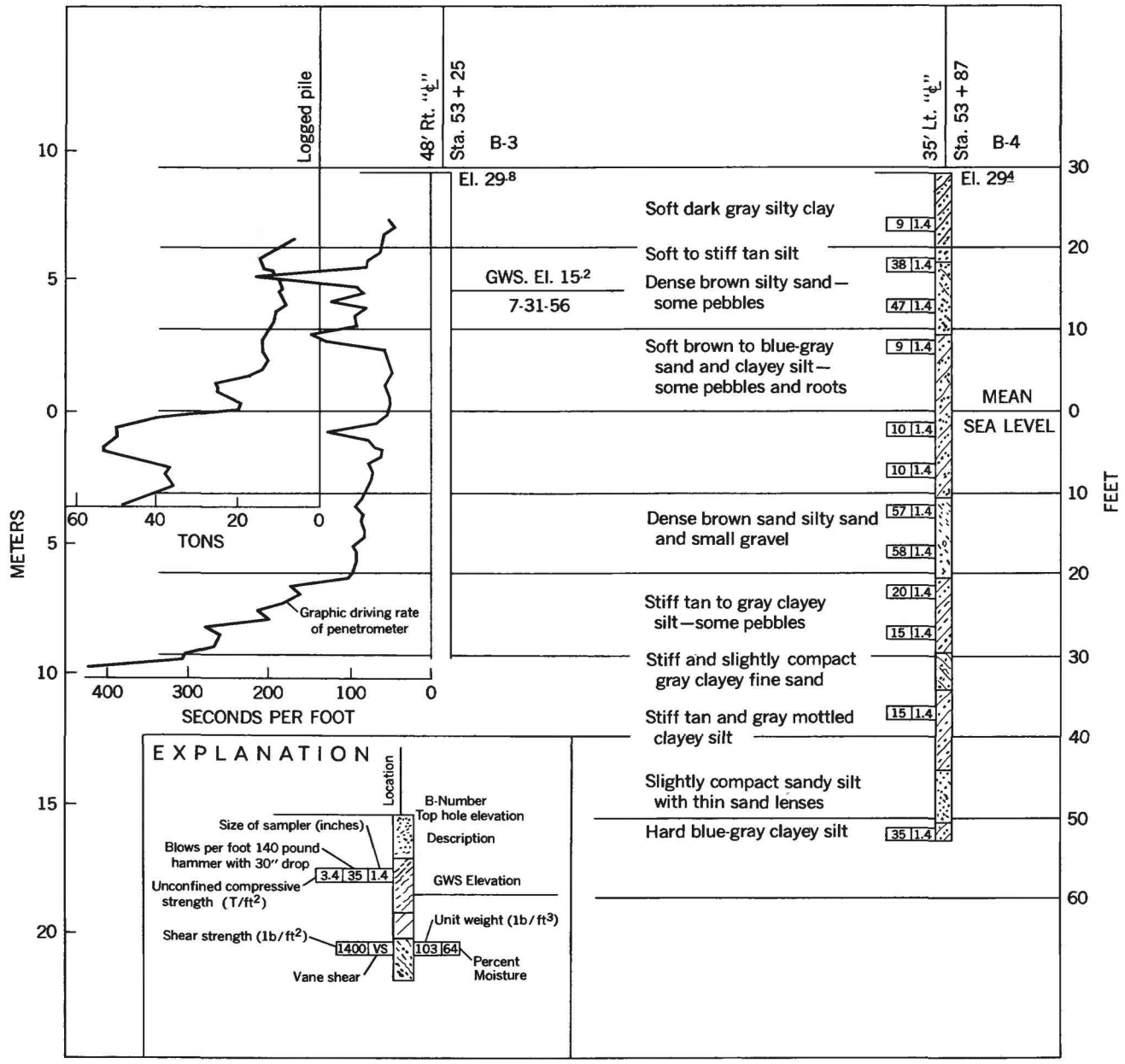


FIGURE 20.—An unpublished highway engineering boring log from which thickness and physical properties of alluvial deposits were partly derived. The sudden decrease in the driving rate of the penetrometer at 20 feet (6.3m) is interpreted to be the stratigraphic contact between the Holocene alluvium and the underlying late Pleistocene alluvium.

FIGURE 22.—Ranges of relative natural moisture content of the geologic map units shown on plates 1–3. Moisture content is the amount of moisture in a given mass of natural material expressed as weight of water divided by weight of oven-dried material, usually multiplied by 100 to give a percentage. Usually moisture content decreases with geologic age; however, units that extend below sea level, such as beach and dune sand deposits (Qhs), Pleistocene beach? and dune sand deposits (Qps), and marine terrace deposits (Qpmt) may be saturated.

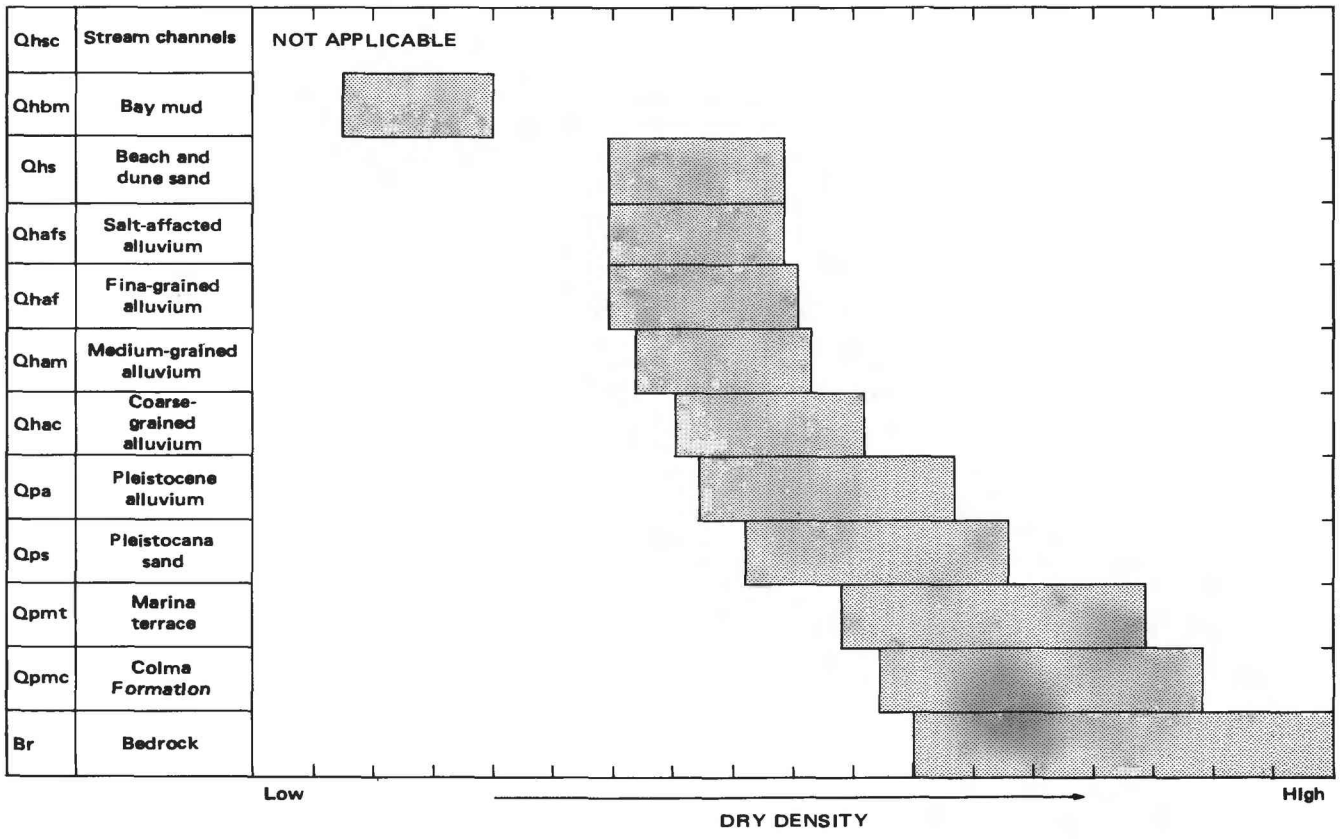
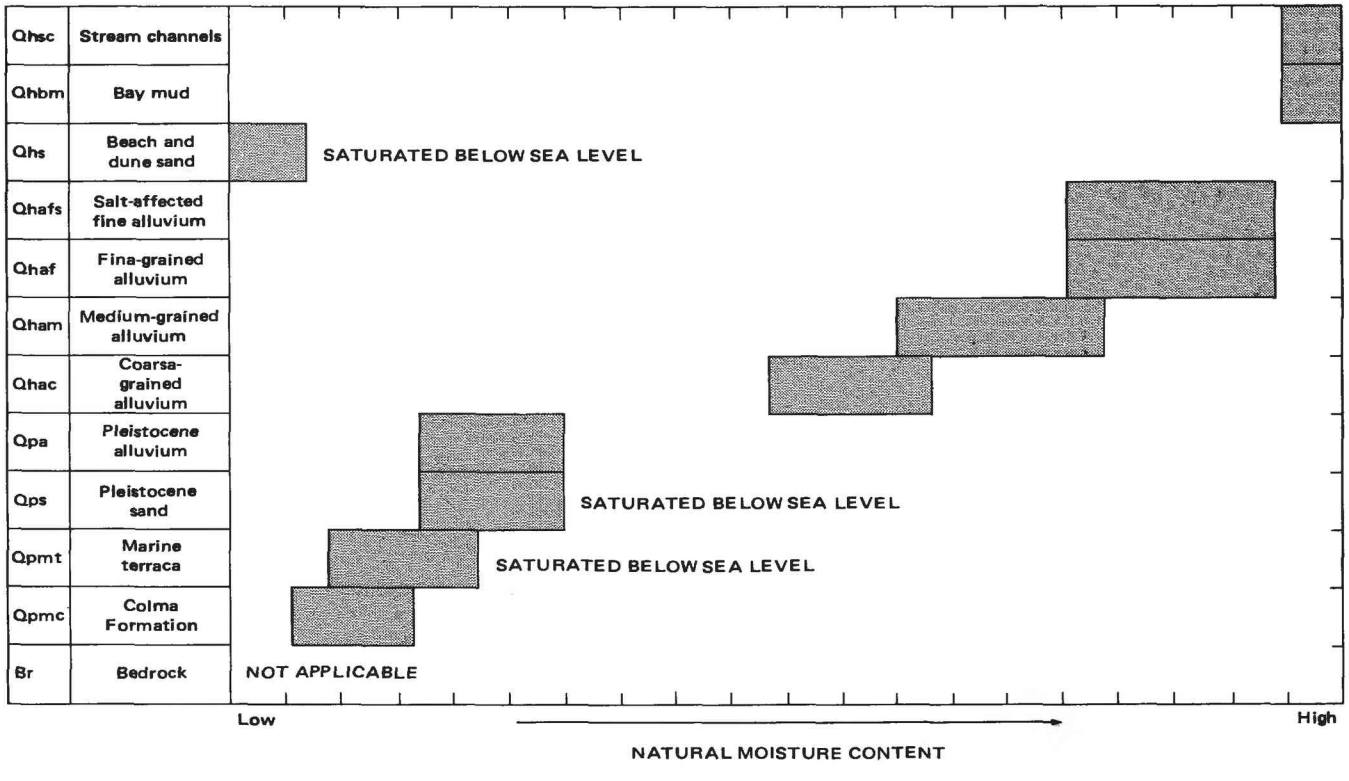


FIGURE 21.—Ranges of relative dry densities of the geologic map units (pls. 1–3). Dry density is a measure of the mass of earth materials relative to an equal volume of water. For planning purposes geologic units that have higher densities are generally better foundation materials and behave with lower ground-motion amplification during earthquakes. It should be noted the dry densities increase with geologic age of the map unit.



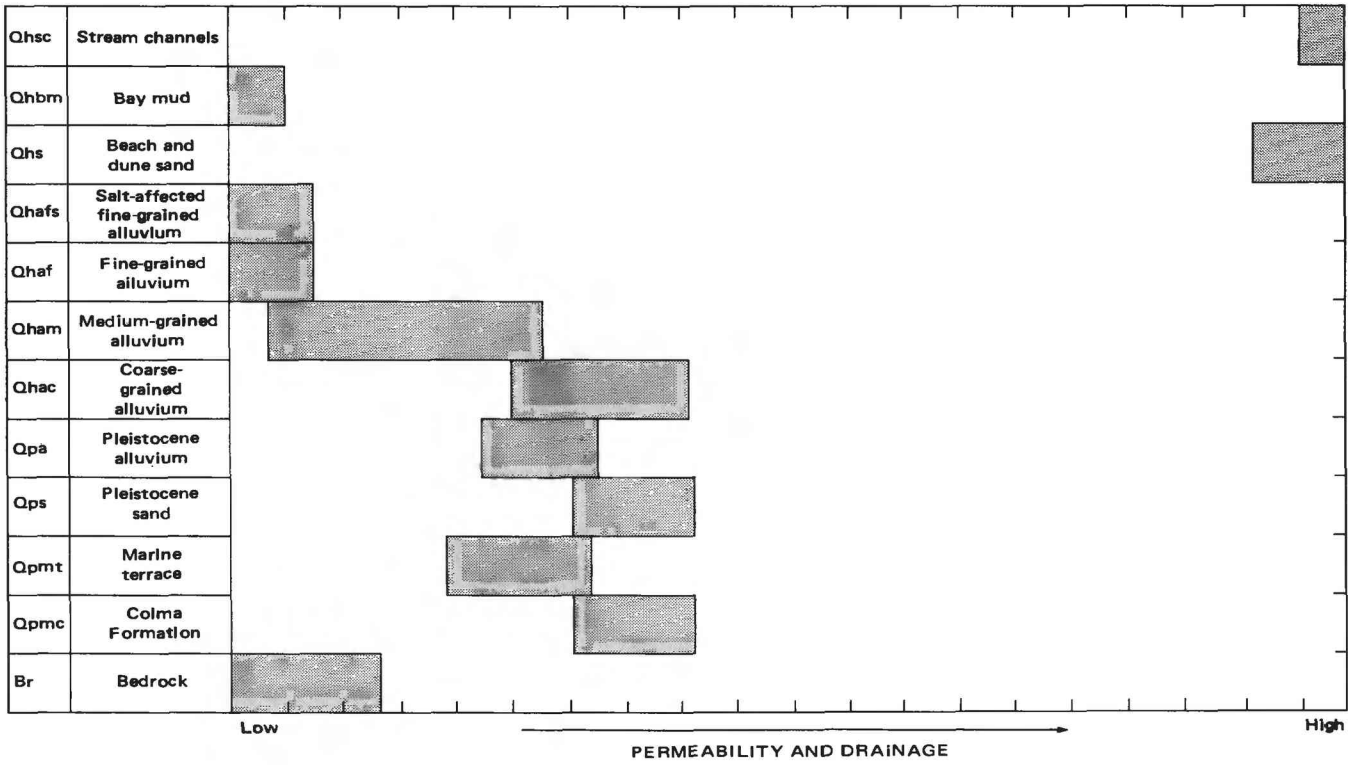
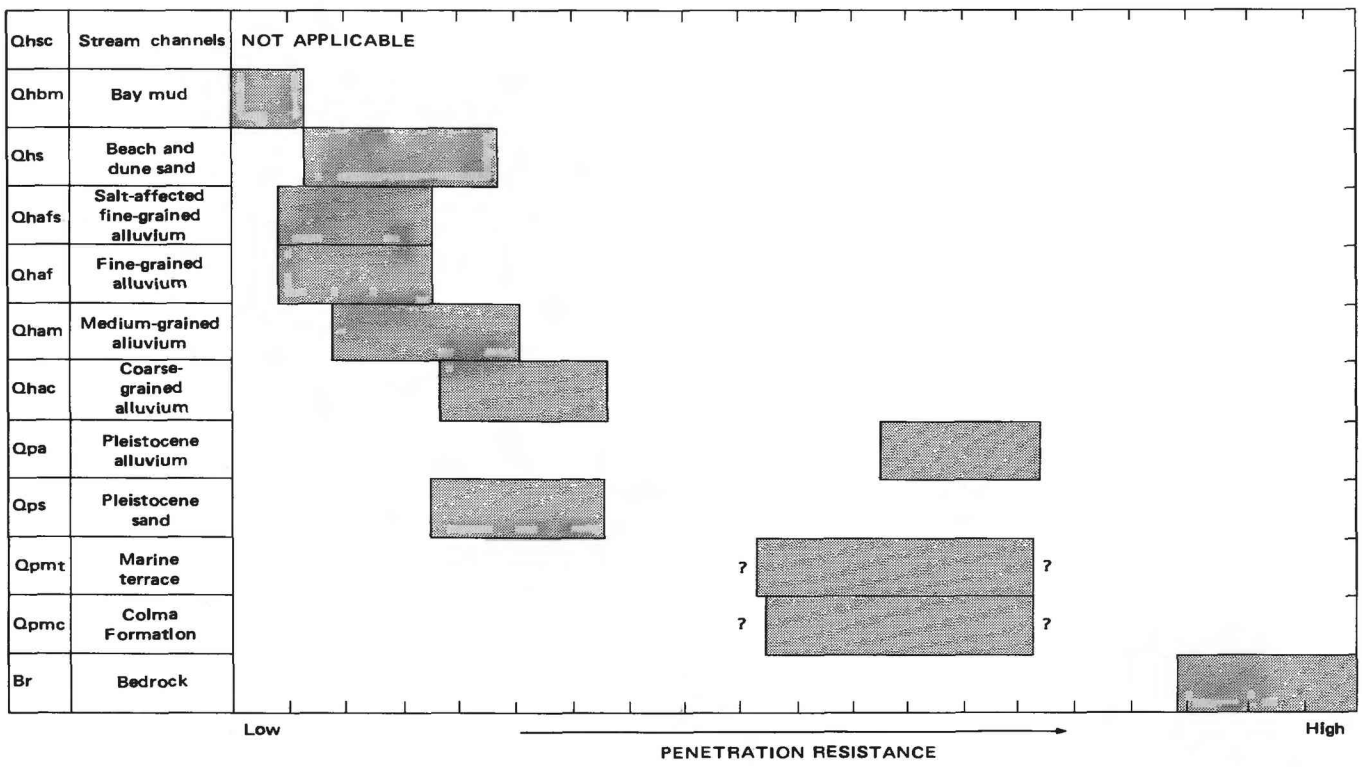


FIGURE 23.—Ranges of relative permeability of the geologic map units. Here permeability refers to the property or capacity of a geologic unit to transmit a fluid; it is a function of the porosity and compaction of the geologic units. In general, fine-grained units such as Qhbm (bay mud) and Qhaf (fine-grained alluvium) have low permeabilities and are poor transmitters of fluids. Such units will be poorly drained and pose problems of standing water especially during the rainy season.



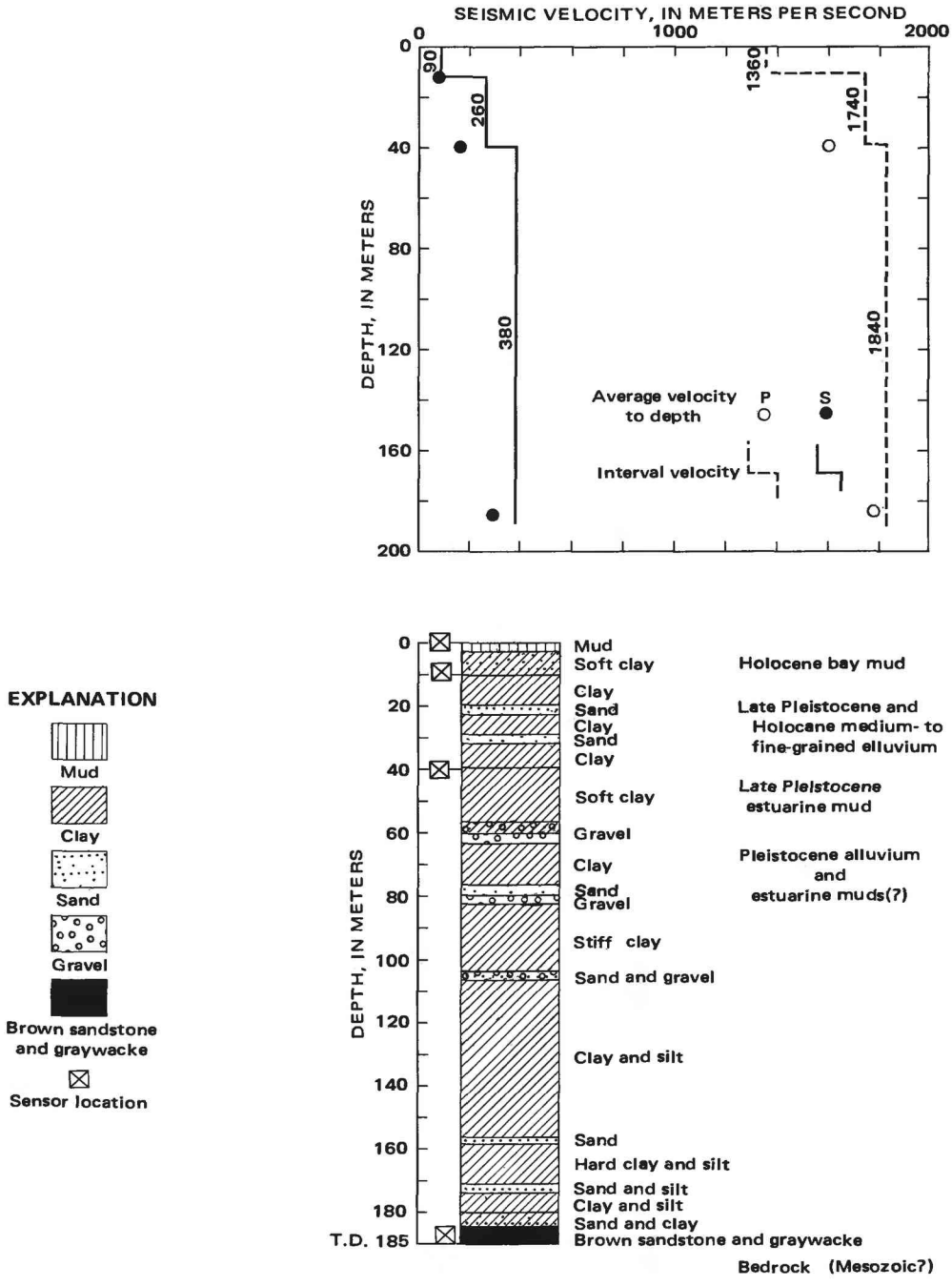


FIGURE 25.—The seismic properties of the rock units at Ravenswood Point, San Mateo County (Warrick, 1974). The schematic vertical section shows the sediments related to depth; the graph shows the change in P-wave and S-wave velocities in relation to depth and age.

◄ FIGURE 24.—Ranges of the relative penetration resistance of the geologic map units. Penetration resistance is measured in the field by the "standard penetration test" that determines the number of blows required by a standard weight (140 lbs, 63 kg), when dropped from a standard height (30 in, 0.76 m), to drive a standard sampling spoon a standard penetration (12 in, 0.3 m). Units with low penetration resistance generally make poor foundation materials. Note that penetration resistance tends to increase with geologic age.

FLOODING

Because the Holocene alluvial sediments were deposited primarily by floods along streams of the present drainage system, there should be a significant correlation between their distribution and the

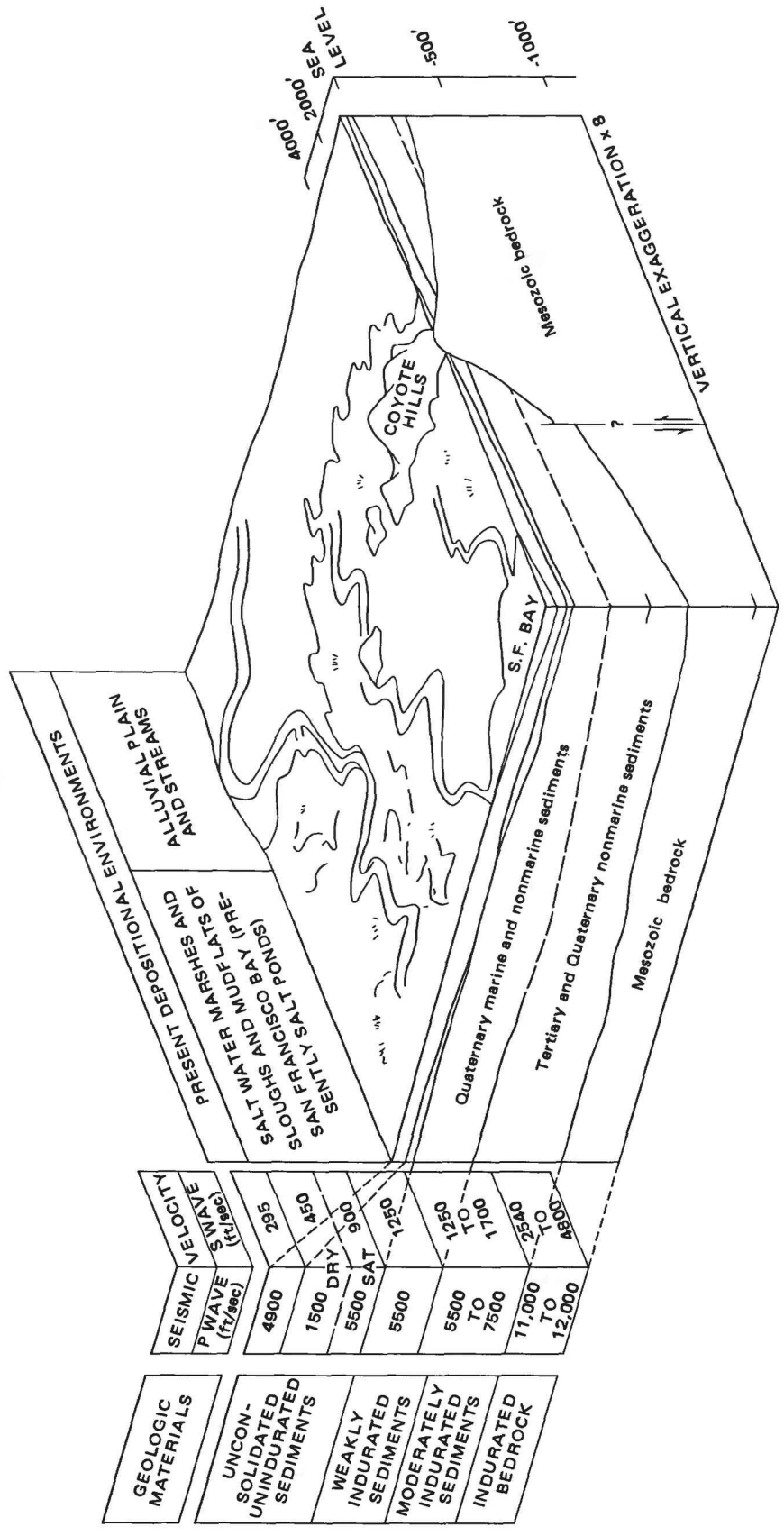


FIGURE 26.—Stratigraphic relations and seismic velocities.

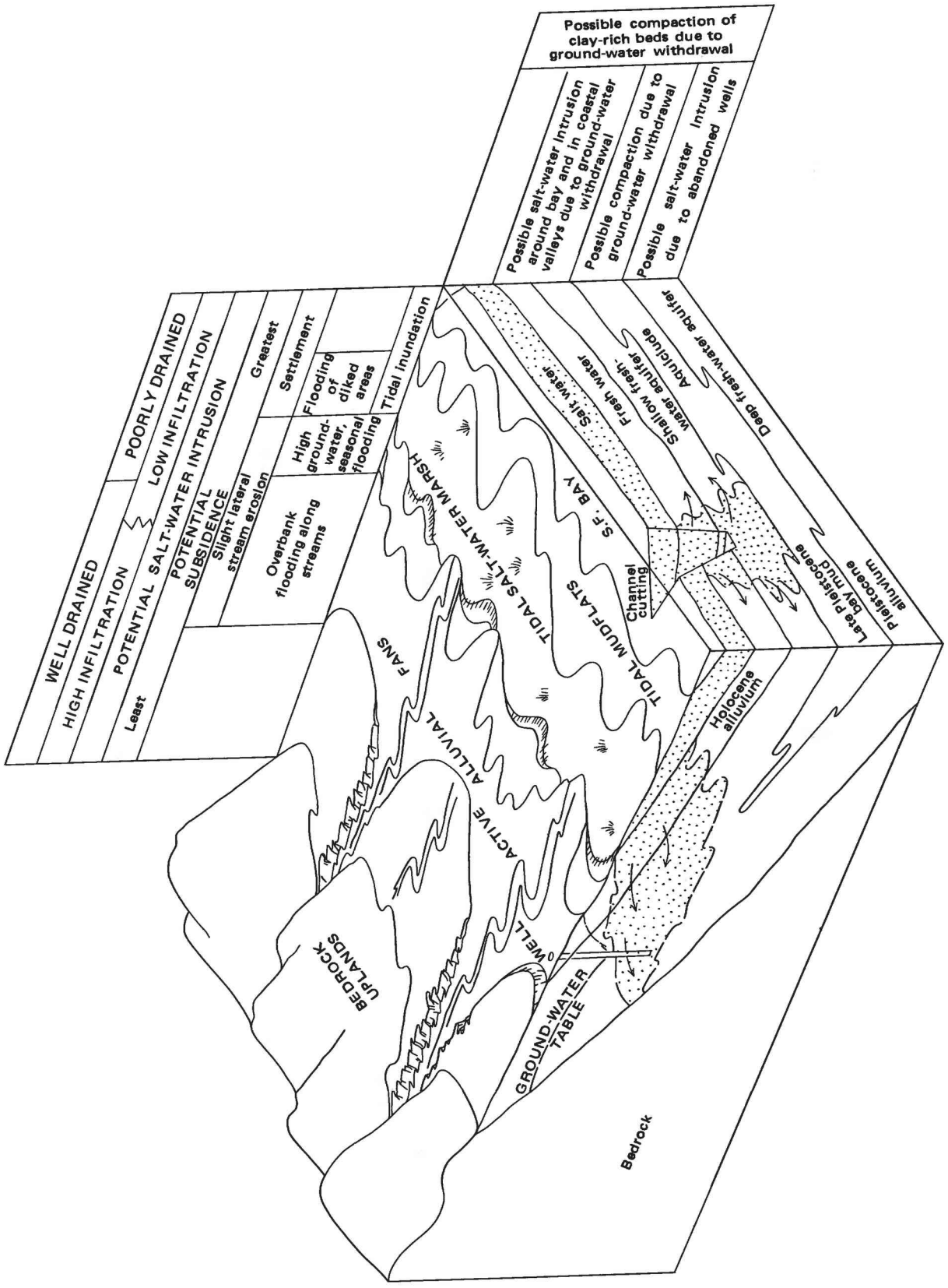


FIGURE 27.—Potential water problems on the alluvial plain bordering San Francisco Bay.

areas inundated by historic floods. A comparison of maps showing the distribution of Holocene deposits (fig. 18) and flood-prone areas derived from historical flood data and hydrographic data (fig. 28) indicates that this correlation is strongest on modern flood plains underlain by the coarse- and medium-grained Holocene deposits and the low floodbasins underlain by fine-grained deposits at the outer edges of the Holocene alluvial fans. Without modern flood-control measures the correlation would probably have been greater in the alluviated areas. As expected, the tidal marshes underlain by Holocene estuarine deposits are flood prone.

The map of flood-prone areas provides a more accurate delineation of areas currently subject to flooding than the flatland deposits map. However, in areas where direct information pertaining to flooding is not available, an approximate delineation of flood-prone areas can be made if the distribution of young alluvial deposits is known. In addition to geologic maps of unconsolidated deposits, such as the flatland deposits map, soils maps showing alluvial materials may be used to locate flood-prone areas.

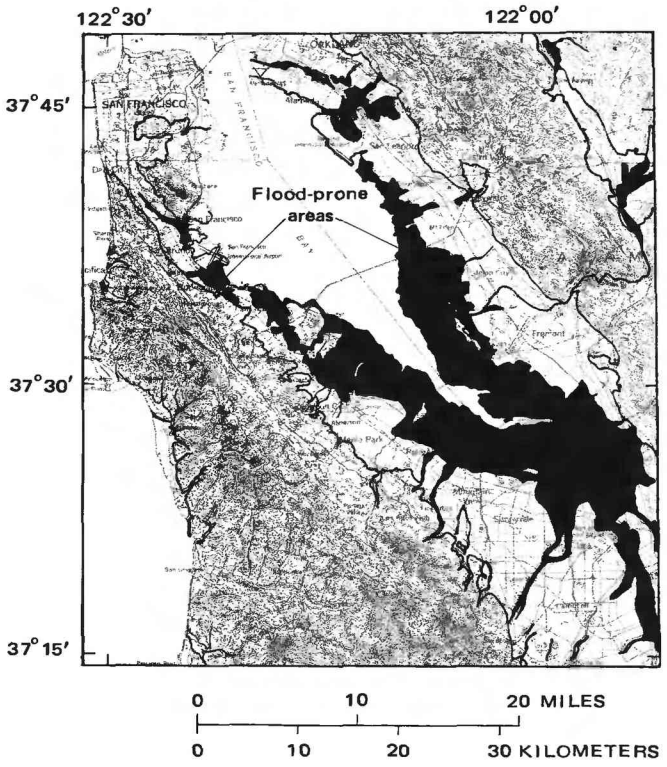


FIGURE 28.—Flood-prone areas in the San Francisco Bay basin based on distribution of Holocene sediment. The sediments at the ground surface within the shaded areas were deposited predominantly by floodwaters over the past 5,000–7,000 years. After Limerines, Lee, and Lugo (1973).

STREAM CHANNEL CHANGES

Natural lateral stream migration is a slow process generally caused by streambank erosion and occurs most commonly on flat valley floors where streams rework their own levee and flood-plain deposits (principally the coarse- and medium-grained Holocene deposits). However, the channels of most streams have been severely modified by artificial channels and revetments, and lateral migration caused by streambank erosion has been greatly reduced.

Under natural conditions, sudden changes in stream courses may occur on gently sloping alluvial fans and flat valley floors when floodwaters cut through natural levees or when stream channels are filled with flood-borne debris and the stream is diverted. The numerous abandoned natural stream channel and levee systems branching from each other and radiating from the heads of large Holocene alluvial fans indicate that stream course changes were common over the past 5,000 years or so (fig. 17). Many streams, particularly those in the developed areas, have been artificially diverted into buried culverts or fairly straight lined ditches for flood control. Along many other streams natural levees have been built up and streambanks revetted. These and other flood-control practices have virtually eliminated the possibility of sudden stream course changes.

SALT-WATER INTRUSION

Salt-water intrusion or encroachment is the movement of salt water into a ground-water aquifer normally containing fresh water. Encroachment in the bay region is possible only along coastal regions where fresh-water aquifers lie below sea level and are in hydraulic continuity with sea water. Salt-water intrusion is natural in some coastal areas and bay margin where precipitation is low and aquifer recharge from upland areas is insufficient to prevent the sea water from percolating into the aquifer. Salt-water intrusion can also be caused artificially by overdraft of ground-water aquifers that are in hydraulic continuity with ocean water. Figure 29 illustrates four ways fresh-water aquifers may be intruded by salt water.

In the coastal area of central California, precipitation and ground-water recharge are generally sufficient to prevent salt-water intrusion. In the San Francisco Bay region where most ground-water aquifers are unconsolidated sedimentary deposits, salt-water intrusion is possible in alluviated lowlands surrounding the bay and in lower parts of narrow alluviated coastal valleys (fig. 30). In all

these areas, aquifers consisting of medium- to coarse-grained alluvium are in hydraulic continuity with salt water but under natural conditions have a sufficient head of fresh water to prevent intrusion.

Salt-water intrusion has affected the shallow aquifers (less than 100 feet (30 m) deep in the southern San Francisco Bay region. Several factors contributing to this condition include decline of pressure in the deep confined aquifers, lowering of the water table in the shallow aquifers, and subsidence, which has lowered stream channels and allowed tidal inflow to penetrate farther upstream and contaminate ground water from the surface (Page and Wire, 1969). Water from shallow wells in the northern Santa Clara Valley commonly contains 100 parts per million chloride but may contain as much as 700 parts per million (Page and Wire, 1969). The chloride content of water from these areas has not changed since it was first recorded in the late 1930's (Tolman and Poland, 1940). Restoring ground-water levels, sealing abandoned wells, and restricting deep dredging in the bay which might expose fresh-water aquifers can eventu-

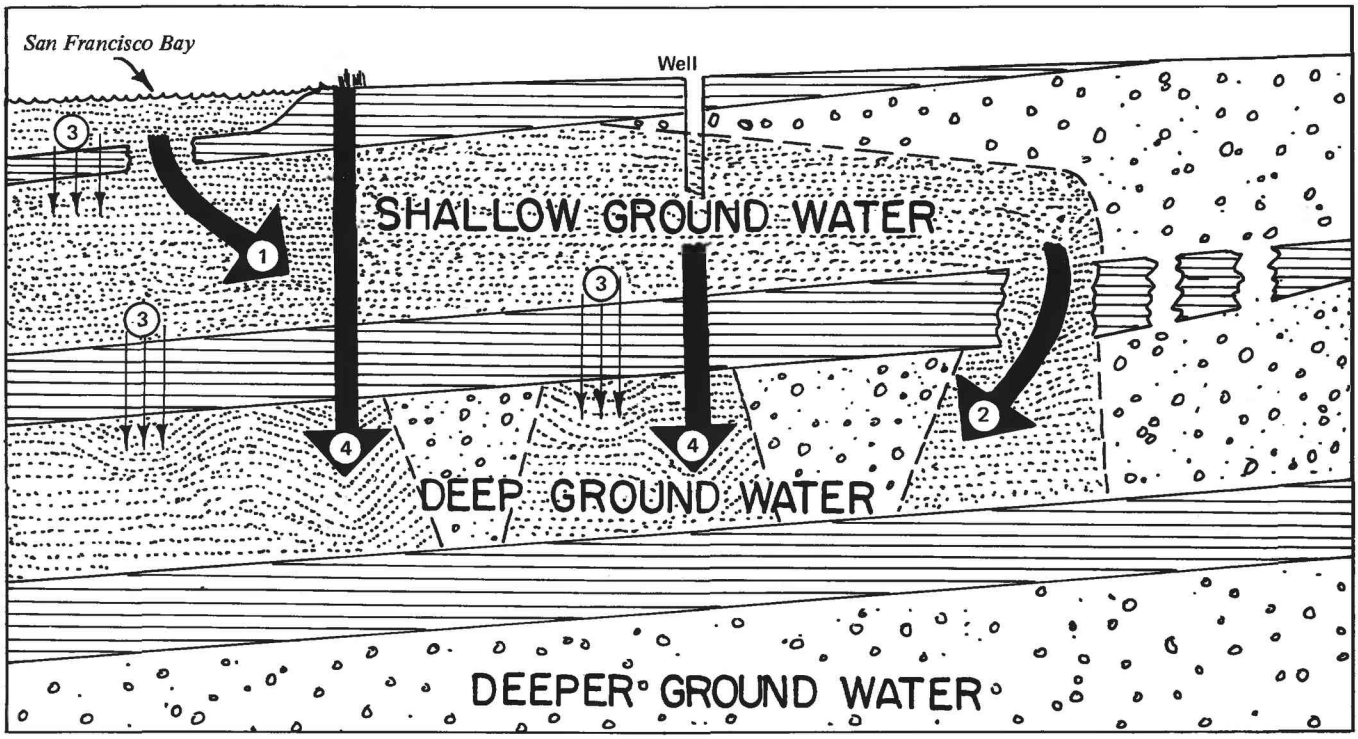


FIGURE 29.—Four ways that salt-water intrusion can occur.

ally eliminate this problem (Page and Wire, 1969). Man-induced causes of salt-water intrusion in the bay region are (1) overdraft of fresh-water aquifers in hydraulic continuity with ocean water, (2) subsidence of coastal regions owing to withdrawal of liquids or gas, which allows tidal ocean water to

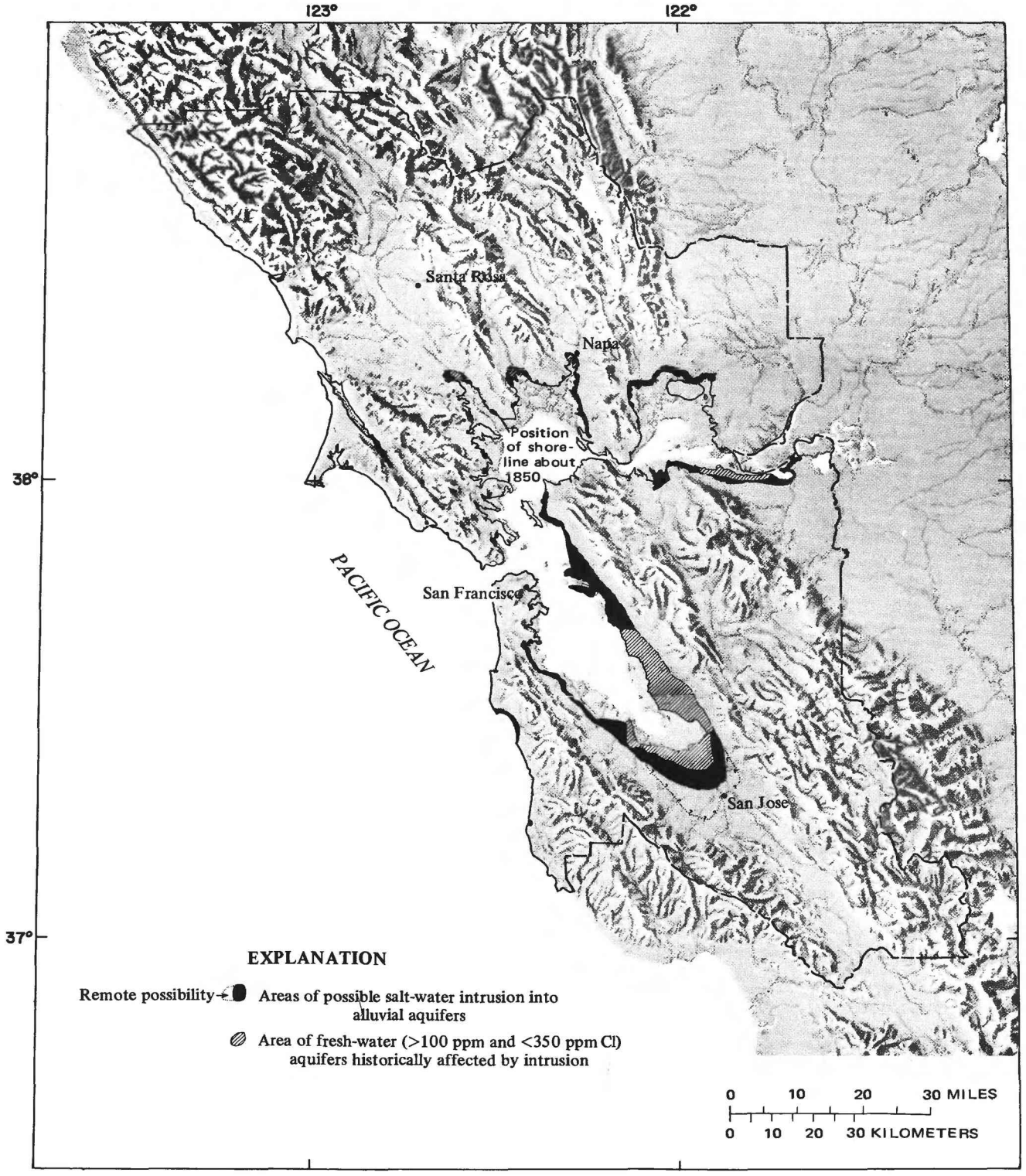


FIGURE 30.—Areas of salt-water intrusion.

penetrate farther up coastal streams, (3) depletion of discharge of coastal rivers, which allows tidal ocean water to penetrate farther upstream, and (4) penetrating aquicludes beneath estuaries by dredging or drilling, which allows salt water to enter underlying fresh-water aquifers.

SUBSIDENCE

Subsidence is the gradual settling or sinking of an area with little or no horizontal motion. Subsidence is common in flatland areas and creates land-use problems especially in coastal regions if land subsides below sea level.

Subsidence is caused by natural processes such as oxidation, solution, thawing, drying, wetting, compaction of subsurface materials, tectonic downwarping, or by a combination of these factors. The rate of natural subsidence is not known but is so low that it has not significantly affected man's activities in the bay region over the past 200 years.

Subsidence may also be caused by man's activities, such as removal of subsurface solids, liquids, or gases, or by wetting certain types of dry clay-rich sediments resulting in collapse of intergranular supporting structures. Subsidence caused by these processes may be relatively rapid and have significant impact on man's activities. This rapid subsidence is generally not hazardous to human life except where conditions are created that may trigger the failure of a dam or levee. However, subsidence has caused millions of dollars worth of property damage and necessitated expensive protective measures throughout the country.

Within the bay region subsidence primarily is restricted to the flatlands (fig. 31) and is mainly caused by three different processes: (1) collapse of clay-rich beds at depth in the center of the bay region owing to excessive ground water withdrawal, (2) oxidation of peat-rich beds near the surface in the delta region after lowering of the ground water table, and (3) withdrawal of natural gas from Tertiary rocks at depth in the Rio Vista area. Subsidence due to the first two processes is directly related to the character and distribution of flatland deposits.

Subsidence caused by ground-water withdrawal is a major problem in several parts of the bay region. Subsidence in Santa Clara Valley has been described by Poland (1971). The land adjacent to the bay subsided 2–8 feet (0.6–2.4 m) between 1912 and 1967 because of overdraft of water from confined aquifers (more than 100 ft (30 m) deep) (figs. 32 and 33). Dikes and levees have been constructed to prevent flooding of about 30 square miles (78 km^2) of salt evaporation ponds and 17 square miles (44 km^2) of area landward of these ponds. The public cost, as of 1971, of levee construction due to subsidence was about $9 million, and general cost of repair to water wells damaged or destroyed by compaction was at least $4 million.

The primary cause of the rapid subsidence in the Santa Clara Valley area was the compaction of fine-grained, clayey sediments in the central part of the valley where the ground-water table was lowered drastically by pumping. These fine-grained materials such as clay, silt, and sandy clay, which are compressible and which restrict the movement of ground water, constitute a major part of the valley fill and are most abundant in the central part of the basin. The valley fill around the margins of the basin is incompressible coarser grained material such as sand and gravel which allows ground water infiltration. To a depth of 500 feet (153 m) the deposits at Campbell are about 75 percent gravel, whereas the deposits between Agnew and Alviso to 500 ft are 80 percent clay. The subsidence potential due to compaction of fine-grained sediments is therefore much greater in the central part of the basin than around its margins (fig. 32).

Subsidence in the Santa Clara Valley was virtually halted by 1971 because the water table was raised by an extensive ground water recharge project. Water was imported and stored in percolation ponds located in the permeable deposits (primarily late Pleistocene alluvium) around the southern margins of the basin. Poland (1971) predicts that if ground water management can raise and maintain artesian head at least 20 feet (7 m) above 1971 levels, man-induced subsidence will be stopped permanently in the Santa Clara Valley.

In general the potential for subsidence caused by ground-water withdrawal in flatland regions is greatest in areas underlain by thick sequences of fine-grained sediment and least in areas underlain by a thin veneer of sediment or by coarse-grained deposits. On the basis of this generalization, the potential for subsidence in the bay region is highest in the low central part of the bay basin where bay mud and fine-grained Holocene alluvium are underlain by a thick sequence of similar deposits, and lowest at the high basin perimeter where coarse-grained sediments at the surface are underlain by thick sequences of similar deposits. Such a generalization can serve only as a very rough approximation of possible problem areas, which need to be investigated in more detail. Many other factors, particularly man's activities, influence the occurrence and rate of subsidence. It should be emphasized that compaction of fine-grained deposits makes subsidence irreversible, hence it is extremely important to avoid an overdraft of the ground water in the first place.

Subsidence primarily caused by oxidation and compaction of artificially drained peat deposits as much as 40 feet (12 m) thick, which underlie about 450 square miles (1,165 km^2) of the Sacramento-San Joaquin delta, affects a small area in the eastern part of the San Francisco Bay region (Weir, 1950). Peat is

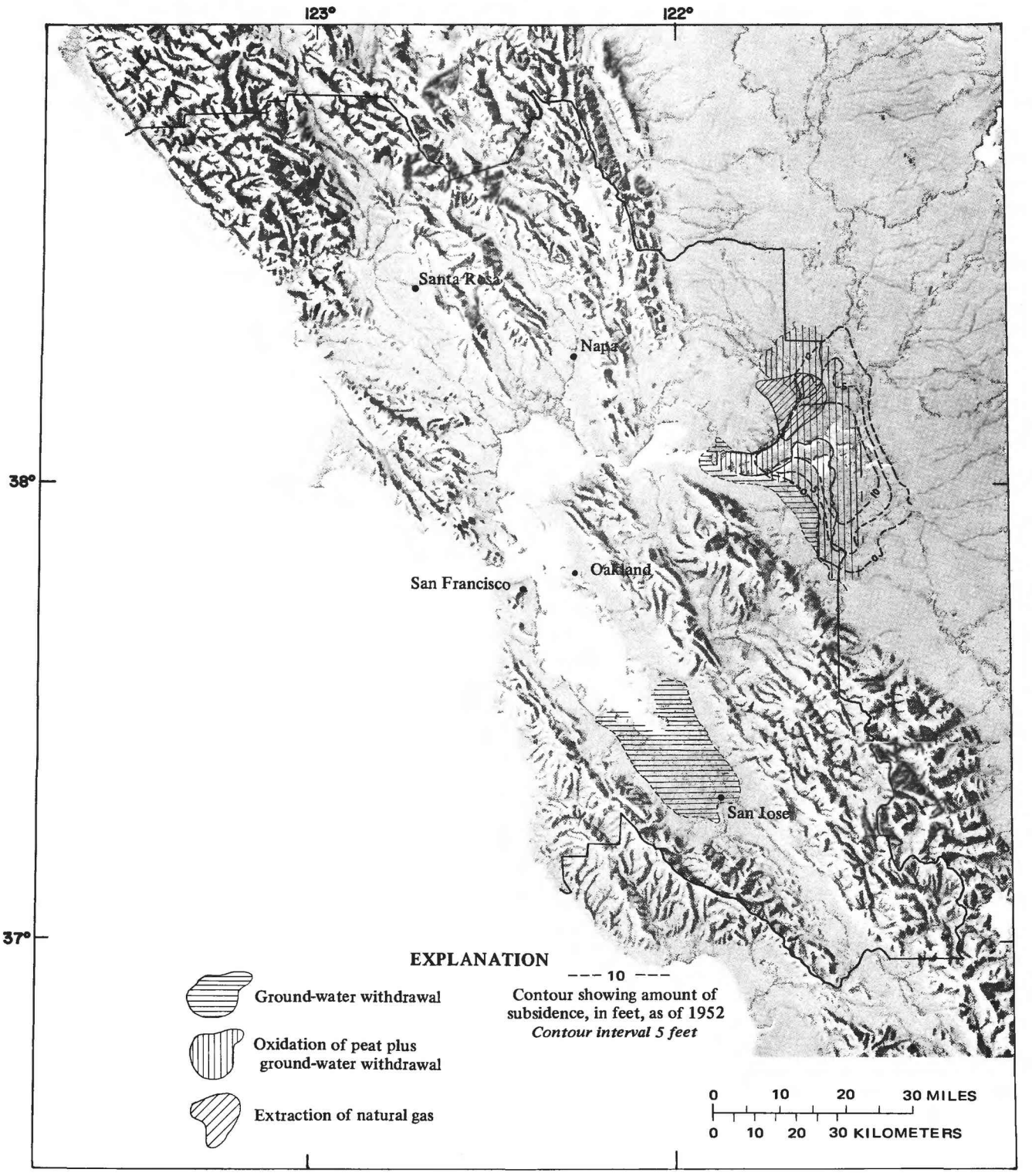
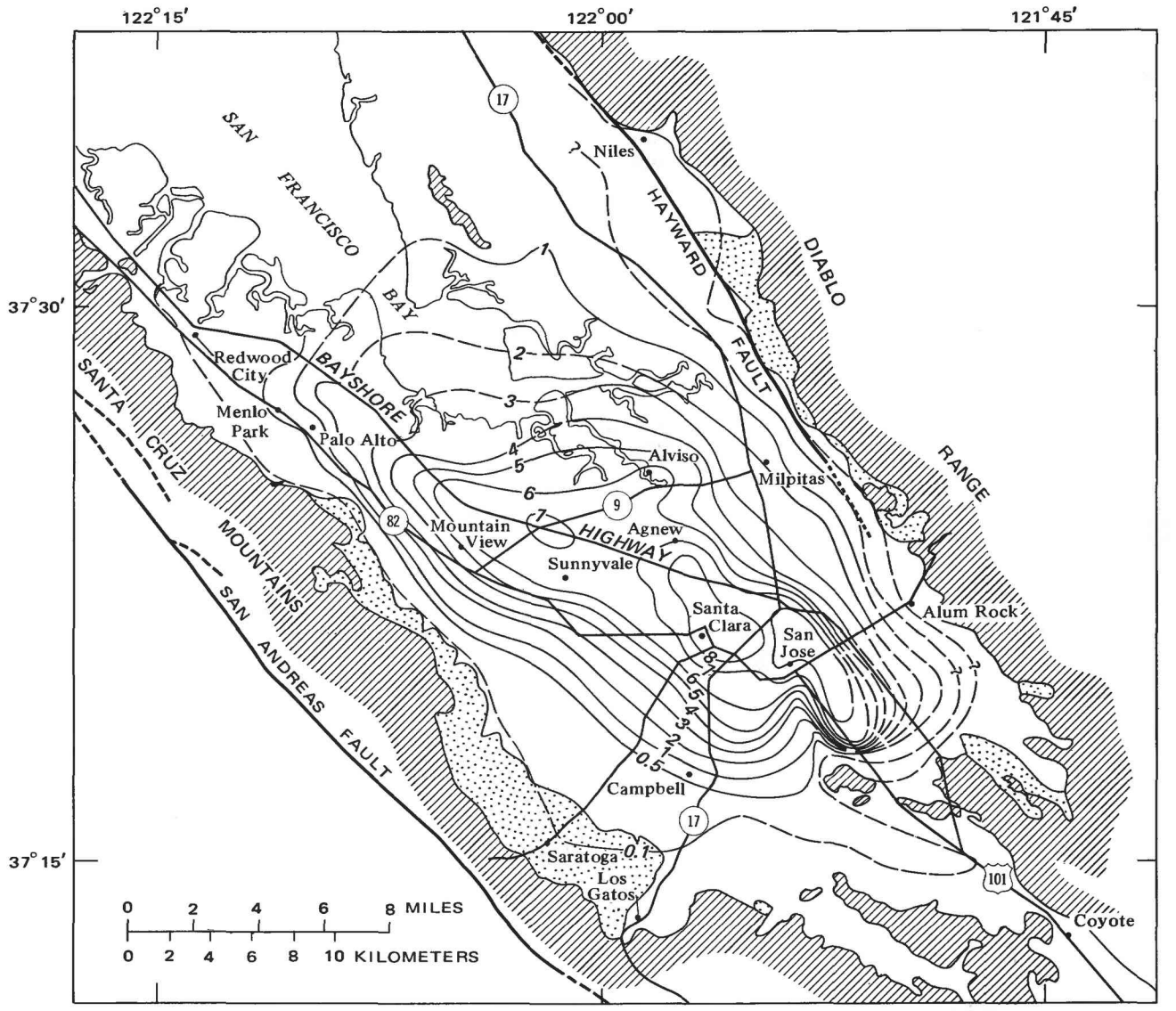


FIGURE 31.—Areas affected by subsidence.



EXPLANATION

Alluvium and bay deposits

Santa Clara Formation
Semiconsolidated deposits

Consolidated rocks
Undifferentiated igneous, metamorphic, and consolidated sedimentary rocks

Fault
Dashed where approximate; dotted where concealed

0.1
Line of equal subsidence
Interval 1, 0.5, and 0.1 foot; dashed where poorly controlled. Compiled from leveling of U.S. Coast and Geodetic Survey in May-September, 1934, February-March, 1967, and intervening releveling

Multiply by 0.304 to convert to meters

FIGURE 32.—Land subsidence from 1934 to 1967, Santa Clara Valley, California (Poland, 1969).

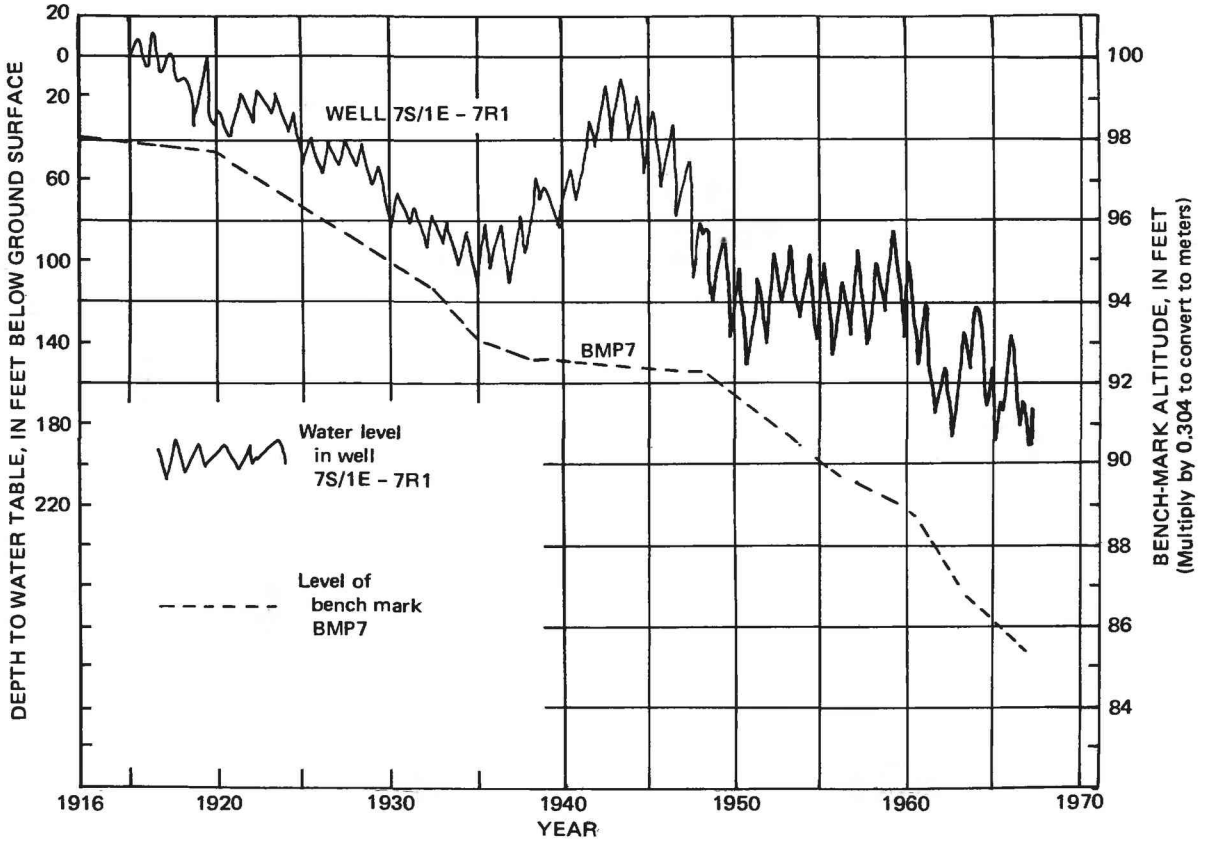


FIGURE 33.—Change in altitude at bench mark BMP7 in San Jose and change in water-table level in nearby well (from Poland, 1971). Note the close correspondence with time between the drop in water level and bench mark BMP7. Note that the scales for water level and bench mark level are different. The water table dropped almost 200 ft (60m) between 1925 and 1967, which resulted in a 13 ft (4 m) subsidence of the bench mark.

an unconsolidated deposit of partially carbonized marsh or bog plant remains with a high water content. Peat generally accumulates under acidic conditions in quiet water where there is little bacterial activity. Subsidence in areas underlain by peat-rich sediments is caused by drainage, which results in shrinkage from drying, oxidation, and wind erosion (Weir, 1950). Compaction by farm machinery and burning also contributes to subsidence in these drained, peat-rich sediments.

The total subsidence pattern in the delta area is complicated because subsidence due to ground water withdrawal is occurring throughout much of the delta region and subsidence due to natural-gas extraction from bedrock units is occurring around Rio Vista (fig. 31). The proportion of subsidence due to each process is not presently known. The subsidence due to gas extraction is not related to the flatland deposits but contributes to a serious local problem.

The main problem created by subsidence in the delta region is flooding where low flatland areas have sunk below sea level. Several parts of the delta have flooded in recent years, and the flood potential becomes greater as subsidence continues.

Three tracts of land adjacent to Contra Costa County—Bacon Island, Mildred Island, and Roberts Island—which were originally at or slightly above sea level were between 10 and 11 feet (3.0–3.4 m) below sea level (fig. 34). Between 1922 and 1946 these three islands subsided at rates between 0.2–0.3 feet (0.06 m–0.09 m) per year. The most recent data on the subsidence in the delta were published in 1948. Unfortunately no later data are available. An extensive network of dikes is needed to protect the islands from flooding. Dike failure during high tides and periods of heavy runoff has resulted in flooding of extensive areas. In 1952 the levees on Franks Tract in eastern Contra Costa County failed and the island was flooded. This island was not drained after the flood and is now a state recreation area used for sport fishing. In the winter of 1968–69 a section of levee on Sherman Island failed and the island was flooded (Poland, 1969). This island was inundated by floodwaters again in the winter of 1970–71. The potential for flooding is even higher during earthquakes when levee failure may be extensive.

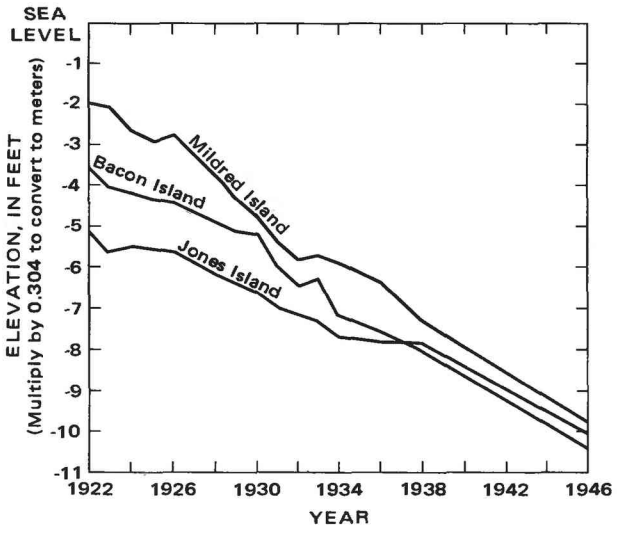


FIGURE 34.—Progressive subsidence of Mildred, Bacon, and Jones Islands in the Sacramento-San Joaquin delta primarily due to peat oxidation between 1922 and 1946 (from Weir, 1950).

Levee-maintenance problems will increase in the delta region as continued drainage for cultivation lowers the land surface farther (Poland, 1969). Total subsidence will be greatest in those areas where the proportion of peat to mineral detritus in the sediment is highest. In some areas where peat constituted only a small part of the accumulated sediment and has been completely oxidized, subsidence may have ceased or is at least greatly reduced. Where peat has been completely depleted, the residual mineral silt and sand are still rich in organic nutrients and make excellent agricultural soil.

SETTLEMENT

Settlement is the gradual downward movement of an engineered structure due to compaction of the unconsolidated material below the foundation. Settlement is most extreme over mud and loose fine-grained sediments (clay and silt) having a high water content. If the load of an engineered structure is relatively small or is emplaced gradually, the water in the voids between the silt and clay grains can escape slowly until the grains are in sufficiently close contact to carry the load and resist further compaction. In this case the settlement of an engineered structure would be relatively slow and would eventually cease. If the load is relatively large or applied suddenly, the high pore water pressures produced in the underlying mud will reduce the shear strength of the mud, which may result in failure. Under these conditions the mud may flow laterally out from under the load and produce bulges or mud waves around the sinking structure. It is likely that both these processes work simultaneously but at different rates under real but variable conditions. In any case the rate of settlement is usually most rapid immediately after loading and gradually decreases with time. The total amount of settlement that may occur is dependent on the physical properties of the sediment, its thickness, laterally confining conditions, and the size and distribution of the load (fig. 35).

The deposit that most frequently is associated with settlement problems in the San Francisco Bay region is the fine-grained Holocene estuarine mud. The extremely low shear strength of this loose, water-saturated material, which is a major cause of settlement, is reflected in its low shear-wave velocities, around 300 ft/sec (90 m/sec) (figs. 25 and 26). Lee and Praszker (1969) review the causes of settlement and discuss several case histories in the bay region.

Settlement problems are usually associated with structures placed on artificial fills overlying thick deposits (>10ft, 3 m) of bay mud. Structures placed on piles founded on secure materials beneath bay mud may also have problems if the surrounding region settles and leaves the structure stranded above grade. This problem is particularly serious at the Alameda Naval Air Station where ramps have been built to maintain access to several buildings (case history 3, Edgar Becker, in Lee and Praszker, 1969).

If a structure on artificial fill settles uniformly, the major problems created are poor drainage and failure of rigid subsurface utility connections. If one part of a structure settles more or at a different rate than another part—differential settlement—mechanical components such as doors and elevators may no longer work, but more importantly the structure itself may be seriously weakened. Structures weakened by differential settlement may not perform well, particularly during earthquakes. Structural weakening due to differential settlement prior to and during earthquakes may be the main cause of the greater observed damage to buildings on artificially filled land over unconsolidated mud (Steinbrugge, 1969). Modern engineering practices can minimize the effects of settlement, but the costs of mitigating measures are high, and there is still the greater likelihood that an average modern building on bay fill will have greater preearthquake stresses within it then will a similar building on structurally firm ground (Steinbrugge, 1969).

Some of the most severe settlement problems in the bay region exist in the low basin areas of San Francisco, the Embarcadero waterfront, (Lee and Praszker, 1969) (fig. 36), and the Mission basin (Steinbrugge, 1969) (fig. 37). In these areas structures were

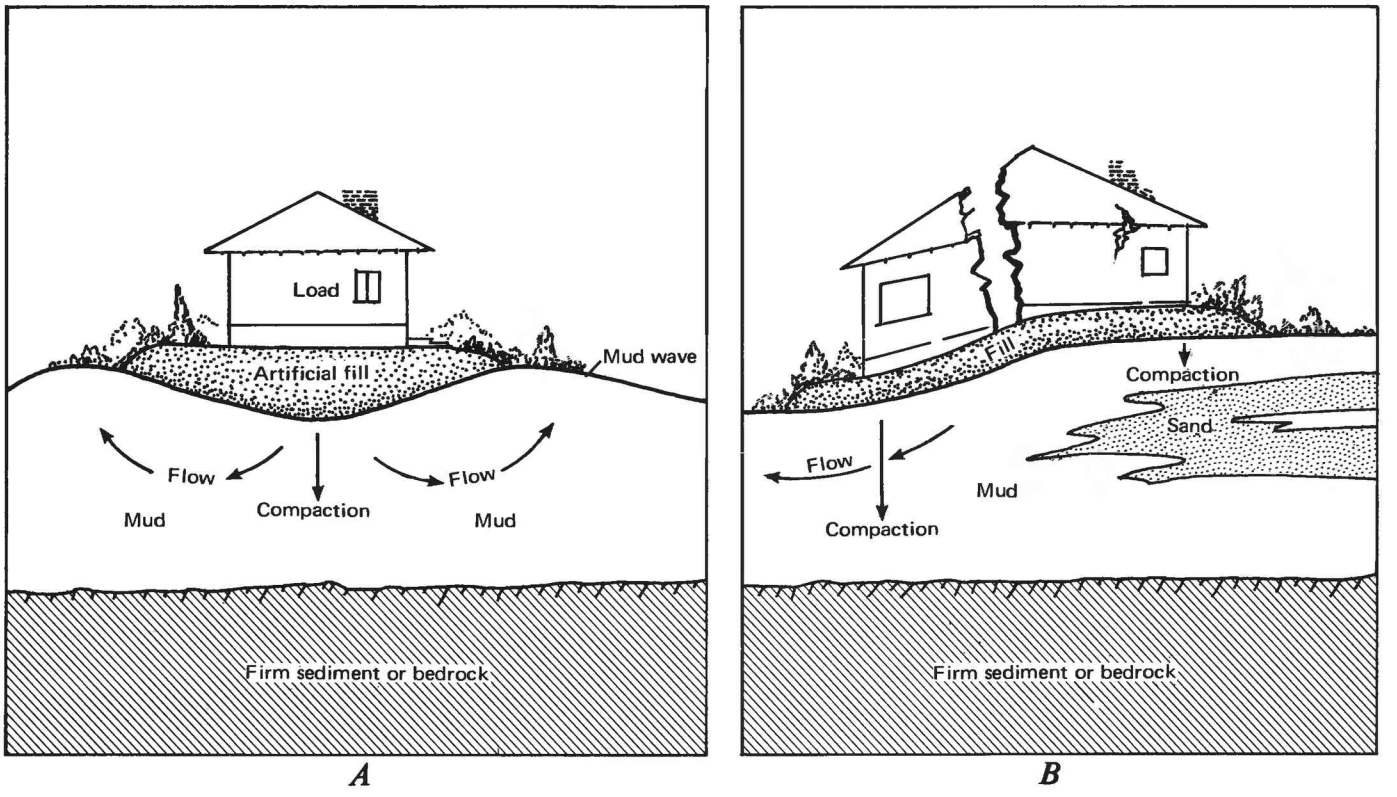


FIGURE 35.—Diagrammatic cross sections showing examples of settlement. *A*, Settlement of an engineered structure placed on artificial fill overlying mud that has low shear strength. *B*, causes and effects of differential settlement. The lateral variability in the underlying mud results in differential settlement, which may damage the engineered structure.

built on randomly placed fill, consisting principally of rubbish, overlying Holocene bay mud.

Settlement problems also occur on more recently placed fills overlying the bay mud at the toll plaza of the San Francisco-Oakland Bay Bridge, Treasure Island, and the Alameda Naval Air Station (Lee and Praszker, 1969). The phenomenon of differential settlement is clearly observed and felt along freeway segments constructed on engineered fills overlying bay mud, such as the Candlestick Causeway in South San Francisco, where the flexible asphalt road surface is deformed into a series of low-amplitude waves. Small offsets in runways caused by minor differential settlement are a continuous maintenance problem at airports built on fill overlying bay mud.

Differential settlement has also created problems in some residential communities built on artificial fills overlying bay mud. A recently constructed apartment complex in Larkspur along Corte Madera Creek was severely damaged by settlement and had to be abandoned (Brewer, 1973). Several homes in Foster City, which is built on artificial fill overlying bay mud along the bay shore of San Mateo County, are beginning to show signs of structural damage caused by differential settlement.

SHRINK-SWELL

Shrink-swell is a cyclic change in volume that occurs in fine-grained sediments because of expansion and contraction of clay caused by wetting and drying (fig. 38).

The potential for shrink-swell problems in the bay region is highest in areas underlain by the Holocene bay mud and the fine-grained Holocene basin deposits, which contain high quantities of expansive clay derived from the uplands by erosion. The Pleistocene alluvial deposits may contain large quantities of expansive clay at the surface. (This clay was formed in place by weathering.) The coarse- and medium-grained Holocene alluvial deposits contain less detrital expansive clay and are not intensely weathered, therefore, they have moderate or low shrink-swell problems.

Because of the relatively minor economic losses resulting from shrink-swell conditions on alluvial deposits, this problem is usually ignored in determining land uses; however, large economic losses have occurred on such soils formed on bedrock (Meehan and others, 1975). Shrink-swell problems can usually be overcome with proper foundation engineering. The main effect, therefore, is on the cost of construc-

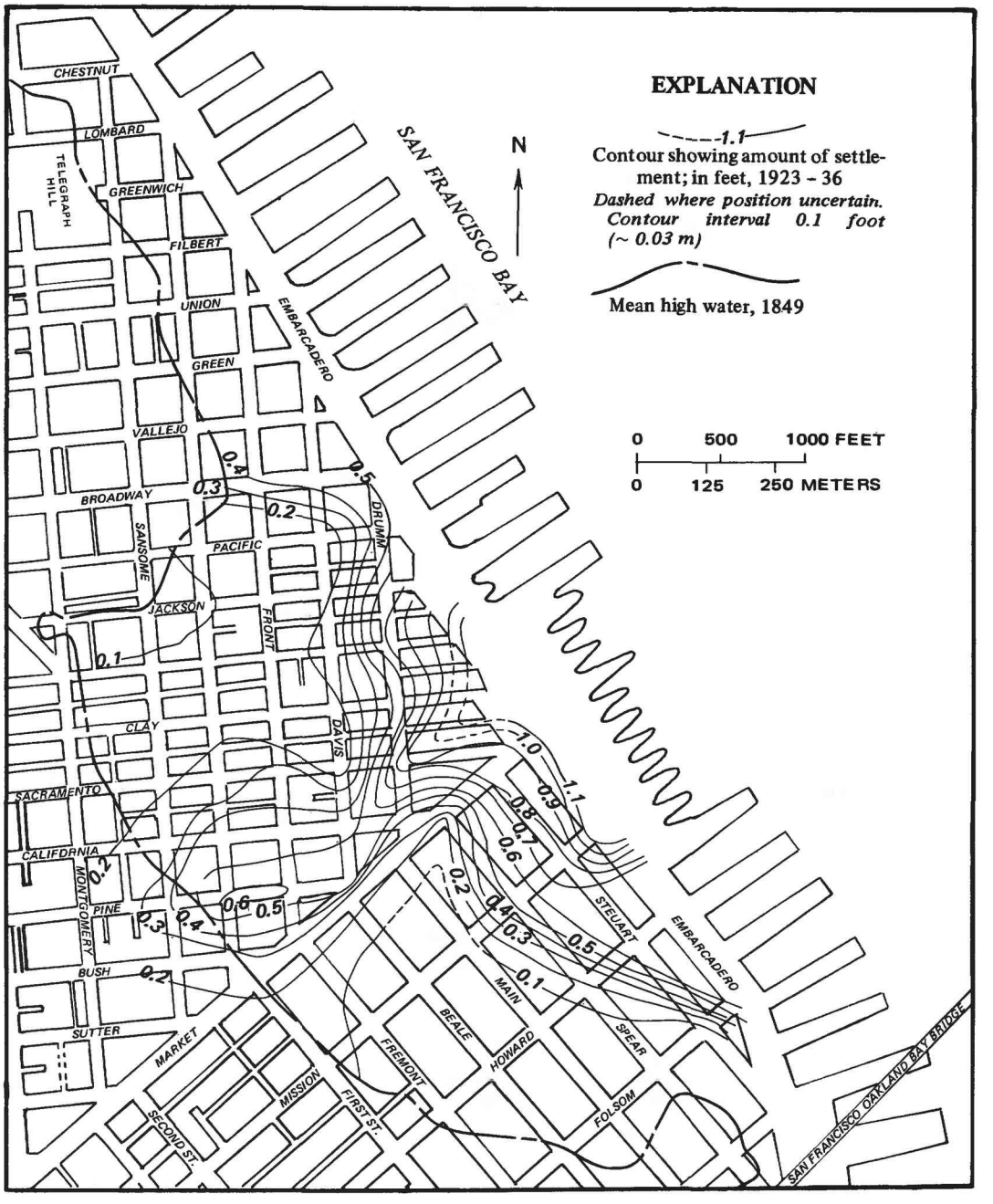


FIGURE 36.—Settlement of the land surface on the San Francisco waterfront. From Lee and Praszker (1969).

tion in areas underlain by clay-rich deposits with shrink-swell potential.

SEISMIC HAZARDS

SEISMIC RESPONSE

Seismic response is the total reaction of a particular area to earthquake shaking. Therefore, seismic response includes the type and intensity of ground shaking, permanent changes of elevation (uplift and subsidence), temporary changes of condition such as liquefaction, and ground failure, lurching, lateral spreading, and landsliding (fig. 39). The level of ground shaking at a particular site depends on distance from the epicentral region and local geologic conditions. In regions underlain by bedrock, ground shaking will be greatest at the epicenter and decrease with distance away from the epicenter. In regions underlain by thick sequences of unconsolidated sedimentary deposits, certain frequencies of ground shaking may be amplified above bedrock levels ow-

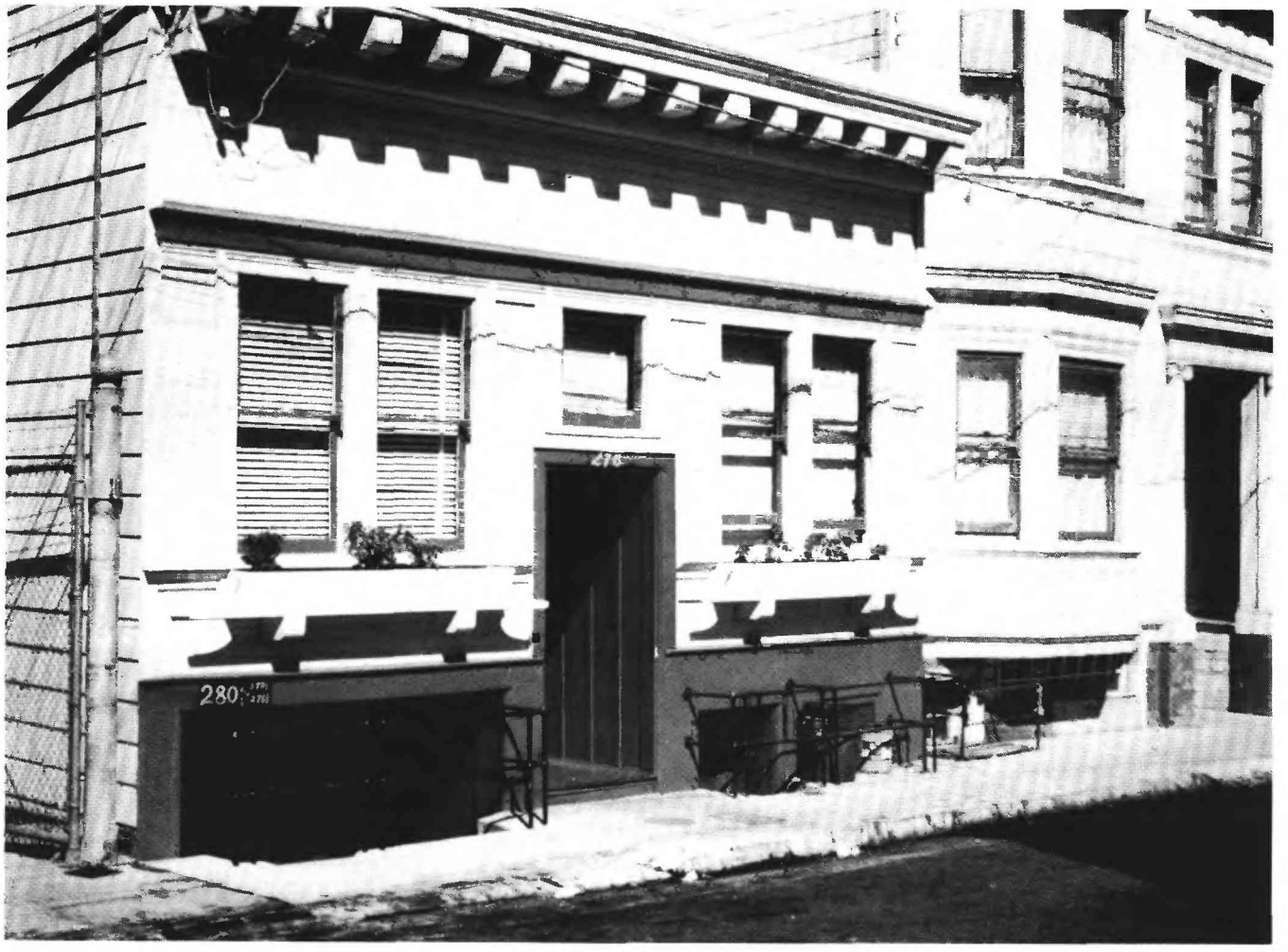


FIGURE 37.—Subsidence of San Francisco buildings built on filled ground that was formerly swamp. Street and sidewalk have been raised by additional fill; the top of the garage door on the left side of the house is now only about 2 feet (0.6m) above the sidewalk (California Division of Mines and Geology, 1966, p. 452).

ing to resonance and impedance contrasts. The block diagram (fig. 39) summarizes potential seismic hazards from the bedrock uplands downslope across the alluvial plain and across the tidelands into the bay itself. In this example, seismic energy originates at the San Andreas fault zone and is attenuated in the bedrock with distance from the fault. Seismic amplifications at the land surface on different materials—alluvium and bay mud, for example—may differ from the bedrock amplification in response to conditions described in the following section.

SEISMIC AMPLIFICATION

Medvedev (1965) showed that seismic impedance (defined as the product of S-wave velocity and bulk density, $Vs \times \rho$) can be used roughly to predict relative ground response. The potential for seismic amplification increases as the impedance contrast between adjacent layers increase if other parameters such as stratigraphic thickness are constant. Because thickness is important, downhole measurements are necessary to help predict amplification. Amplification of seismic waves from nuclear test blasts was measured at three surface sites (fig. 40), and amplification of horizontal ground motion generated by the San Fernando earthquake of February 1971 was measured at a downhole site at Ravenswood Point, San Mateo County (fig. 41). The trend of the amount of amplification recorded at the three different surface sites is quite similar to the trend of the amplification measured at different levels at the downhole site.

Density, S-wave velocity, and therefore impedance of geologic units increase with age (fig. 42).

The Holocene bay mud has the lowest impedance owing to both its low density and its low S-wave

FIGURE 38.—Surface cracks formed in clay-rich sediments due to shrinkage during desiccation. When these sediments are again wetted, the expansive clay (mostly montmorillonite) will absorb water and expand, thus causing a change in volume that will close these cracks and elevate the surface slightly. Movement caused by this cyclic change in volume may be damaging to improperly designed structures. Young unweathered coarse-grained deposits generally have low clay content and therefore have low shrink-swell potential. Older, deeply weathered coarse-grained deposits may contain high concentrations of clay in the B-horizon of soils developed on them, and therefore, may have a moderate to high shrink-swell potential.

velocity. The three facies of the loose Holocene alluvium (pl. 1, 2, and 3) have very similar physical properties and therefore are combined into one geologic unit; this unit has only slightly lower impedance values than the weakly consolidated late Pleistocene alluvium. The variability of physical properties within and between the bedrock units is reflected in their relatively wide range of moderate to high impedance values.

The schematic cross section in figure 42 shows the generalized stratigraphic relations in the southwestern bay region with the high impedance contrasts between units represented by slightly heavier contact lines. Considering only the impedance contrasts, amplification of bedrock motion would be expected to be low to moderate where bay mud overlies late Pleistocene alluvium or where Holocene alluvium overlies Pliocene and early Pleistocene alluvium. The impedance data suggest that the highest levels of amplification would occur where thick deposits of bay mud directly overlie Franciscan bedrock.

Because seismic amplification is dependent frequently on and therefore controlled by other factors such as stratigraphic thickness, predicted amplification potential using only impedance data is not very precise. These crude predictions are consistent, however, with comparative low-strain ground motion measurements which show that the highest amplification occur on bay mud sites. It is probably significant that four of the generalized geologic units with distinct low-strain amplifications roughly correspond to the four groups of geologic units with similar impedance values (groups separated by heavy lines in figure 42).

Combining the geologic units into groups with similar impedance values provides a useful means of evaluating earthquake intensity data and low-strain-level response data. For example, if deposits with similar impedance values behave differently in an earthquake, other variables such as stratigraphic thickness might be investigated. Borcherdt, Gibbs, and Lajoie (1975), using intensity data from the 1906 San Francisco earthquake, amplification spectra from nuclear explosions, and seismic properties of the geologic map units, produced a map showing estimated relative intensities of ground shaking that would be produced in the south San Francisco Bay region by a large earthquake on either the San Andreas or the Hayward fault (fig. 43).

Although we cannot now predict when, where, and how great the next earthquake will be, we can for planning purposes anticipate where the effects of ground shaking will be severe. That this can be done may be seen in the comparison between local geology and earthquake damage for the February 1974 earthquake in Dunedin, New Zealand (figs. 44 and 45). Areas experiencing greatest damage are commonly underlain by loose unconsolidated sediments, Holocene estuarine mud, and Pleistocene and Holocene alluvium.

LIQUEFACTION POTENTIAL

Liquefaction is defined as the transformation of a loose, water-saturated granular material such as sand from a solid state to a liquefied state as a consequence of increased pore-water pressure (Youd and others, 1973). In the solid state, the sand grains are touching each other and the weight of any overlying material is supported by these intergranular contacts. In a liquefied state, the sand grains lose contact, usually only momentarily, and the weight of any overlying material is transferred to the water, which is incompressible, filling the spaces between sand grains. In this state the sand can flow like a fluid but will do so only if it is not confined. This description of liquefaction defines liquefaction as a transformation process rather than the actual flow of liquefied material (or ground failure) that might

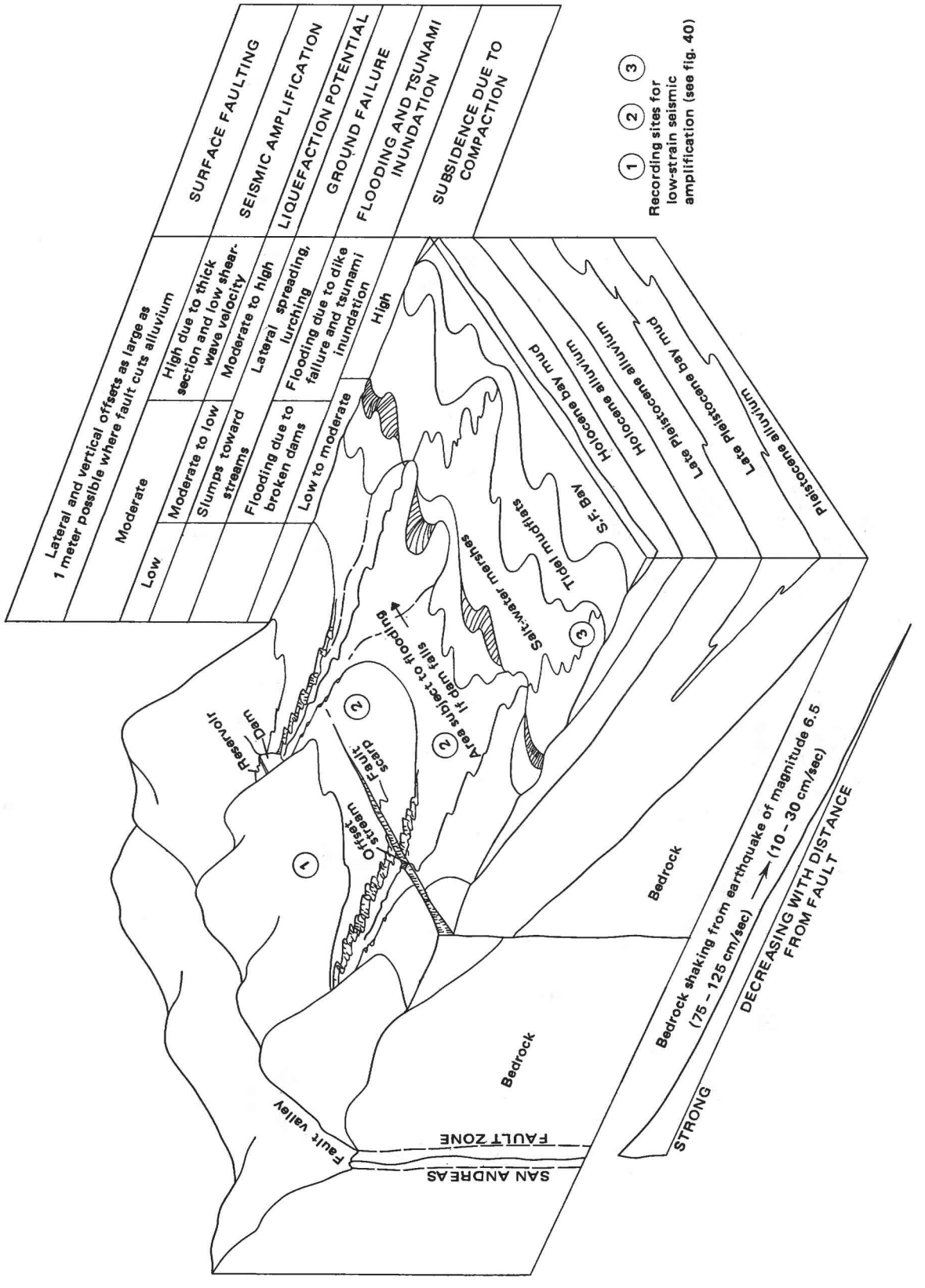


FIGURE 39.—Potential seismic hazards on the alluvial plain and near the bay.

result from this flow. Therefore, a potential for liquefaction does not necessarily imply a similar potential for ground failure.

A major cause of liquefaction is ground shaking during earthquakes. Seismic shaking raises the porewater pressure repeatedly so that the sand grains are momentarily forced apart. The geologic materials most likely to liquefy during an earthquake are loose water-saturated well-sorted (i.e., little or no clay-size material present) silt and sand lying within about 100 feet below the ground surface (Youd and others, 1975). At greater depths the pressure from the weight of the overlying materials is generally too high to be overcome by the seismically induced increased fluid pressures, and liquefaction rarely occurs.

If a bed of silt or sand liquefies during an earthquake and can flow toward a free face such as a cliff or down a gentle slope, ground failure may occur.

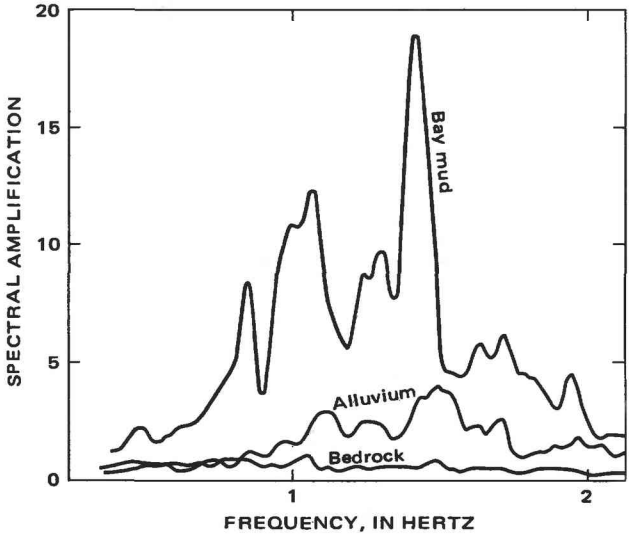


FIGURE 40.—Seismic amplification (Gibbs and Borcherdt, 1974). This diagram illustrates the effect of local geology on ground motion. Seismic waves generated in Nevada by underground nuclear test blasts were recorded at three different sites in the southern San Francisco Bay region. Site 1 was on bedrock, site 2 was on a thick sequence of alluvial deposits, and site 3 was on bay mud. The bedrock signal was slightly amplified where it traveled upward through a thick sequence of alluvium. This same bedrock signal was amplified even more where it traveled upward through a thick sequence of alluvium and then through a layer of bay mud. Note that the seismic waves with frequencies between 1 and 1.5 hertz were amplified the most. The seismic waves recorded at these three sites were so small that they could not be felt. For seismic waves that are large enough to be felt, the amplification ratios most likely would be smaller than those illustrated here, but the general relation of bay mud amplifying more than alluvium would be maintained.

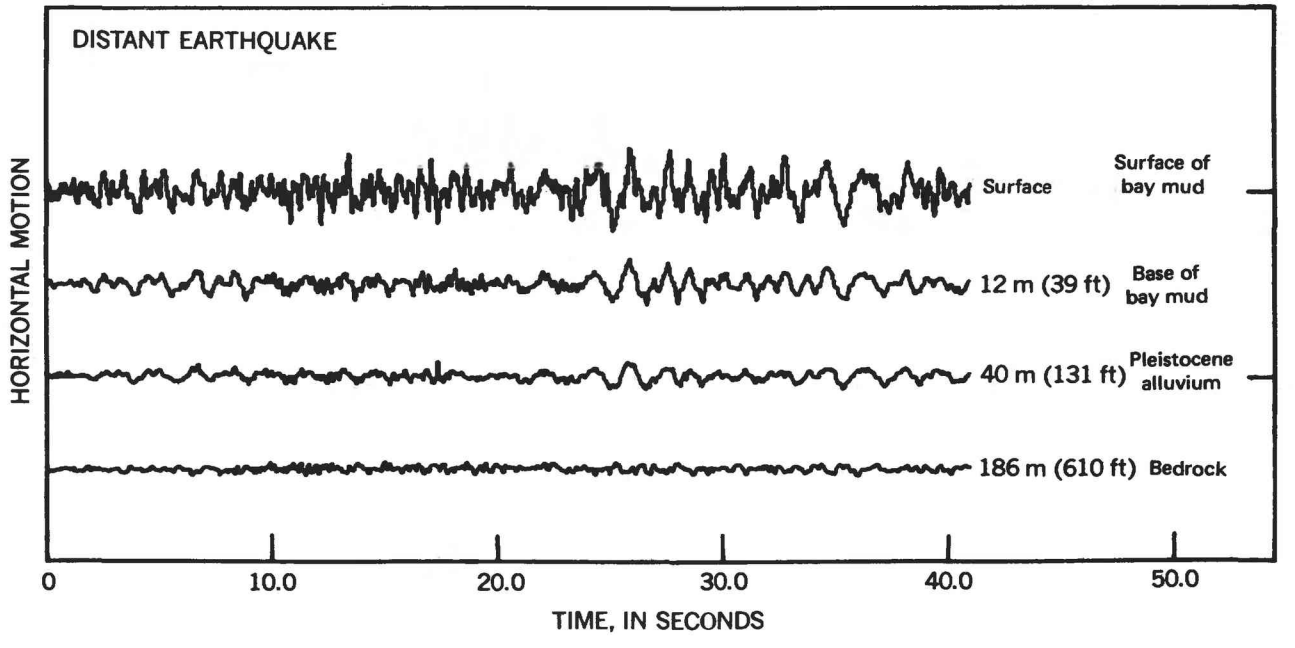
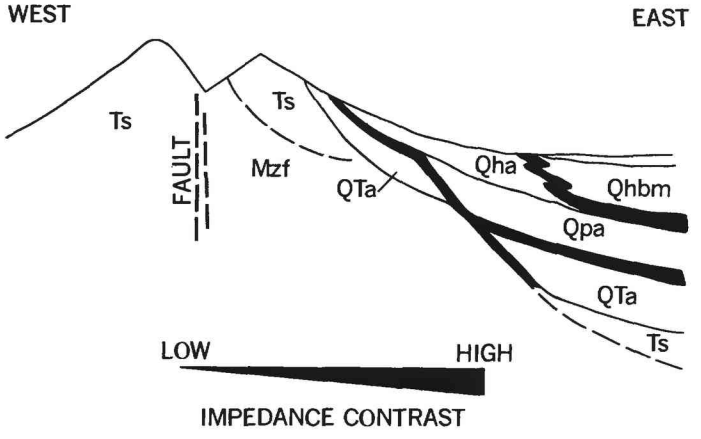


FIGURE 41.—Horizontal ground motions at Ravenswood site recorded on downhole seismometers from a distant earthquake (Borcherdt, Joyner, Warrick, and Gibbs, 1975). The horizontal motions of the bedrock were amplified significantly as they traveled upward through the 571 feet (174 m) of weakly to moderately consolidated alluvium and 39 feet (12 m) of unconsolidated estuarine mud. Note that the trend in amplification at this one site is similar to the trend observed on three different sites (fig. 40).

Severe and extensive ground failure occurred during the 1906 San Francisco earthquake in the Monterey Bay region where large areas along the Pajaro and Salinas Rivers shifted laterally due to liquefaction and the flow of sand and silt beds underlying the river banks (Youd, 1975). At several localities in this area, liquefied sand flowed upward through cracks to the ground surface and formed small volcanolike craters. Also during the 1906 earthquake, ground failure was extensive in Colma Valley in south San Francisco where liquefied alluvium caused lateral shifting of several tens of feet down the gentle slope along the axis of the valley (Youd, 1975).

Liquefaction-induced ground failure can also occur on level ground if the liquefied material is unevenly loaded. In this case the liquefied sand may flow out from under the area bearing the heaviest load. Tall apartment buildings in Niigata Japan, toppled over during an earthquake in 1964 because sand beds beneath them liquefied and could not support the uneven load of the buildings.

Areas that are potentially liquefiable can be mapped if the physical properties of the sediments are known or can be reasonably inferred. Beds of loose water-saturated well-sorted silt and sand have the highest liquefaction potential, and beds of dry, poorly sorted, well-indurated sediment have the lowest liquefaction potential (fig. 46). A map of liquefaction potential for moderate to large earthquakes in the southern San Francisco Bay region (Youd and others, 1975) was produced using standard penetrometer data to assess relative density of the geologic units mapped by the present authors and by Webster (1973). The saturated clay-free coarse silt and sand with relative densities less than 65 percent (poorly consolidated) are considered to have high liquefaction potential even in a moderate earthquake (M4–6.5). Water-saturated clay-free sediments



EXPLANATION

Qhbm	Bay mud
Qha	Holocene alluvium
Qpa	Late Pleistocene alluvium
QTa	Early Pleistocene and Pliocene alluvium
Ts	Tertiary sandstone
Mzf	Franciscan Formation

Unit	Thickness (m)	Relative bulk density, ρ (g/cm^3)	Penetration resistance[1] (blows/ft)	P-wave velocity, V_p (m/sec)	S-wave velocity, V_s (m/sec)	Impedance, $V_s \rho$
Qhbm	0–36	1.3–1.7	0	*1400* [2]	90–130 [3]	117–153
Qha	0–15	1.9	20–80	300–600 [4]	*200–300*	380–*570*
Qpa	10–45	2.1	100	1500–2100	200–400 [5]	420–*630*
QTa	0–250?	2.0	100-refusal	2500	*1200*	*2400*
Ts	0–*300*	2.4	Refusal	1500–3300	500–*1400*	*1200–3360*
Mzf	------	2.7	Refusal	2800–4000	*1400–2000*	*3780–5400*

[1] Test used 140-lb hammer dropped 30 in.
[2] Figures in italics are estimated values
[3] From Warrick (1974)
[4] Above water table. Below water table $V_p = 1500–1700$
[5] R. E. Warrick (oral commun., 1974)

FIGURE 42.—Schematic cross section of southwestern San Francisco Bay and description of certain physical properties of the generalized geologic units (Lajoie and Helley, 1975, fig. 31).

with relative densities greater than 90 percent (highly consolidated) are considered to have low liquefaction potential, even in a major earthquake. Saturated clay-free sediments with relative densities between 65 and 90 percent have moderate liquefaction potential that depends on intensity and duration of ground

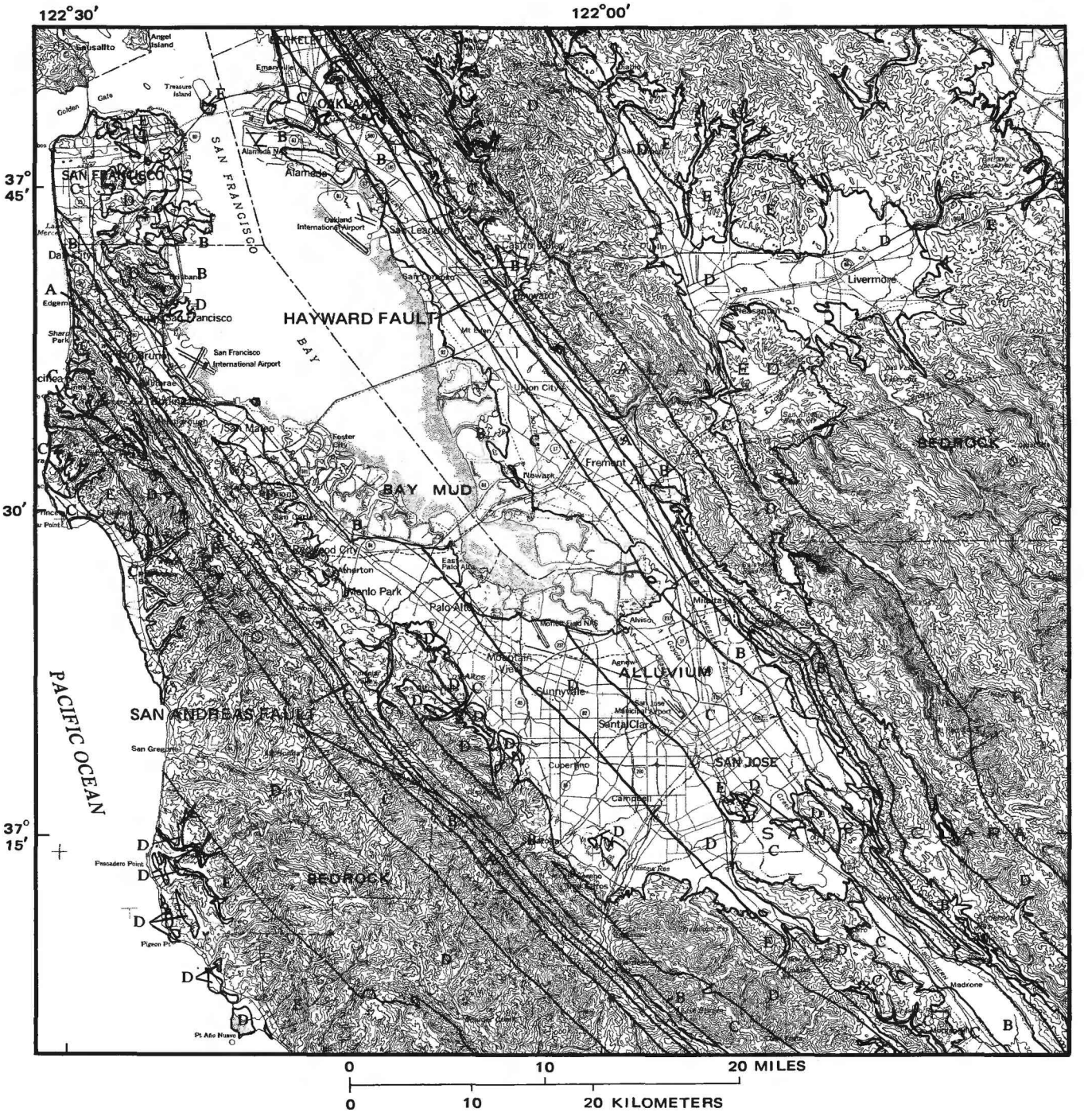


FIGURE 43.—Estimated relative intensities of ground shaking in the south San Francisco Bay region from large earthquakes on the San Andreas and Hayward faults (Borcherdt, Gibbs, and Lajoie, 1975). 1906 San Francisco earthquake scale of Wood (1908): (A) Very violent, (B) Violent, (C) Very strong, (D) Strong, (E) Weak. Note that areas of violent intensity (B) lie immediately adjacent to the faults in the regions underlain by bedrock but lie at successively greater distances from the faults in areas underlain by alluvium and bay mud. This broadening of the higher intensity zones is due to seismic amplification of the bedrock waves by the unconsolidated sedimentary deposits.

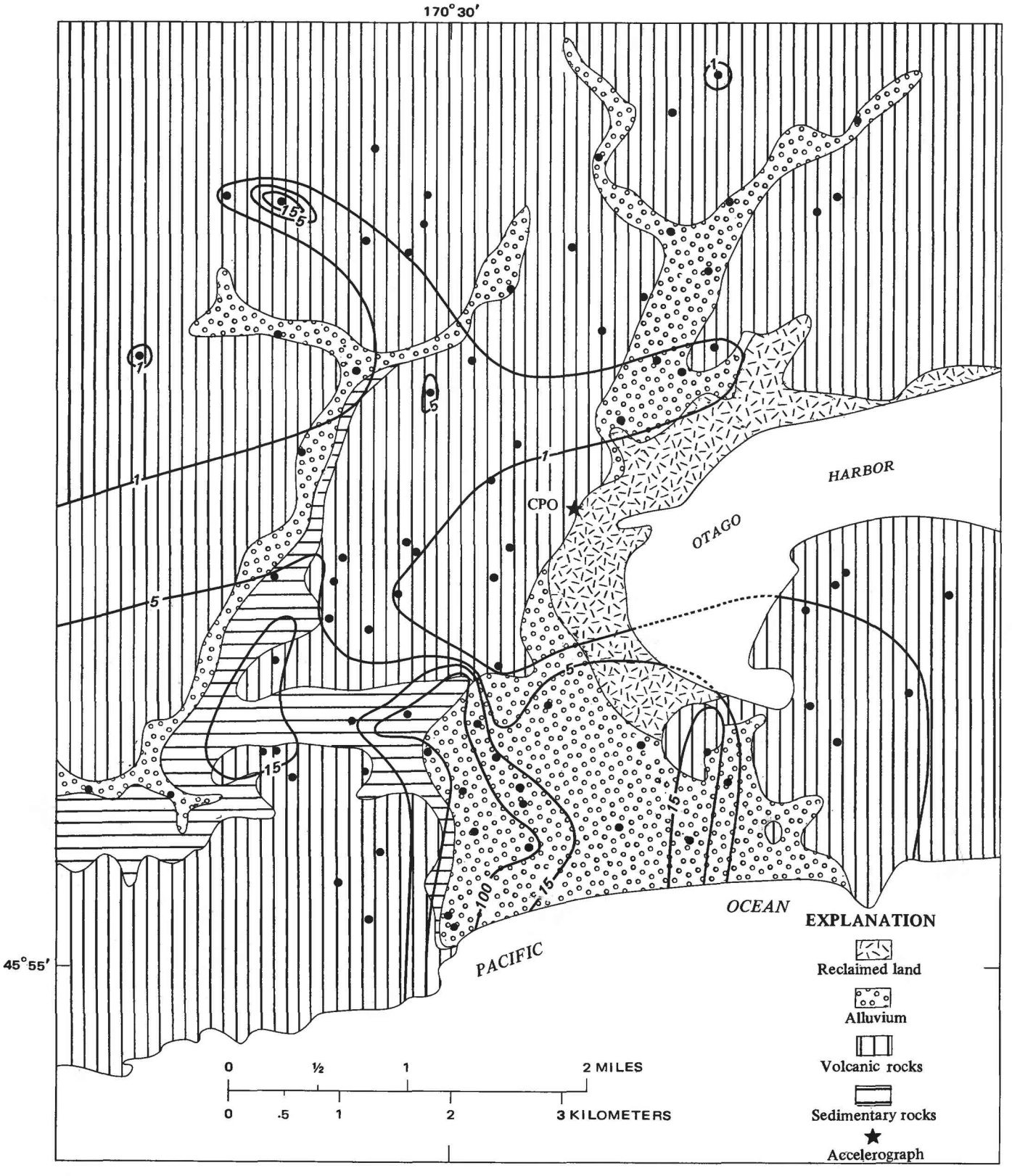


FIGURE 44.—Simplified geologic map of the Dunedin area (modified from Bishop 1974) with isoseismal contours based on the number of fallen items in grocery stores (heavy dots). Contours at 1, 5, 15, and 100 items.

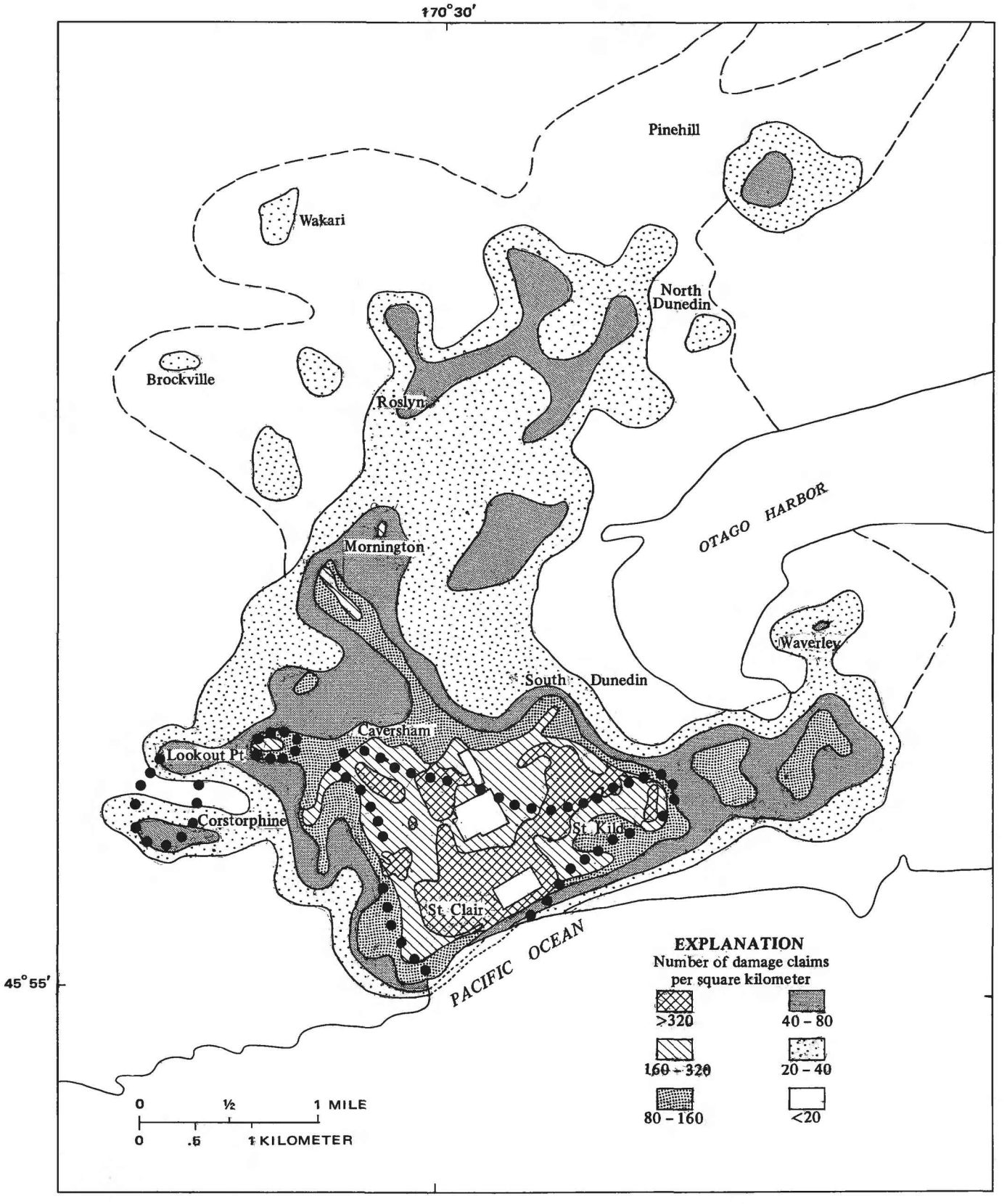


FIGURE 45—Density of damage claims resulting from the Dunedin earthquake. Contours at 20, 40, 80, 160, and 320 claims per square kilometer. Dashed line indicates limits of built-up area where it extends beyond the lowest contour. Heavy dotted line indicates inner zone of more intense chimney damage. Unshaded rectangular areas are large playing fields.

shaking and textural properties of the sediments. In general, granular sediments in the young alluvial and estuarine deposits exhibit more of the properties conducive to liquefaction than the older alluvial deposits (fig. 46). Table 2 summarizes the standard penetration data used to determine the liquefaction potential of the various alluvial deposits in the southern bay region (Youd and others, 1975). Because the alluvial deposits over the entire bay region were distinguished by using the same criteria, conclusions

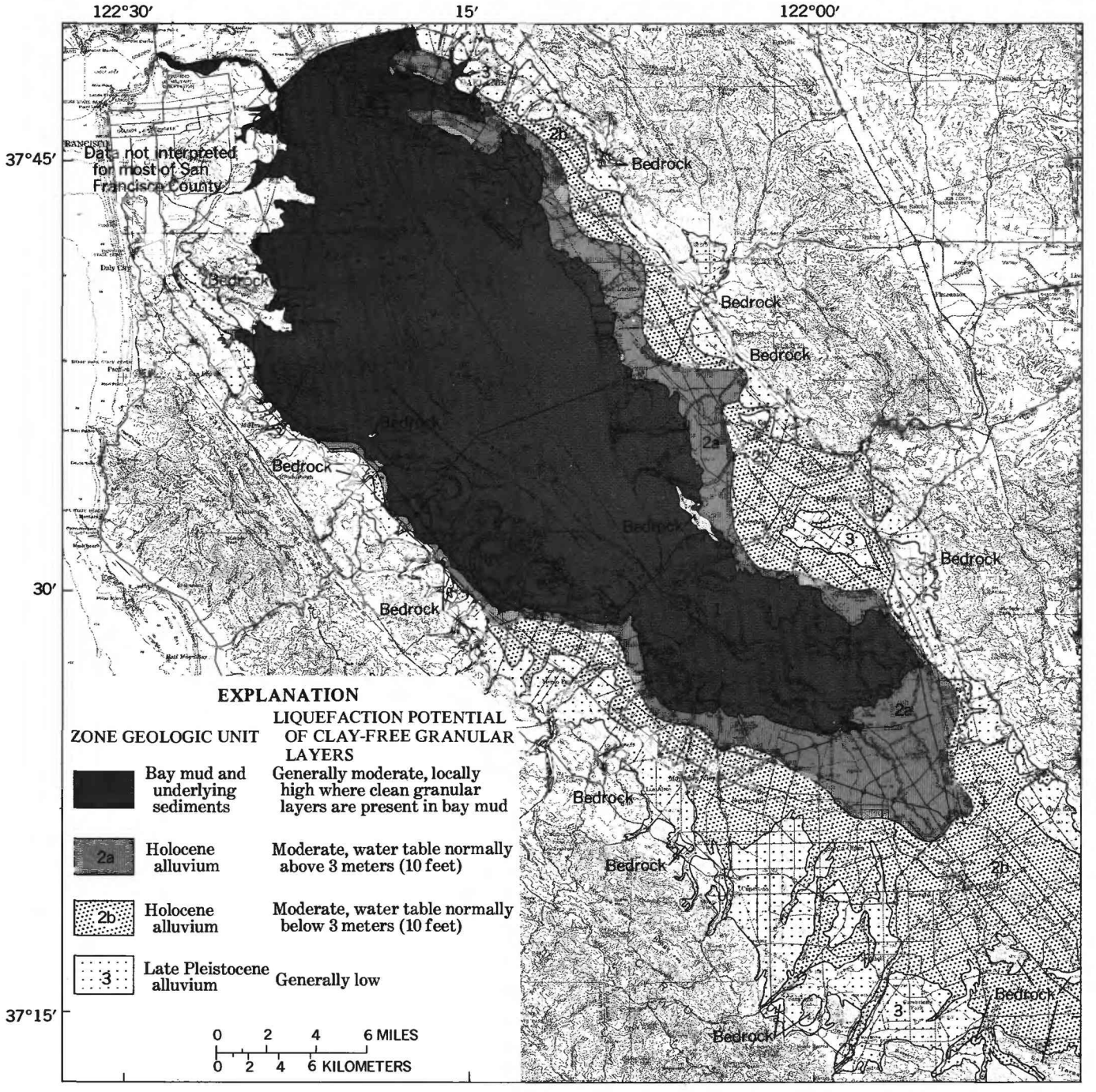


FIGURE 46.—Preliminary map showing liquefaction potential for the southern San Francisco Bay region. The map shows generalized liquefaction potential of granular layers in each map zone but does not delineate locations of these layers. Hence, the map is useful for designating zones where special consideration should be given to the possibility of liquefaction, but it is not valid for assessing the liquefacation potential of a given site. From Youd, Nichols, Helley and Lajoie, 1975, fig. 50.

TABLE 2.—*Summary of liquefaction potential analysis using standard penetration data*

[Two probable local earthquakes are considered; (a) a moderate earthquake (M=6.5) and (b) a large earthquake (M=8.0). Sediments likely to liquefy during a moderate earthquake are classified as having high liquefaction potential; those unlikely to liquefy during a large earthquake are classified as having low liquefaction potential; and those intermediate between these two categories are classified as having marginal liquefaction potential. D_r = relative density.]

Zone	Sedimentary unit	Standard penetration test date (percent indicating) $D_r < 65$ percent (high liquefaction potential)	65 percent $< D_r <$ 90 percent (marginal liquefaction potential)	$D_r > 90$ percent (low liquefaction potential)	Number of tests
1	Older (Pleistocene) alluvial deposits	11	29	60	357
2	Younger (Holocene) alluvial deposits	22	33	45	708
3	Deposits underlying young bay sediments	33	28	39	155
3	Deposits within young bay sediments	73	21	6	53

drawn from these data in the southern bay region can be extrapolated to other areas as a first approximation of liquefaction potential. However, because of local variability, these data cannot be used to determine the liquefaction potential of a particular site even in the southern bay area where engineering data were analyzed. A qualitative list of factors and conditions controlling liquefaction are given in table 3. This summary provides a list of properties that must be investigated on any site to evaluate the potential for liquefaction.

TABLE 3.—*Factors and conditions controlling liquefaction*

Factor	Condition conducive to liquefaction	Conditions not conducive to liquefaction
Grain size of sediment	Coarse silt and fine sand	Clay, coarse sand, gravel
Sorting (Variability in grain size)	Well sorted Uniform grain size Clay free (less than 3 percent)	Poorly sorted Nonuniform grain size High clay content (more than 3 percent)
Cementation[1]	Uncemented Loose	Cemented Hard
Consolidation (Compaction)	Unconsolidated Noncompacted Loose Low shear strength	Semiconsolidated to consolidated Moderately to high compacted High shear strength
Relative density[2]	Low relative density Less than 65 percent for small earthquakes	High relative density More than 90 percent for largest earthquake
Standard penetration[3]	Low	High
Geologic age[4]	Generally young Holocene Late Pleistocene	Generally older Pleistocene and older
Water saturation	Saturated Pore spaces filled High ground-water table Bay deposits, flood basins, lower parts of alluvial fans	Partly unsaturated to dry Pore spaces not filled Low ground-water table Higher parts of alluvial fans
Pore-water pressure	High Greater than lithostatic load	Low Less than lithostatic load
Depth	Within 100 feet (30 m) of surface Low lithostatic load	Greater than 100 feet (30 m) depth Less than lithostatic load
Seismic activity	High seismic activity High probability of moderate to great earthquakes	Low seismic activity Low probability of moderate to large earthquakes

[1] Particles may be cemented together by calcite, silica, iron oxides, or other materials.
[2] Relative density primarily reflects the degree of compaction in a sediment. 100 percent relative density means a sediment is at its maximum compaction; all the pore space is filled. 0 percent relative density means a sediment is at its minimum compaction; it is in its loosest condition and pore space is at a maximum.
[3] Standard penetration generally reflects degree of induration, which is a combination of compaction and cementation. Low standard penetration values indicate a sediment that is not compacted and is not cemented.
[4] In a general way, the age of a deposit is reflected in certain physical properties such as induration. Older alluvial deposits are generally more highly indurated than younger deposits.

RESOURCES AND POTENTIALS

WATER RESOURCES

Infiltration is the movement of surface water into the ground through cracks in rocks or through the interconnected spaces between the constituent grains of sedimentary deposits. The rate of infiltration into a sedimentary deposit is controlled by its permeability and the depth to the ground water table. The higher the permeability, the higher the possible infiltration rate. Permeability is determined by numerous factors (table 4) including grain size, grain shape, and sorting that combine to control the size and continuity of the spaces between grains. Well-sorted, coarse-grained sediments, such as alluvial gravel and dune sands, generally have large interconnected spaces between the particles of rock and therefore would be expected to have relatively high permeabilities and infiltration rates compared to finer grained sediments.

The geologic units of flatland materials can be roughly ranked in terms of permeability and, hence, infiltration rate on the basis of grain size. The infiltration rate would be expected to be high in stream channel deposits and sand; moderate in coarse-grained Holocene alluvium and Pleistocene deposits and low in the fine-grained Holocene deposits. Figure 47 shows expected infiltration rates based on the distribution of the various sedimentary deposits.

Depth to ground water table is another important factor controlling infiltration rates. If the water table is close to the ground surface, the infiltration rate will be low. Within the bay region, high water tables and therefore low infiltration rates are found most commonly in the tidal mudflats underlain by bay mud

TABLE 4.—*Factors affecting porosity and permeability of sedimentary deposits*

Factor	Porosity	Permeability
Grain size:		
Fine grained	Smaller pore space	Lower
Coarse grained	Larger pore space	Higher
Sorting:		
Well sorted	Increased pore space	Higher
Poorly sorted	Decreased pore space	Lower
Compaction:		
Uncompacted	Pore space at maximum	Increases
Compacted	Pore spaced reduced	Decreases
Cementation:		
Not cemented	Pore space open	Increases
Cemented	Pore space reduced	Decreases
Depth of burial:		
Shallow	Low pressure, pores open	High
Deep	High pressure, pores closed	Low, but Transmissibility may be high
Geologic age:		
Young	At maximum	At maximum
Old	Decreasing	Reduced

and the low floodbasins at the outer margins of alluvial fans, which are underlain by fine-grained alluvial deposits. Low water tables occur along the higher well-drained parts of the alluviated areas underlain by coarse-grained alluvial deposits.

Information concerning infiltration rates is important in land-use planning for several reasons:

1. Areas with low infiltration rates are likely to present drainage problems that can affect both rural and urban use of the land.
2. Areas with very high infiltration rates are potential sites for aquifer recharge areas. Urbanization of such areas inhibits the replacement of ground water supplies lost through natural seepage or withdrawal by man.
3. The quality of ground water is affected by land uses within and near areas of high infiltration potential. For example, the location of solid-waste disposal sites in such areas may cause ground water contamination.

Areas favorable for ground water recharge can be precisely delineated by means of resistivity investigations (fig. 48). By comparing maps that show favorable recharge areas with other maps that show areas known to have high infiltration rates, unfavorable or undesirable recharge areas can be eliminated. It can also serve as the basis for determining where resistivity investigations should be undertaken. A modern soil survey also evaluates soil units in terms of permeability and, if available, can be used to delineate areas with recharge potential and with probable drainage problems.

SOIL

Soil, the natural medium for growth of land plants, is one of the primary elements in the life support system of all terrestrial life and is therefore one of the most valuable natural resources. The highest quality agricultural soils are fine- to medium-grained, well-drained sediments that are high in nutrients, easily worked, and have moderate water-holding capacity. In the San Francisco Bay region, these conditions are found most frequently on the Holocene alluvial deposits on flat valley bottoms and on the gently sloping fans marginal to the bay. These deposits have been built up primarily by floods over the past 5,000–7,000 years. Because these deposits are very youthful, they have not been deeply weathered nor significantly indurated. The soil profiles developed on these deposits lack well-developed clayey B horizons and are therefore permeable and easily tilled. Also, the lack of deep weathering means that the mineral nutrients have not been leached. Along levees and flood plains that are frequently flooded, fresh material brought in from the upland areas periodically replenishes the supply of mineral nutrients.

The most widespread ranking of land for agricultural uses is done by the U.S. Soil Conservation Service (1970); it has developed a standard format for expressing land capability for agriculture. Information developed by USGS for this report uses Soil Conservation Service soil survey data wherever available. In those areas where modern soil surveys have not been done, agricultural capability is inferred from the usual characteristics of the soil associated with each mapped geologic unit.

Figure 49 contains a brief description of the SCS capability classes and shows a typical topographic distribution of the eight classes. Generally speaking, class I, II, and III soils, those most suitable for agriculture, occur in flatland areas. Utilizing the Soil Conservation Service ranking system, the geologic units with the highest potential for agricultural use (class I, II, and III soils) are Holocene fine-, medium-, and coarse-grained alluvium, Pleistocene alluvial fans, and Quaternary marine terraces.

The flatlands map (pl. 1) provides a generalized overview of areas that may have agricultural potential. However, in areas where modern soil surveys have been completed, the soil surveys more accurately identify agricultural potential.

The distribution of water and soil resources in the flatlands bordering the bay is shown in figure 50. The

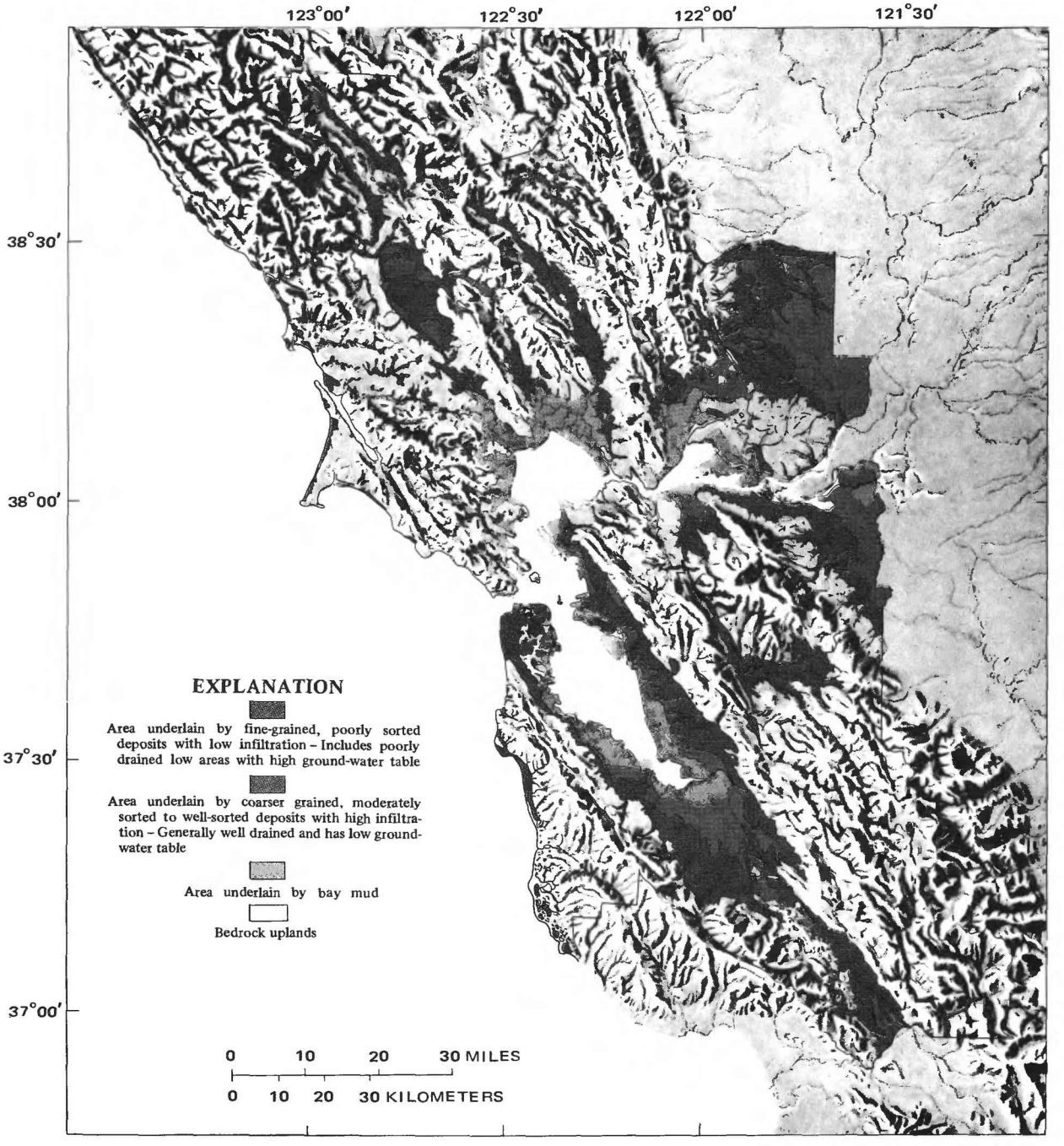


FIGURE 47.—Areas of high and low rates of ground-water infiltration, San Francisco Bay region.

best soils are to be found on the active alluvial fans, which are the Holocene map units. These same units also provide the best sites for infiltration to recharge the ground-water reservoir. The lower areas of the active fans are finer grained and less permeable but provide fair agricultural soils when properly drained. The flatlands immediately adjacent to the bay are useful as flood basins and also provide areas in which to evaporate salt from the bay water.

MINERAL RESOURCES

The mineral resources of the San Francisco Bay region are evaluated in detail by Bailey and Harden (1975), and those found in the flatlands are discussed here only briefly. The most important and essential mineral resources in the flatlands are sand and gravel. All other mineral resources—clay, salines, shell, and peat—are of lesser economic importance.

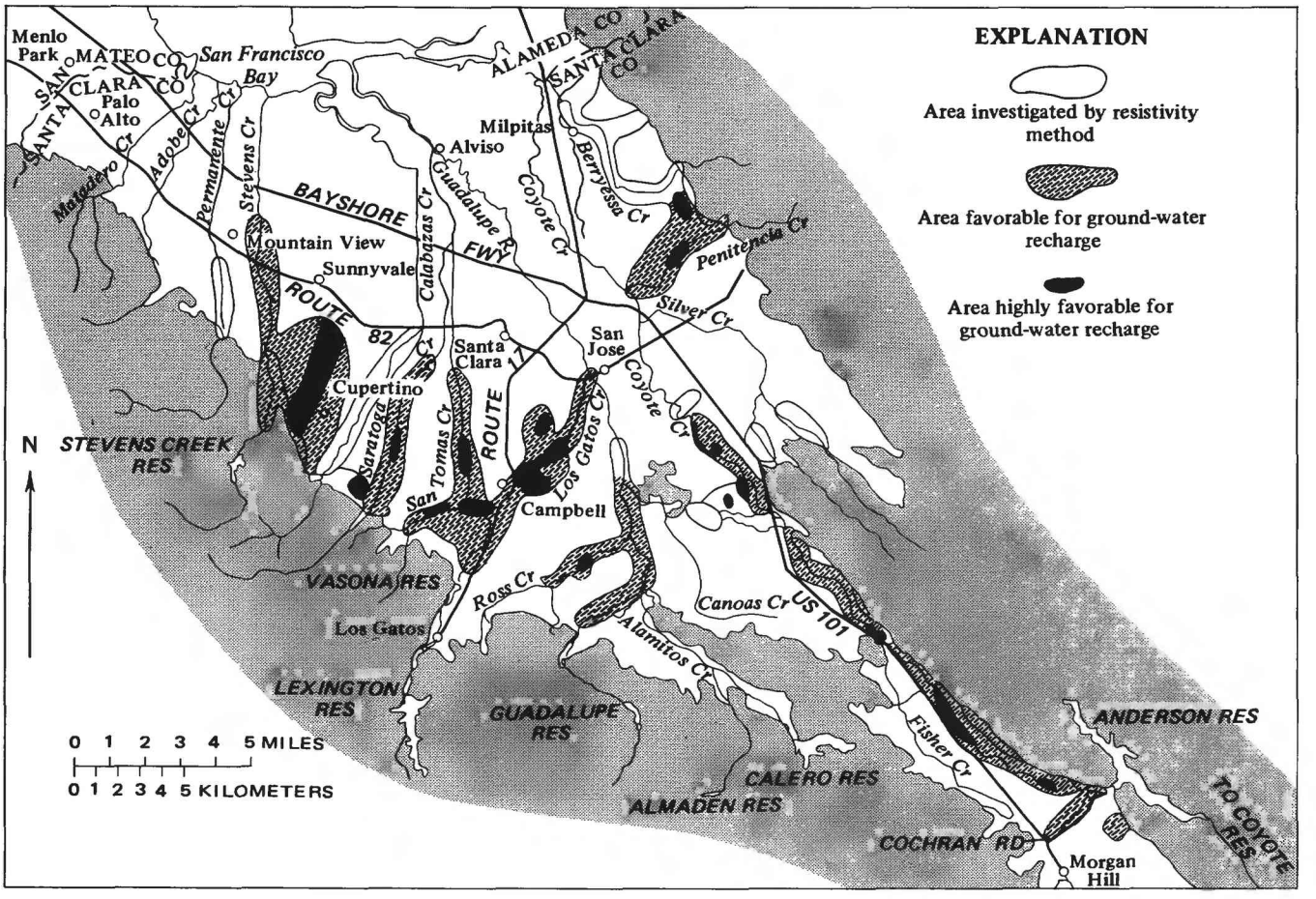


FIGURE 48.—Areas favorable for ground water recharge in southern Santa Clara County. After Page and Wire (1969).

SAND AND GRAVEL

Though sand and gravel—basic construction materials—are widespread in the flatlands, they are not unlimited resources. Indeed, minable sand and gravel resources are small in terms of projected needs (Burnett and Barneyback, 1975). About half the sand and gravel used in the bay area is for aggregate in concrete and the rest for bituminous pavement, road base, and fill (Burnett and Barneyback, 1975).

Deposits of sand and gravel occur in all bay area counties, but much of this material is unusable because it is of poor quality. Minable deposits occur in half the bay counties in both modern and ancient stream-channel, flood-plain, and alluvial-fan deposits (fig. 51). Small quantities of sand have been mined from the beach and dune deposits along the coast. Much of the originally available sand and gravel is not presently minable because of urbanization.

Much of the sand and gravel in the alluvial lowlands cannot be used for concrete because of certain undesirable physical or chemical properties. The most stringent quality requirements apply to sand and gravel used for concrete aggregate. This material should consist of durable minerals, such as quartz and feldspar, and should contain minimal amounts of unstable minerals (dark minerals or clay, for example) and reactive minerals (opal, zeolites, and glass). Unweathered hard tough dense well-rounded rock granules are the most desirable for concrete aggregate. This type of material is commonly found in the stream beds and on the alluvial fans of streams draining terrain underlain by old volcanic rocks and highly indurated sedimentary rocks.

The particle size distribution is also important in concrete aggregate, particularly in the sand fraction (Price, 1966; in Burnett and Barneyback, 1975). In general, the largest grain size of aggregate consistent with practical limitations is desirable. The grain-size distribution of an aggregate is controlled by processing, but the primary ratio of various sizes is important in determining the feasibility of exploiting a particular sand and gravel deposit. Therefore, depos-

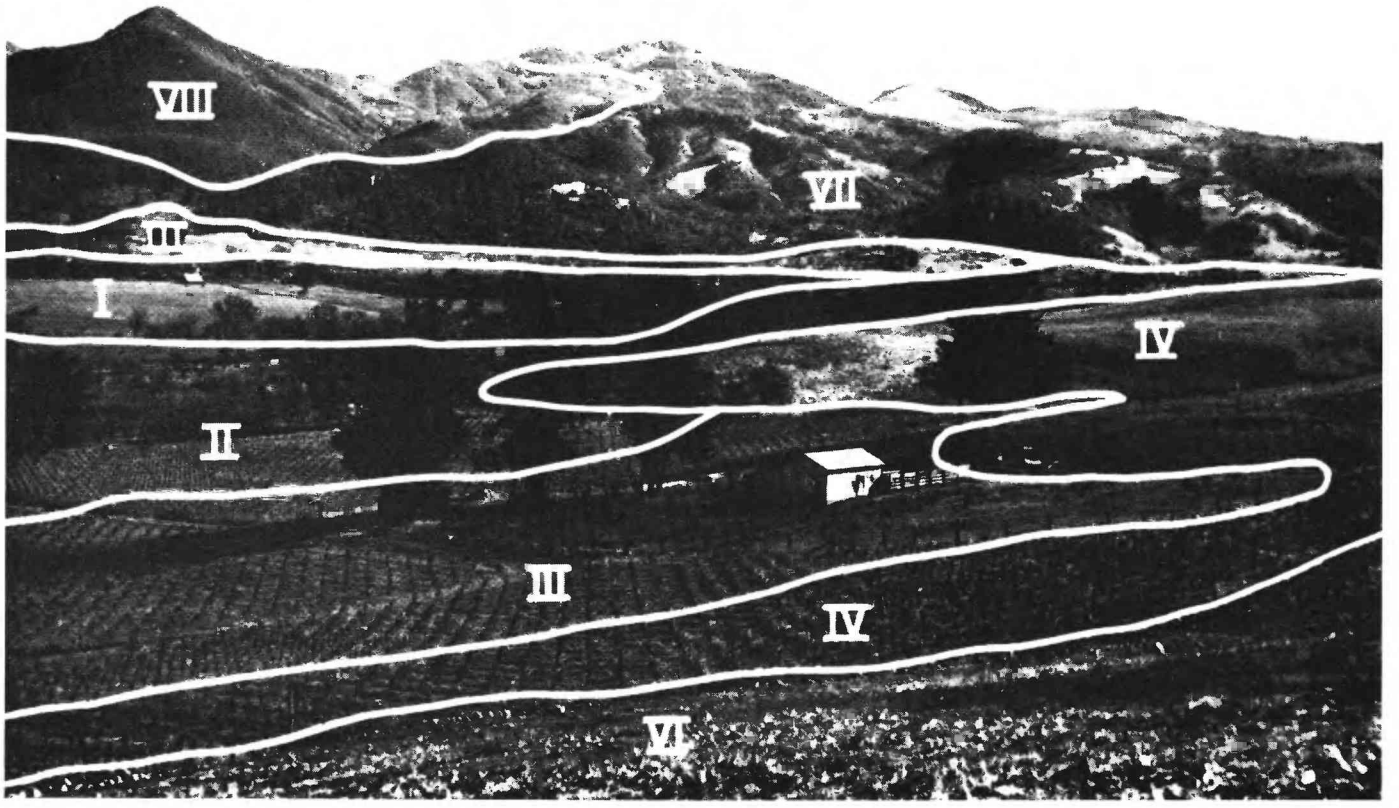


FIGURE 49.—Soil capability classes. From class I to class VIII, the choices in use become fewer and the risks become greater. From U.S. Department of Agriculture (1970).

its of relatively well sorted (low silt and clay content) sand and gravel consisting of tough, resistant particles are the most valuable for concrete aggregate. Deposits with these characteristics are abundant in outlying areas of the bay region (fig. 51), but many are a considerable distance from market centers, and many of those that are close are being eliminated as an exploitable resource by urbanization.

The deposits along the southern margin of Livermore Valley in Alameda County have supplied a major part of the sand and gravel used in the bay region. This high-quality material, which has been excavated to depths of 125 feet (38 m), consists of Holocene and, most likely, late Pleistocene alluvial fan deposits of Arroyo Mocho and Arroyo del Valle, which drain a large mountainous area underlain by Franciscan rocks.

The extraction of sand and gravel in large quantities can have very deleterious environmental effects. Large open pits frequently remain after the gravel and sand have been removed. The material removed is lost for ground-water storage, but in some areas such as Los Gatos, the resultant open pits are used as percolation ponds for ground-water recharge. At Livermore, open pits left after sand and gravel were extracted have been converted to recreation lakes.

CLAY

In the early days of California, most brick and sewer-pipe clay used was of alluvial origin and was found in valley-fill and flood-plain deposits of rivers and streams (Turner, 1951). Local red burning clay for bricks and terra cotta has been produced from the Holocene and late Pleistocene deposits of Livermore Valley and the Niles area of Alameda County. Clays have been mined extensively from deposits of similar age in the area north of San Jose in Santa Clara County.

The clay resources in the alluviated flatlands have never been systematically mapped or evaluated. Most clay deposits of commercial value probably lie in the floodbasins of the central lower parts of the alluviated lowlands where the streams carry and deposit predominantly fine-grained silt and clay. Clay may also accumulate in quiet water filling cut-

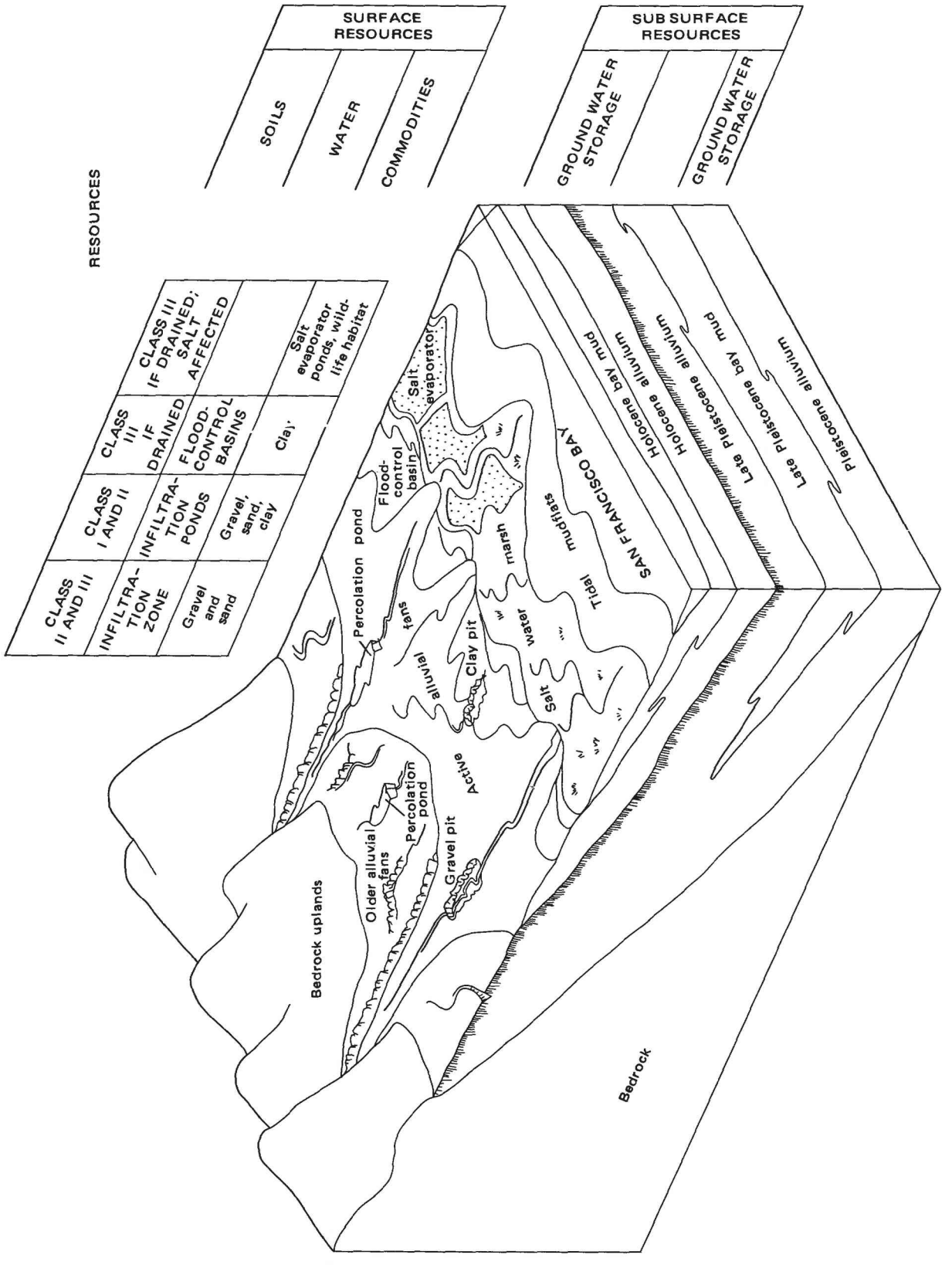


FIGURE 50.—Distribution of water and soil resources in the flatland deposits.

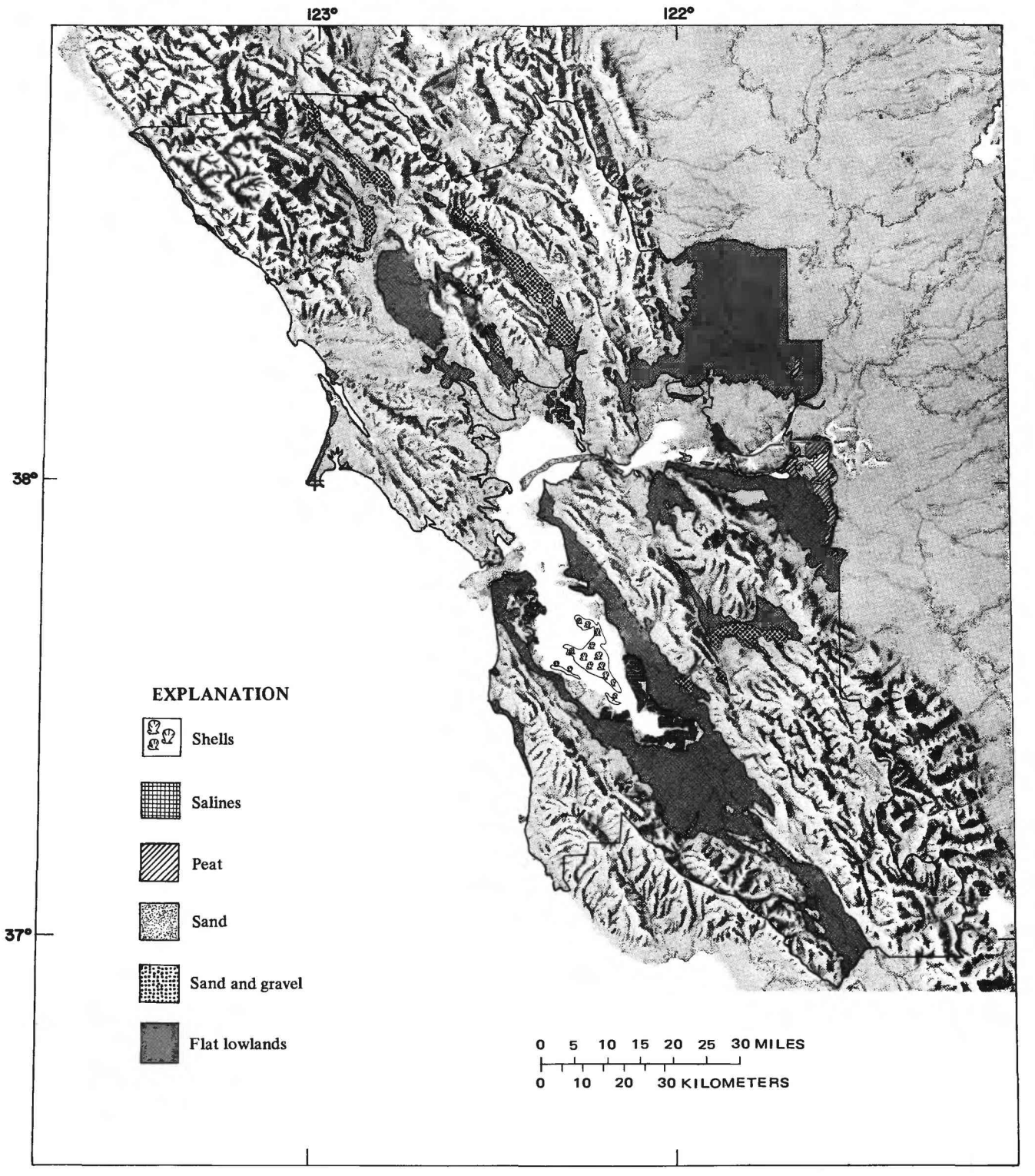


FIGURE 51.—Resources in flatland areas of bay region.

off meander loops and other natural depressions in the higher parts of alluviated areas, but these deposits are smaller than those in floodbasins.

SALINES

Salines in the bay area are derived entirely from sea water (Ver Planck, 1951). The earliest European settlers in the area gathered naturally precipitated salt from tidal lagoons along the margins of the bay. When these natural deposits were depleted around 1860, artificial evaporating ponds were constructed and continually expanded until most of the salt marsh areas in the south bay and some in northern San Pablo Bay were converted to salt production by 1970 (fig. 51).

The main natural factors that make salt production by solar evaporation a profitable business are the broad expanse of low-lying salt marshes adjacent to the bay and the cloudless summer weather. The marshes are at or close to sea level, which minimizes pumping, and the fine-grained Holocene bay mud provides a natural water-tight bottom that reduces leakage (Ver Planck, 1951).

Former salt ponds are presently being converted to urban lands such as Foster City and Redwood Shores. However, the preservation of salt ponds for salt production, which is an important economic product of the bay region, and open space, such as the Federal wildlife preserve, will probably prevent the rapid conversion to other uses at least in the near future (Goldman, 1969).

SHELL

Deposits of oyster shell, primarily *Ostrea lurida*, occur as thin discontinuous lenses on the surface of and within the upper 20–30 feet (7–9 m) of Holocene bay mud in the southern part of the bay. Roughly 30 million tons of these shells have been dredged from San Francisco Bay since 1924 (Hart, 1975; Goldman, 1969). Most of this material was used in the manufacture of cement but some was used as a source of calcium in poultry and livestock feed. The dredging of oyster shells and mud from the bay for cement manufacture ceased in 1970 due to environmental and economic reasons, but small amounts used for poultry and livestock feed and soil conditioning are still recovered by a single operator (Hart, 1975).

The distribution and character of shell deposits within the bay are not well known so the reserves of this locally important commodity cannot be definitely determined, but Welday (*in* Hart, 1975, p. 64–74) estimates that of 60 million tons (54.4 million tonnes) of available shell, about 40 million tons (36.3 million tonnes) usuable. Most of the shell extracted to date lies at or near the bottom of the bay and is therefore very young. The living populations of *Ostrea lurida* have been almost completely destroyed by pollution of bay waters and dredging of the oyster beds so the commodity is not being replenished. Consequently, when the present oyster beds are depleted, older and more deeply buried shell beds may be exploited.

PEAT

Peat reserves in the bay region are described by Stinson (1975). Peat, which is used exclusively as a soil conditioner, occurs in the eastern parts of Contra Costa and Solano Counties in fairly pure beds greater than 30 feet (10 m) thick in some places and in three small areas near Gilroy in southern Santa Clara County (fig. 50). At present peat is recovered only from Franks Tract, a subsided and flooded island in eastern Contra Costa County where it is mined by a floating clamshell dredge in 6–8 feet (2–3 m) of fresh water.

The extraction of peat from permanently flooded areas does not conflict with other high-priority land uses. Peat extraction from diked and drained lands in the delta region would conflict with the agricultural uses of these areas. Peat is obtainable from other parts of the Sacramento-San Joaquin delta outside the bay region and therefore is not a particularly valuable resource in the bay region. Also, various substitutes for peat are available for agricultural and horticultural uses.

IMPORTANCE OF FLATLAND GEOLOGY TO COMPREHENSIVE PLANNING

By William Spangle and Martha L. Blair

Knowing the characteristics of flatland deposits is obviously important in land-use planning. Many costly and hazardous situations can be avoided or mitigated if good geologic information is available before land-use and development decisions are made. In the past, planners have relied on soil maps to identify the problems and resources of flat alluvial areas. Soil maps show deposits at the surface to a depth of rarely more than a few feet. Geologic mapping considers deposits at greater depth and is largely based on the processes forming the deposits. The delineation, description, and interpretation of flatland deposits are a new approach to geologic mapping and interpretation, designed explicitly for appli-

cation to land-use planning. In the past, geologic maps rarely differentiated the various alluvial deposits common to lowland areas. These differences, as described in the entitled sections "Potential Problems in Flatlands Regions" and "Resources and Potentials," have important planning implications.

Because the information presented here is new, actual examples of successful application to land-use planning do not exist. Thus, to describe the potential planning application of data on flatland deposits, two approaches are used. First, a hypothetical example of the use of flatlands information in land-capability studies is presented to illustrate how the interpretations of the preceding two sections can be integrated and related directly to land-use planning and decisionmaking. Second, actual planning responses to selected flatland issues are described to show how land-capability considerations and information describing flatland characteristics can be incorporated into a planning and decisionmaking process. In both approaches, the objective is to describe a planning framework for the effective use of data on flatland deposits.

A basic planning and decision making framework is outlined in the section "Introduction." Geologic and other earth-science information is important in each step of the planning process shown in figure 3. The outline below provides a general framework indicating how planners, working with earth scientists, can effectively introduce geologic considerations throughout the process.

1. Identify problems and define goals and objectives.
   a. Obtain readily available geologic information for preliminary identification of natural hazards and resources.
   b. Review the data in relation to current land-use plans and policies, projected growth trends, and anticipated changes.
   c. Develop a tentative set of objectives and priorities, giving special consideration to hazards and resources.
2. Collect and interpret data.
   a. Evaluate adequacy of available geologic data and develop a program for compiling new data.
   b. Arrange with earth scientists to prepare basic and interpretive maps and texts. Map information should relate in scale and detail to other basic planning information.
   c. Estimate the probable future demand for land, considering projections of population growth and distribution, economic activity, social and cultural needs, and transportation requirements.
   d. Prepare land-capability maps showing the natural capability of each land unit to accommodate each potential use.
3. Formulate plans.
   a. On the basis of land-capability maps, appropriate projections, and economic, social, and political analyses, consider feasible alternative arrangements of land uses.
   b. Prepare alternative land-use policies and plans, incorporating as much detail as necessary to guide future decisions.
4. Evaluate impacts.
   a. Evaluate alternative land-use policies and plans for environmental, economic, and social impacts.
   b. Evaluate exposure to risk from natural hazards associated with alternative land-use policies and plans.
5. Review and adopt a plan.
   a. Present plan alternatives for review and selection by the appropriate legislative body.
   b. Schedule and hold public hearings.
   c. Adopt plan with such modifications as may be needed to respond to information provided and opinions expressed at public hearings.
6. Implement the plan.
   a. Prepare and seek adoption of land-use regulations and any land-acquisition and capital-improvement programs needed to carry out the plan.
   b. Establish guidelines and a procedure for conducting the geologic investigations needed to evaluate development proposals.
   c. Develop the procedures and capability for reviewing soils and geology reports, environmental impact assessments, and project proposals.
   d. Arrange for modification of previous steps as new or more detailed information becomes available.

DESCRIPTION OF LAND-CAPABILITY STUDIES

Land-capability studies are an important element of the land-use planning and decisionmaking framework outlined above. In any area, the existing natural features and processes present a range of constraints and opportunities for different uses of land. It is well known that the natural characteristics of different parcels of land vary as well as the physical requirements for different uses of the land. For example, farmers seek fertile soils; manufacturers in heavy industry want level sites with good foundation conditions; golf course developers look for rolling terrain with adequate surface and subsurface soil conditions.

Land-capability studies systematically record and

formalize judgments concerning the physical features of the land with regard to particular categories of land uses. Such studies evaluate, for a specified land use, the relative physical merits of the lands in a study area. The natural features and processes considered usually include topography, hydrology, geology, soils, vegetation, and climate.

Methods of evaluating land capability differ. A study may be largely descriptive, pulling together in narrative form information concerning the natural features and processes relevant to a particular land use. Or a study may involve a fairly sophisticated effort to quantify, weigh, and aggregate the earth science information relevant to specific uses for all lands within a planning area. In any case, judgment is needed and the studies should be carried out by planners with the assistance of experienced earth scientists. Land capability analysis involves four basic steps:

1. Defining the focus of the study and the land use or uses to be considered,
2. Determining the natural characteristics affecting capability for the use or uses selected,
3. Gathering, analyzing, and presenting information describing the natural characteristics, and
4. Evaluating relative capability of land units to support the selected use or uses.

Judgments concerning the importance of each factor as well as the range of conditions within each factor can be expressed numerically. The main advantage of a quantified analysis is not greater precision of results, but greater ease in combining many judgments into an overall rating of land capability.

Land capability studies vary in focus as well as method. A study may focus on identifying constraints for particular uses; another on factors favorable for particular uses; and another on both constraining and favorable factors using positive and negative ratings. A common variation is a risk analysis, which rates land within a study area in terms of relative risk from selected natural hazards. A study may be very detailed, dividing an area into small units which are evaluated for a specific use such as a sanitary landfill; or it may be general, dividing a study area into large units which are evaluated for a broad use category such as urban development.

Judgments about relative costs involved to overcome natural conditions adverse to particular uses commonly affect values assigned in a land-capability study. The Association of Bay Area Governments in a land-capability study recently completed as part of the San Francisco Bay Region Study (Laird and others, 1979) expressed land capability directly in terms of the dollar costs associated with hazard-mitigation measures, potential property damage from natural hazards, and loss of natural resources. The method was tested in a pilot land-capability analysis of part of the Santa Clara Valley.

The pilot study focuses on geologic and hydrologic hazards and resources and makes excellent use of many San Francisco Bay region reports. Natural factors considered in evaluating land capability include earthquakes, flooding, bearing materials problems (potential for shrink and swell, settlement, liquefaction, and subsidence), slope stability, erosion and sedimentation, septic-tank limitations, and natural resources. Lands in the study area were evaluated for a range of uses: agricultural or rural, semi-rural residential, single-family residential, multi-family residential, regional commercial, downtown commercial, industrial manufacturing, and freeway.

The total expected cost associated with each natural constraint and resource for each land use was calculated. Cost information for all natural resources and problems for each 24.9-acre grid cell was aggregated for each land use. The resulting number indicates for each cell the expected dollar cost per acre of developing that cell with that land use. The range of total costs was divided into six capability levels and a land-capability map for each use was printed by computer.

Analyses of land capability provide only part of the information needed for land-use decision. Economic, social, political, and aesthetic considerations are also important. The physical capability of a parcel of land to support an intensive use may be poor, but other factors, such as location and accessibility, land cost, absence of alternative lands, or overriding public need may well indicate that the parcel should be intensively developed.

A study that systematically evaluates economic, social, and political factors, in addition to physical capability factors, is called a "land-suitability study." A land-capability study is often undertaken as part of a broader land-suitability study. On occasion, capability is, or should be, the determining factor. Areas with very low capability for sustaining a particular use can sometimes be eliminated from further consideration on that basis alone, allowing the planner to focus attention on more realistic options.

Land-capability studies are becoming increasingly important to land-use planning at all governmental levels. They assure that physical characteristics of the land will be given systematic consideration in the development of land-use plans and policies. The earth-science information requirements for such

studies vary with the total land area and the specific use to be studied. At the regional level, for example, fairly generalized data may be appropriate for an analysis of land capability for regional open space. On the other hand, a study undertaken, at any governmental level, to locate specific sites with good capability for sanitary landfill will require detailed information.

IMPORTANCE OF FLATLAND DEPOSITS IN REGIONAL STUDIES

Regional land-use planning is primarily concerned with those issues that are independent of local political boundaries and thus require a coordinated response. Moreover, many areawide problems, such as water and air pollution, are directly linked to the use of land. An appropriate focus of a regional land-use plan is to identify areas where urban growth can occur with minimum environmental damage, loss of resources, private and public cost, and risk to persons and property.

Federal regulations governing eligibility for funds under the Comprehensive Planning Assistance Program (U.S. Congress, 1974) require that all agencies applying for grants must have an adopted land-use element by August 22, 1977. For areawide agencies this element must include the following:

> (1) Long and short term policies, and where appropriate administrative procedures and legislative proposals, with regard to where growth should and should not take place:
> (2) The type, intensity and timing of growth;
> (3) Studies, criteria, standards and implementing procedures necessary for effectively guiding and controlling major decisions as to where growth shall and shall not take place; and
> (4) Policies, procedures, and mechanisms necessary for coordinating local, areawide, and State land use policies with functional planning and capital investment strategies, when available, and improvements in governmental structures, systems and procedures that will facilitate the achievement of land use objectives. (U.S. Department of Housing and Urban Development, 1975, p. 36862)

The regulations also require that federally funded planning activities be conducted in accord with the National Environmental Policy Act of 1969, Public Law 91-190, (U.S. Congress, 1969) through the inclusion of environmental planning in the comprehensive planning process. Specifically, each agency shall:

> (1) Identify salient elements of the natural and the man-made environments, their interrelationships, and major problems and/or opportunities they present for community development;
> (2) Assess those environmental factors which will:
> (i) Minimize or prevent undue damage, unwise use, or unwarranted pre-empting of natural resources and opportunities;
> (ii) Recognize and make prudent allowance for major latent environmental dangers or risks (e.g., floods, mud slides, earthquakes, air and water pollution); and
> (iii) Foster the human benefits obtainable from use of the natural environment by wise use of the opportunities available (e.g., use of natural drainage systems for park and recreational areas); (U.S. Department of Housing and Urban Development, 1975, p. 36860)

Regional or areawide planning agencies are also being funded by the Environmental Protection Agency (EPA) under Section 208 of the Federal Water Pollution Control Act of 1972 (U.S. Congress, 1972) to carry out waste-water management planning. Each plan must contain a land-use element. EPA and HUD have signed an interagency agreement to assure that land-use plans prepared under one program meet the requirements of the other.

Because of Federal support for areawide land-use planning emphasizing environmental concerns, land-capability studies are needed and are likely to be applied with increasing effectiveness. Evaluating land capability is important in developing policies with regard to "where growth should and should not take place" (U.S. Department of Housing and Urban Development, 1975). Such evaluation helps identify (1) areas where land preparation, building, and maintenance costs are likely to be higher than average; (2) areas where structures are subject to damage from natural processes and occupants may be subject to injury or loss of life; and (3) areas where certain uses of the land may alter or interfere with natural features or processes.

In the San Francisco Bay region, evaluation of capability of flatland areas to accommodate urban uses is particularly important, because most urban growth is expected to occur in these areas (Association of Bay Area Governments, 1970, p. 6). Urban growth is a process of converting land from rural or other relatively nonintensive uses to urban use. Thus evaluating capability of lands for agriculture and other open-space uses is also essential in order to identify areas of conflicting capability and possible trade-offs. As stated in ABAG's adopted regional plan:

> It is on the Bay plain area that circles the Bay, and the larger valleys of Santa Clara, Napa, Sonoma, Petaluma, Livermore, and Ygnacio that the greatest amount of urban development has occurred. These valley lands, separated only by intervening ridges, are being steadily converted from agricultural to urban use to serve the needs of a growing urban population. Due to the difficulties of building on steeper slopes, those valley lands that remain unurbanized are prime targets for future urban development. The region will have to choose either to retain the prime agricultural lands and unique natural settings that these lands provide, or to allow them to be transformed by urbanization. (Association of Bay Area Governments, 1970, p. 4).

Regional evaluation of land capability must also include hillside lands. Options for location of needed housing or facilities are limited by existing development. In some areas, it may be necessary to choose between hillsides and unstable flatlands for needed

development. Information on relative capability of all available lands within a planning area is necessary for rational land-use decisions.

Capability studies are especially helpful in evaluating lands for uses in which natural characteristics are critical. For instance, urban uses can be physically accommodated on most land, at some development cost, but only land with specific natural characteristics can accommodate agricultural uses. Sand and gravel extraction, fish and wildlife habitats, sanitary landfills, and ground-water recharge areas are other examples of land uses with specific physical requirements. Early identification, at the regional level, of areas capable of sustaining such uses can avert unnecessary loss of resource potential. Recent emphasis by State and areawide agencies on identifying and protecting areas of critical environmental concern recognizes the relation between land use and natural characteristics of the land.

APPLYING INFORMATION ON FLATLAND DEPOSITS

The maps of flatland deposits and the interpretation derived from these maps provide a basis for ranking the flatland areas in terms of capability for some uses. An example of the use of the flatlands information in regional land-capability analysis is outlined in the following sections. The example indicates how the information can be used to identify potentials and problems that need further analysis. For direct use in plan formulation, the capability evaluation should cover the entire planning area (not just flatlands) and incorporate information from other sources. The example serves two purposes:

1. It indicates possible implications of the interpretations contained in the preceding two sections for regional land-use planning.
2. It illustrates a method that is useful in regional land-capability analysis.

The example is presented according to the four basic steps of land-capability studies already listed.

DEFINING THE FOCUS OF THE STUDY

The example uses the characteristics of flatland deposits to identify areas with potential land-use conflicts based on capability for urban residential development, agriculture, ground-water recharge, and sand and gravel extraction.

DETERMINING THE NATURAL CHARACTERISTICS AFFECTING LAND CAPABILITY

In the next step, those flatland characteristics affecting the capability of land to support each use are selected. Capability for agriculture is based on soil characteristics of each geologic unit as interpreted on p. 62. Capability for ground-water recharge is based on permeability of the flatland materials (as shown in fig. 47) and capability for sand and gravel extraction is derived from figure 51 and the discussion on p. 64. Capability for urban residential use is affected by several flatland characteristics: flood potential, permeability, shrink-swell potential, settlement potential, possibility of liquefaction-induced ground failure, and seismic-wave amplification. Table 5 lists (1) the characteristics affecting land capability for urban residential development derived from the map of flatlands deposits, (2) the nature of the impact, and (3) the general relation of the characteristic to the map of flatland deposits.

Other characteristics that affect land capability for urban residential uses include soil-bearing capacity, erosion potential, scenic qualities, vegetation, slope stability, and faulting. These characteristics are not considered in this example because they cannot be directly derived from the map of flatland deposits.

TABLE 5.—*Characteristics of flatland deposits affecting capability for urban residential development*

Characteristics	Nature of impact	Relation to flatland deposits
Flooding	Potential loss of life; damage to structures, personal property; erosion; cost of flood insurance; increase in flood extent or depth	Flood potential confined to Holocene alluvium and bay mud.
Permeability	Ponding; excavation problems; cost of engineered solutions such as pumping, channeling, waterproofing	Problems severe in bay mud and fine-grained alluvium.
Shrink-swell	Extra cost of foundation engineering; damages from shifting and cracking of improperly engineered foundations	Problems most likely in bay mud and fine-grained alluvium.
Settlement	Damage to structures, especially if differential settlement occurs; extra cost of special foundation engineering	Potential exists only in bay mud and delta area peats.
Liquefaction-induced ground failure	Destruction or damage to structures during earthquakes	High potential in water-saturated sand within bay mud.
Seismic wave amplification	Damage and potential destruction of structures; loss of life from seismically induced ground shaking	Potential in all flatland materials depending on thickness underlying material; most significant in bay mud.

GATHERING, ANALYZING AND PRESENTING THE INFORMATION

The objective of the next step is to rate the relative capability of selected land units for the uses being considered. Several tasks are usually involved. First the land units to be rated are defined. These may be census tracts, political units, grid cells, or virtually any configuration that can be mapped and that is generally consistent in size with the scale of the data and the purpose of the study. In the example, the land units evaluated are the geologic units on the map of flatlands deposits (pls. 1, 2, and 3).

A scoring system is then devised to express the degree each natural factor affects the land capability. In the example, a simple scoring system is used: 3, indicates high capability; 2, moderate capability; 1, low capability; and 0, no capability for the use. More complex scoring systems can be used to define high, moderate, and low categories more precisely. For example, categories of flooding might be: Areas subject to flooding on the average of once every 1-10 years, once every 10-100 years, once every 100-500 years, or areas not subject to flooding. Regardless of how precisely the categories are described, the assignment of a numerical score is a judgment based on knowledge of the factor.

A weight is also assigned to each natural factor representing the importance relative to the other factors as a determinant of capability. The judgments made in assigning the rating and weights are crucial to the conclusions and should always be explicitly stated. In the example, a simple weighting scale of 1 to 5 was chosen.

The score is multiplied by the weight to get a weighted capability rating. The ratings for all natural factors for each unit are totalled to produce an aggregated weighted rating. The aggregated weighted ratings permit a comparison of relative capability of each unit for each use. Tables 6 and 7 summarize these operations. The scores shown in table 6 are based on the following judgments:

(1) High permeability and low potential for flooding, shrink-swell, settlement, liquefaction, and seismic wave amplification are favorable for urban residential development.

(2) High potential for flooding is a severe constraint for urban residential development and, accordingly, is given a score of zero.

The judgments made in assigning weight are less evident. They include the following considerations:

(1) Flooding affects capability for urban residential development more than the other five factors. This judgment is based on the high cost, both monetary and environmental, of providing flood protection; the relatively small area involved; the importance of flood-prone areas for other uses; and the high social and economic loss caused by floods in residential areas.

(2) Shrink-swell is judged the least important of the factors because the potential for damage can be readily and fairly inexpensively identified and mitigated with appropriate site investigation and foundation engineering.

(3) Seismic-wave amplification can cause severe damage to residential structures but, because of the infrequency of major earthquakes, uncertainties in delineating areas of high potential, and ability to design residential structures to withstand ground shaking, this factor is judged slightly less important than flooding.

(4) Settlement and liquefaction are considered moderately important. Damage to residences caused by settlement can usually be averted with appropriate site investigations and properly engineered fills. Ground failure from liquefaction can cause severe damage to residential structures, but it occurs infrequently and only in parts of the areas with high or moderate liquefaction potential.

(5) Permeability is important primarily if septic-tank systems are to be used in a residential development. Problems resulting from low

TABLE 6.—*Capability weighting and scoring system for urban residential development*

Factor	Degree of potential	Score	Weight	Weighted capability
Flooding	High	0		0
	Moderate	1	5	5
	Low	3		15
Permeability	High	3		6
	Moderate	2	2	4
	Low	1		2
Shrink-swell	High	1		1
	Moderate	2	1	2
	Low	3		3
Settlement	High	1		3
	Moderate	2	3	6
	Low	3		9
Liquefaction	High	1		3
	Moderate	2	3	6
	Low	3		9
Seismic-wave amplification	High	1		4
	Moderate	2	4	8
	Low	3		12

permeability can generally be overcome by installing adequate drainage and sewer systems.

EVALUATING RELATIVE CAPABILITY OF LAND UNITS

The capability ratings in table 7 indicate that Holocene deposits generally have lower capability for urban development than do Pleistocene deposits, and among the Holocene deposits, bay mud appears to be in a category by itself with very low capability. The numbers employed in the analysis provide only a means of aggregating the impact of various physical characteristics of each unit on urban development. The results thus need to be expressed in generalized terms. Possible aggregated ratings range from 13 to 54. Dividing the range into three nearly equal ranges representing high, moderate, and low capability gives the following results:

13–26 low capability: bay mud (Qhbm)

27–40 moderate capability: fine-grained alluvium, fine-grained-salt affected alluvium, medium-grained alluvium, and beach and dune sand deposits

41–54 high capability: coarse-grained alluvium, late Pleistocene alluvium, early Pleistocene alluvium, Pleistocene sand, Quaternary marine terrace deposits, and Colma Formation

These ratings can then be mapped as shown in figure 52 to show the general distribution of areas with high, moderate, and low capability for residential uses based on the factors considered in the example. This map and ratings can then be compared with those for the other uses being considered to identify areas of potential conflicts.

Developing a capability rating of the land units for agriculture, ground-water recharge, and sand and gravel extraction is, in this case, very simple. The ratings expressed in terms of high, moderate, and low capability are derived directly from the section, on "Resources and Potentials." These are summarized, along with the ratings for urban residential development, in table 8.

USE OF LAND-CAPABILITY STUDIES

At this point it is appropriate to see what has been learned from this preliminary exercise as a start in directing subsequent more complete and detailed investigations. The following observations can be made:

(1) Bay mud has low capability for all the uses considered. Special attention should be given to identifying positive attributes for other uses. Fish and wildlife habitats, oyster shell deposits, salt production, and water-related recreational activities should be identified and evaluated.

(2) High capability for all uses exists in areas underlain by coarse-grained alluvium and moderate or high in areas underlain by medium-grained alluvium and late Pleistocene alluvium. The need to determine appropriate land uses for these areas is obvious. Since relatively few areas have high potential for agriculture and ground-water recharge, these uses should be given priority consideration in land-use determina-

TABLE 7.—*Capability rating of geologic units for urban residential development*

[Qhsc, which is shown on the map, is not rated because it occurs only in active stream channels and is not suitable for urban development]

Capability rating	Low	Moderate				High					
	Geologic units										
Characteristic	Qhbm	Qhaf	Qhafs	Qham	Qhs	Qhac	Qpa	Qpea	Qps	Qpmt	Qpmc
Flooding	0	0	0	0	[1]5	5	5	15	15	15	15
Permeability	2	2	2	4	6	6	6	6	6	6	6
Shrink-swell	1	1	1	2	3	3	2	3	3	2	3
Settlement	3	9	9	9	9	9	9	9	9	9	9
Liquefaction[2]	3	6	6	6	3	9	9	9	6	9	9
Seismic wave amplification	4	12	12	12	12	12	12	12	12	12	12
Aggregated weighted capability	13	30	30	38	38	44	53	54	51	53	54

[1]Qhs, where it occurs as beach sand, is subject to daily tidal flooding; where it occurs as dunes, it may not be flooded at all.

[2]Liquefaction potential exists only where well-sorted granular material at shallow depth is saturated with water and is confined within impermeable layers.

CAUTION: Taking these numbers literally may be hazardous to your planning area!

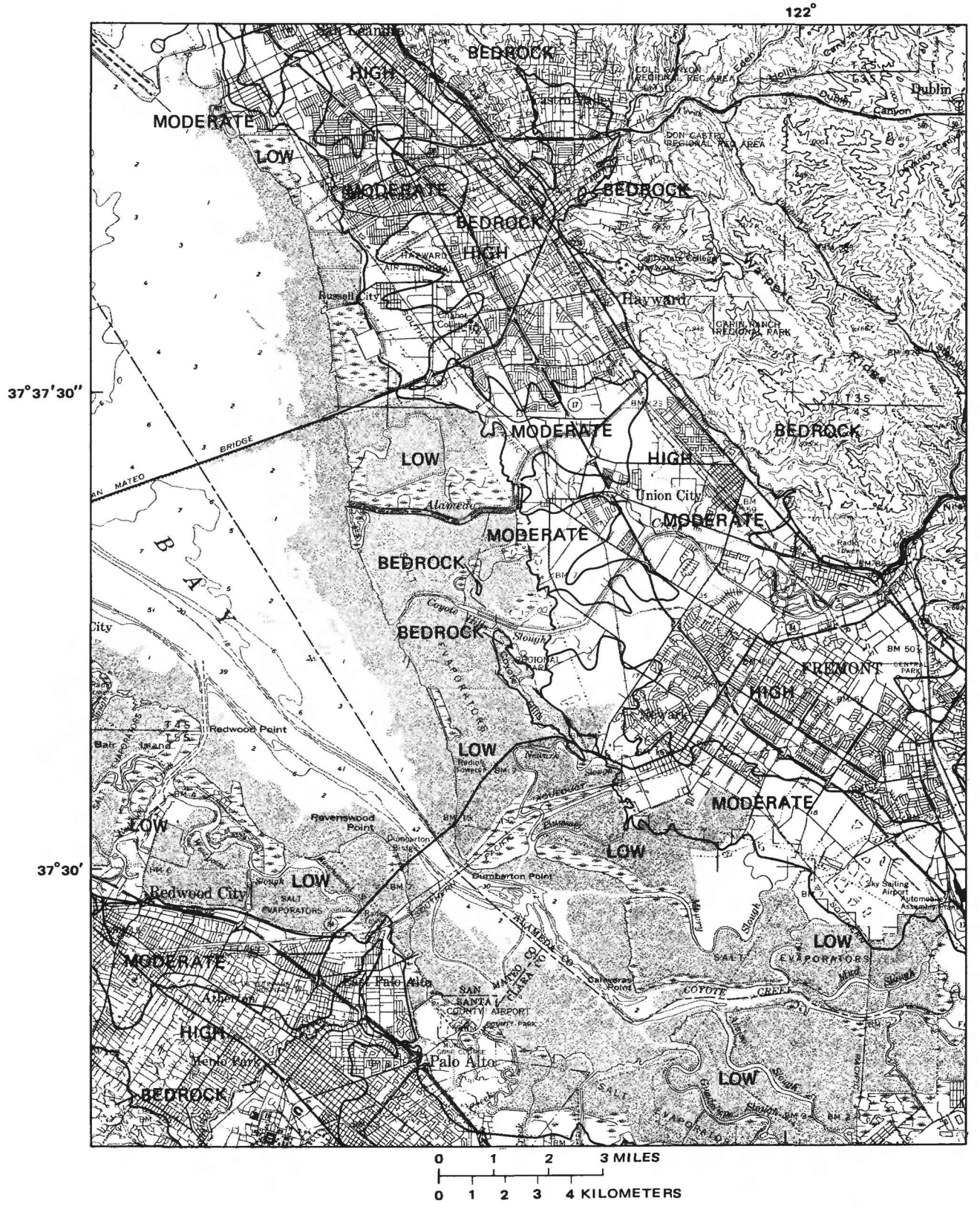


FIGURE 52.—Part of bay region showing areas with high, moderate, and low capability for urban residential development.

TABLE 8.—*Capability rating of geologic units for selected uses*

Land units	Land uses			
	Agriculture[1]	Ground-water recharge[2]	Sand and gravel extraction[3]	Urban residential development
Qhbm-----	Low	Low	Low	Low
Qhaf------	Moderate	Low	Low	Moderate
Qhafs-----	Low	Low	Low	Moderate
Qham-----	High	Moderate	High	Moderate
Qhac------	High	High	High	High
Qhs-------	Low	High	Moderate	Moderate
Qpa-------	Moderate	Moderate	High	High
Qpea------	Low	Moderate	Low	High
Qps-------	Low	Moderate	Low	High
Qpmt-----	Moderate	Moderate	Low	High
Qpmc-----	Low	Moderate	Low	High
Qhsc------	Low	High	High	Not applicable

[1] Rating from section on "Soil."
[2] Rating from figure 47 and section on "Water Resources."
[3] Rating from figure 51 and section on "Sand and Gravel."

tions. Suitability factors are likely to be important in these areas.

(3) Many of the units have high capability for urban development. Natural characteristics are less constraining for this use than for the other uses considered. The ratings indicate where constraints to urban development may occur and where potential for urban growth conflicts with potential for priority uses.

Capability ratings are only part of the information needed to formulate land-use plans. Final decisions must rest upon other environmental, social, economic, and cultural information. Combining all relevant information can be accomplished through a suitability study, as noted earlier. The method is the same as for a capability study, but the information requirements are broader. For most urban uses, capability analysis is appropriately carried out as an integral part of a broader suitability study. Even for uses where natural characteristics may be paramount, such as agriculture, sanitary landfills, or other open-space uses, the final decision on land use usually depends, at least in part, on suitability factors. Accessibility, distance from markets, and ecological constraints, for example, may be critical. A capability study is, however, valuable in defining options and limitations early in the planning process and can be effective in narrowing the scope of a subsequent suitability analysis. For example, identifying lands with high capability for agricultural uses early in the planning process focuses the analysis of suitability factors on those lands with high capability. Sequential analysis can save the time and expense of acquiring needless data concerning agricultural suitability for lands clearly incapable of supporting such uses.

In evaluating land for urban uses, suitability factors can be usefully incorporated into the original analysis. This is because most land can physically accommodate most uses. The question is, usually, at what cost and risk. The answer to these questions involves suitability factors.

The ratings based on characteristics of flatland deposits can focus further investigation by identifying problems and potential to be considered throughout the planning process. Table 9 sets forth, by way of example, the planning implications of the capability ratings for urban residential development.

Basically, as noted earlier, a capability rating for urban uses provides an overview of potential public and private costs; risks to property and persons; and, combined with capability information for priority uses, some possible adverse impacts.

PLANNING RESPONSE TO FLATLAND ISSUES

PLANNING FOR THE BAYLANDS

The capability ratings for urban residential development provide a generalized view of differences in the ease and cost of construction and risks of building on different flatland deposits. Characteristics of flatland deposits rarely cause land to be totally incapable of supporting residential uses. They may, however, strongly affect the cost of land preparation, construction, and maintenance. Shrink-swell and settlement problems, poor permeability, and inadequate drainage can generally be overcome using well-established engineering techniques, but these techniques can be expensive, and they do not always avert continuing maintenance problems.

In the San Francisco Bay region, such problems are particularly severe on bay mud, as shown in the capability example and described in the section "Potential Problems in Flatlands Regions." Most land areas underlain by bay mud are subject to tidal action and must be (or have been) diked and filled prior to development. In many places, the demand for flat, buildable land, adjacent to existing urban areas has been strong enough to make diking and filling worth the cost. Commercial, industrial, and residential developments as well as major public facilities including two international airports and a naval air station have been built on fill over bay mud. It is possible to develop the land-fill on top of the bay mud, but the cost will be high.

Foster City is a privately developed new town started in 1963 on a diked and filled island in San Francisco Bay just south of the San Francisco International Airport (also built on filled land). Buildings require foundations of reinforced concrete with continuous footings or piles. In the mid-1960's founda-

TABLE 9.—*Regional planning implications of capability rating for urban residential development*

Steps in Planning Process	Informational Requirements	Land Use Evaluation	Developmental Factors
Data collection and interpretation	Other natural data and economic, social, political, esthetic, and other relevant information should be collected.	Additional detailed information concerning characteristics of flatland deposits, particularly potential for agriculture, should be collected.	Information detailing potential for open space or other nonintensive uses of such areas should be collected.
Plan formulation	Areas can be considered for urban development by process of elimination.	Evaluation of other natural and economic, social, political, esthetic factors is needed to make initial judgments concerning land use. Agricultural uses should be considered.	Areas can be considered for open space by process of elimination; presence of wildlife habitats, sensitive ecological systems, potential for water-related recreation may be important. Urban development should be recommended only if great public benefit can be shown.
Project review A–95 review (Assoc. of Bay Area Governments or permit process (Bay Conservation and Development Commission)	Unless other factors indicate problems, additional information concerning flatland deposits may not be needed.	Site investigations of soil and geology may be needed in reviewing projects.	Site investigations of soil and geologic conditions needed. Developer must provide evidence that site can be safely developed.
Environmental Impact Statement and Environmental Impact Report	Environmental problems not related to nature of flatland deposits likely to be more important.	Environmental assessment should consider constraints posed by flatland deposits.	Detailed environmental assessment of flatland constraints should be provided and considered.

tion construction alone cost an average of $1.00–$1.50 per square foot of floor space more than it would have on firmer ground; the cost would be higher today (Ronald Campbell, oral commun., July 20, 1975). An additional cost of approximately $100 per house was required to provide utility service in the mid-1960's; the additional cost today (1975) is about $300 (Lee Ham, oral commun., July 25, 1975).

Land-preparation costs are also high. The land must be diked, drained, and filled to be usable. At Redwood Shores, a major community development on bay fill just south of Foster City, it costs an average of $8,000 per acre to dewater, demulch, and recondition the already-diked land prior to filling. The filling operation costs about $6,000 per acre per foot of fill to place, spread, and compact (Gene Mascarelli, oral commun., July 25, 1975).

Costs such as these can be readily justified by a land developer, because of the high market value of the prepared land. In Redwood Shores, filled residential land commands a price between $73,000 and $93,000 per acre. The costs of land preparation and construction are assumed by the private sector of the economy. But public costs may also be high, particularly for maintenance of roads, storm and sewer pipelines, and other public improvements. Thus construction on bay mud involves a public as well as private economic commitment. This fiscal impact is an appropriate concern of land-use planning.

As discussed in the section on "Potential Problems in Flatlands Regions," risks from flooding, liquefaction, and seismic wave amplification are also high on lands underlain by bay mud. The ecological-environmental impact from filling the bay for urban developments is also great. Yet in spite of these constraints, urban development on bay mud has taken and continues to take place. The San Francisco Bay Conservation and Development Commission Plan states:

> As the Bay Area's population increases, pressure to fill the Bay for many purposes will increase. New flat land will be sought for many urban uses because most, if not all, of the flat land in communities bordering the Bay is already in use—for residences, businesses, industries, airports, roadways, etc. Past diking and filling of tidelands and marshlands has already reduced the size of the Bay from about 680 square miles in area to little more than 400. Although some of this diked land remains, at least temporarily, as salt ponds or managed wetlands, it has nevertheless been removed from the tides of the Bay. (San Francisco Bay Conservation and Development Commission, 1969, p. 2).

The reduction in size of the bay by diking and

filling (fig. 53) became a major public issue during the 1960's, because of the environmental, ecological, and climatological impacts of continued bay filling as well as growing concern over the safety of structures on bay fill—particularly during an earthquake.

Public efforts to stop indiscriminate filling of the bay led to State adoption of the McAteer-Petrie Act of 1965, creating the BCDC, (Bay Conservation and Development Commission). BCDC was authorized to prepare a comprehensive plan for the conservation of the bay and development of its shorelands and to recommend appropriate procedures and institutions

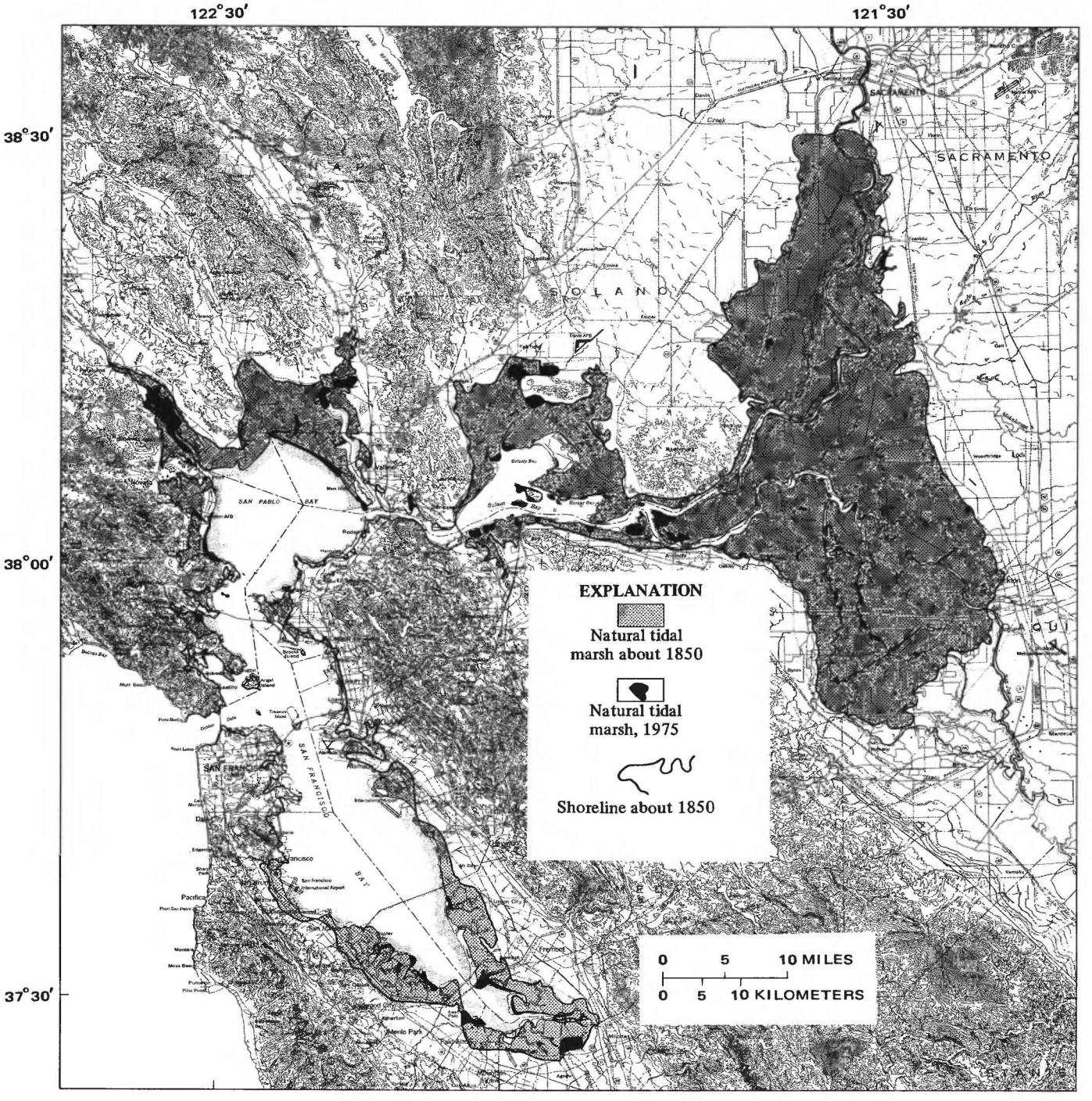


FIGURE 53.—Reduction in area of natural tidal marsh around San Francisco Bay between 1850 and 1975. Location of 1850 shoreline from Nichols and Wright (1971).

to carry out the plan. The San Francisco Bay Plan was completed in 1969 and adopted by the State Legislature (San Francisco Bay Conservation and Development Commission, 1969). BCDC became a permanent organization with responsibility to revise and implement the plan. The findings, policies, and regulatory procedures that are set forth in the San Francisco Bay Plan demonstrate how earth-science information was used to address problems of regional concern.

Although no formal capability analysis was undertaken in preparing the San Francisco Bay Plan, specific information concerning known natural constraints and opportunities for various land uses was sought and applied in the planning process. Twenty-three separate technical reports on the physical, ecological, social, and economic aspects of the bay and its use were published during the planning period, including several related to the nature of flatland deposits. The plan addresses the issues of the environmental impact of bay fill and the safety of fills (San Francisco Bay Conservation and Development Commission, 1969, p. 1).

Major undesirable effects of fill were recognized (San Francisco Bay Conservation and Development Commission, 1969, p. 1-2) as: (1) loss or degradation of an important fish and wildlife habitat, (2) decrease in the ability of the bay to assimilate pollutants, (3) reduction of the moderating effect of the bay upon local climate and an increase in the danger of air pollution, and (4) diminished scenic beauty of the bay.

Despite these harmful impacts, some bay filling may be desirable or necessary if the benefits outweigh the disadvantages. A permit is required from BCDC for any filling or dredging of the bay and lands subject to tidal action. Permits may be issued for fills if one of the following four conditions is met:

> (1) The filling is in accord with the Bay Plan policies as to the Bay-related purposes for which filling may be needed (i.e., ports, water-related industry, and water-related recreation) and is shown on the Bay Plan maps as likely to be needed; or (2) The filling is in accord with Bay Plan policies as to purposes for which some fill may be needed if there is no other alternative (i.e., airports, roads, and utility routes); or (3) The filling is in accord with the Bay Plan policies as to minor fills for improving shoreline appearance or public access; or (4) The filling would provide on privately-owned property for new public access to the Bay and for improvement of shoreline appearance—in addition to what would be provided by the other Bay Plan policies—and the filling would be for Bay-oriented commercial recreation and Bay-oriented public assembly purposes. (San Francisco Bay Conservation and Development Commission, 1969, p. 36).

The question of safety of the fill must also be addressed before BCDC can issue a permit for filling. The following section, adapted from San Francisco Bay Conservation and Development Commission (1969, p. 15, 17), lists the findings and policies of the BCDC plan relevant to safety of fills.

Finding.—Virtually all fills in San Francisco Bay are placed on top of bay mud, which presents many engineering problems. The construction of a sound fill depends in part on the stability of the base upon which it is placed. Safety of a fill also depends on the manner in which the filling is done and the materials used for the fill. Construction of a fill or building that will be safe enough for the intended use requires (1) recognition and investigation of all potential hazards—including (a) settling of a fill or a building over a long period of time, and (b) ground failure caused by the manner of constructing the fill or by shaking during a major earthquake—and (2) construction of the fill or building in a manner specifically designed to minimize these hazards. While the construction of buildings on fills overlying bay deposits involves a greater number of potential hazards than construction on rock or on dense hard soil deposits, adequate design measures can be taken to reduce the hazards to acceptable levels.

Policy.—The bay agency should appoint a Fill Review Board consisting of geologists, civil engineers specializing in soils engineering, structural engineers, and architects competent to and adequately empowered to (a) establish and revise safety criteria for bay fills and structure thereon, (b) review all except minor projects for the adequacy of their specific safety provisions and make recommendations concerning these provisions, (c) prescribe an inspection system to assure placement of fill according to approved designs, and (d) gather and make available performance data developed from specific projects. These activities would complement the functions of local building departments and local planning departments, none of which is presently staffed to provide soils inspections.

Even if the bay plan indicates that a fill may be permissible, no fill or building should be constructed if hazards cannot be overcome adequately for the intended use in accordance with the criteria prescribed by the Fill Review Board.

To provide vitally needed information on the effects of earthquakes on all kinds of soils, installation of strong-motion seismographs should be required on all future major land fills. In addition, the Bay agency should encourage installation of strong-motion seismographs in other developments on problem soils, and in other areas recommended by the U.S. Geological Survey, for purposes of data comparison and evaluation.

Finding.—Flood damage to fills and shore-line

areas can result from a combination of heavy rainfall, high tides, and winds blowing onshore. To prevent such damage, buildings near the shoreline should be above the highest expected flood mark (9 feet above sea level is generally set as the safe mark except in the southern part of the south bay, where the higher tides require almost a foot more elevation) or should be protected by dikes of an adequate height.

Policy.—To prevent damage from flooding, buildings on fill or near the shoreline should have adequate flood protection as determined by competent engineers. As a general rule, buildings near the shoreline should be at least 9 feet above mean sea level (standard USGS datum) or should be protected by dikes of an equivalent height and by any necessary pumping facilities. In the south half of the south bay, this height should be at least 10 feet. Exceptions to the general height rule may be made for development specifically designed to tolerate periodic flooding.

Finding.—Excessive pumping from underground fresh-water reservoirs has caused extensive subsidence of the ground surface in the San Jose area and as far north as Dumbarton Bridge (Poland, 1971, shows subsidence from 1934 to 1967). Indications are that if heavy ground-water pumping is continued indefinitely in the south Bay area, land in the Alviso area (which has already subsided about 7 ft since 1912) could subside up to 7 ft more; if this occurs, extensive dikes may be needed to prevent inundation of low-lying areas by the high tides.

Policy.—To minimize the potential hazard to bayside development from subsidence due to groundwater withdrawal, all proposed developments at the lower end of the south bay should be sufficiently high above mean sea level or sufficiently protected by dikes to allow for the effects of additional subsidence, utilizing the latest information available from the U.S. Geological Survey.

A permit from BCDC is also required for development of the bay shoreline—the area extending inland from the bay a maximum of 1,000 feet (305 m). The control over shoreline development is considered necessary to reduce pressures for bay filling and provide public access to the bay. Water-related uses such as ports, recreation, and wildlife preserves are given priority.

The BCDC plan and permit procedures provide a framework for the continuing use of geologic information in land-use planning and decisionmaking. The kind of information summarized in this report can be used directly by BCDC in revising its plan and in a State-sponsored study of Suisun Marsh. BCDC uses information on flatland deposits in its permit process to evaluate the safety of proposed fills. This general information of geologic characteristics is used to help determine what site-specific information should be required from the applicant.

The Fill Review Board, as presently constituted, has the expertise to review and evaluate soils and geologic reports provided by an applicant. This activity is a critical factor in the agency's effective use of geologic information. Significant improvement in the seismic engineering of fills and design of structures has resulted from the board's insistence on a thorough evaluation of geologic hazards at a project site (San Francisco Bay Conservation and Development Commission, 1974, p. 8).

The availability of geologic information presented in a form understandable to nongeologists is considered very important to BCDC. Such information expands the understanding of both decisionmakers and project applicants and can improve the quality of project proposals and commission decisions.

THE URBAN-AGRICULTURAL CONFLICT

The generally high capability of many flatland areas for both agricultural and urban uses is a major land-use planning concern. In California, the process of urban growth is, for the most part, the process of converting land from agricultural to urban uses. Nearly 4.5 million acres of the State's most productive farmland have been converted to nonagricultural uses since 1947 (Dean, 1975, p. 18). The California OPR (Office of Planning and Research) (California Office of Planning and Research, 1974) states that over the last two decades, 15,000–20,000 acres of highly productive land per year have been converted to nonagricultural uses. Although OPR reports that from 1960–72 California had a net gain of 56,000 acres of agricultural land per year, reversing the trend of the 1950's, the gain is in irrigated land, which commonly requires intensive use of energy and chemical fertilizers to produce high yields.

Planning future land uses to meet the land requirements of both agricultural and urban uses must be based on the best information available concerning land capability for both categories of use. As described in the section on "Land Capability Studies," information on flatland deposits is important in evaluating agricultural and urban land capability. The map of flatland deposits (pl. 1, 2, and 3) provides a generalized view of agricultural capability (see section on "Soil"). Information such as this can be used in combination with Soil Conservation Service soil ratings, if available, to identify lands meriting further investigation for agricultural potential.

Planning for the use of agricultural land requires a broad, even a global, perspective of future productive capacity and food needs. Within a national and State policy framework, regional planning can be particularly important in reconciling urban and agricultural demands for land. The Association of Bay Area Governments (1970) recommends a "city-centered" pattern of development accommodating new growth through in-filling and extension of existing urban areas and development of new communities. A major justification for this growth pattern is to preserve resources, particularly agricultural lands.

The need to preserve agricultural lands is more explicity expressed in ABAG's Open Space Plan, Phase II (Association of Bay Area Governments, 1972). This plan includes lands with agricultural capability in the category, "open space for managed resource production" (Association of Bay Area Governments, 1972). ABAG's draft report, Areas of Critical Environmental Concern (Association of Bay Area Governments, 1975), spells out more specifically the "regional interest" in agricultural lands. The report sets forth the following policies concerning agricultural lands:

(1) Preserve agricultural lands which serve the following functions:
   (a) Production of a unique or specialty crop, a high percentage of which is grown in the region (e.g., wine grapes, brussels sprouts);
   (b) Production of crops and commodities which, in order to realize their productive value, must be produced in locations proximate to urban areas (e.g., dairy products, cut flowers).
(2) Protect all agricultural lands through the support of public service policies which prevent the premature conversion of such lands to urban uses. (Association of Bay Area Governments, 1975, p. 11).

Specific criteria, based on evidence of the capability of land for various agricultural uses, were developed by ABAG to identify "critical areas." Lands meeting these criteria are regionally significant areas of critical environmental concern. Local plans and projects are to be reviewed by ABAG for consistency with the policies and criteria. ABAG also expects local projects and plans to be reviewed for consistency with policies and criteria regarding areas of critical environmental concern as part of required environmental impact statements or reports. As stated by ABAG:

An Environmental Impact Statement or Report, if it is to be considered adequate by ABAG, should follow a two-step process:
1. It should assess first of all whether a proposed plan or project falls within the purview of the Critical Area policies;
2. It should make a finding as to whether such activity is consistent with the policies and criteria contained in this document. (Association of Bay Area Governments, 1975, 83 p.)

In addition to project review, ABAG recommends preserving agricultural lands through local installment purchase and saleback or zoning (Association of Bay Area Governments, 1972). Installment purchase and saleback has not been used to any extent, but local zoning has been effectively used. For example, most of the productive agricultural land of the Napa Valley has been zoned "Agricultural Preserve" (AP) since 1968 (Napa County, 1968). Minimum lot size for new parcels within the 25,000-acre "preserve" is 20 acres. This zoning, permitting extensive agriculture and processing in addition to grazing and cultivation, clearly establishes agriculture as the primary use of the valley.

The AP zone was challenged in the courts by the Napa Valley United Farmers but was upheld by the Superior Court of the County of Napa, in a decision on February 17, 1971, as a proper exercise of police powers which benefited, not only the public at large, but also those whose land was regulated (Overview Corp., 1973, p. 20).

PLANNING FOR HAZARDOUS AREAS

Information on flatlands deposits can help identify areas posing risk from natural hazards. The degree of risk depends on the severity, pervasiveness, and frequency of hazardous events together with the land-use intensity, building type, and occupancy of the hazardous areas. Decisions regarding risk involve balancing the public and private benefits from reducing risk against the costs. The threshold point beyond which no further public action is considered necessary or worthwhile to reduce risk is often referred to as the "acceptable level of risk". The California Council on Intergovernmental Relations defines risk levels as follows:

Acceptable Risk: The level of risk below which no specific action by local government is deemed necessary, other than making the risk known.

Unacceptable Risk: Level of risk above which specific action by government is deemed necessary to protect life and property.

Avoidable Risk: Risk not necessary to take because the individual or public goals can be achieved at the same or less total 'cost' by other means without taking the risk. (California Council of Intergovernmental Relations, 1973, p. IV-26).

Individual judgments concerning acceptable, unacceptable, and avoidable risks are highly subjective judgments at the community level and are made through the political process. These judgments can be improved if information relating the possible losses from the hazards to the cost of reducing them is provided and widely disseminated.

The Urban Geology Master Plan (California Division of Mines and Geology, 1973) attempts to place risk from natural hazards in perspective by project-

ing losses from major hazards from 1970–2000 assuming the present level of risk mitigation. The study estimates both the costs of hazard mitigation and the benefits that could be achieved if all feasible methods of hazard mitigation were employed. This provides the framework for assigning a benefit/cost ratio for risk reduction efforts. Table 10 summarizes the results for hazards present in many flatland areas.

The benefit/cost approach can help a public agency assign priorities for the use of funds for risk reduction. A thorough understanding of the nature of the hazard is necessary to evaluate risk and risk reduction measures.

SEISMIC HAZARDS—A SPECIAL PROBLEM

A major cause of structural damage from earthquakes is ground shaking. The severity of damage from ground shaking depends on both the nature and design of the structure and on the geologic materials that underlie it. A structure resting on bedrock may be relatively little damaged by ground motion, while another of similar design and construction but located on thick, water-saturated unconsolidated deposits may be heavily damaged.

In seismically active areas, the need to plan urban facilities to minimize risk is extremely important. In recent years, new information on the causes and nature of earthquakes and their effects has led to efforts to mitigate those effects where possible. In California, a seismic safety element is now a required part of the general plan for all cities and counties. Development along active faults is controlled under provisions of the Alquist-Priolo Special Studies Zones Act (California State Legislature Public Resources Code, Sec. 2621, 2625, 1972 as amended 1975), and plans for disaster preparedness are now being developed for all seismically active areas of the State. Consequently, many planning agencies need information of the effects of earthquakes, and if this information is available, its use is assured. Seismic risk maps are one means of predicting earthquake effects in a form useful to land-use planners. Such risk maps divide a planning area into zones according to the relative degree of potential damage to structures and are commonly related to an earthquake of stated magnitude (called the "design earthquake".

Knowledge of the properties and thickness of flatland deposits is critical in evaluating the potential risk from ground shaking, whether this risk results from seismic wave amplification or from liquefaction potential. The planner, working closely with a seismic specialist, can then relate land uses, building, and occupancy types to the risk zones. Guidance in this task is provided by the California Joint Committee for Seismic Safety (January 1974). Table 11 describes acceptable risk in terms of the kinds of structures and their occupancy.

At the regional level seismic risk studies are useful in formulating regional growth policies. Careful study of high-risk areas will indicate the cost of hazard mitigation and may reveal areas that are well suited for low-intensity recreational and open-space uses.

Many areas underlain by unstable bay muds, for example are marshes that provide important wildlife habitats. Areas with open-space potential together with risk to urban uses can be important elements of regional open-space plans and preservation efforts.

SANTA CLARA COUNTY BAYLANDS STUDY

Santa Clara County prepared a subarea plan for the baylands within its jurisdiction which takes into account the hazards—seismic and nonseismic—associated with flatland deposits. Consultants' studies of geologic and structural engineering problems were used to identify the natural hazards of the planning area and to describe their implications for specific land uses. The resulting report divided the planning area into risk zones (the basis of potential for settlement and ground failure, under both seismic and nonseismic conditions. Table 12 lists the risk zones and the nature of the hazard in each. Figure 54 is a map of the risk zones. Table 13 relates land and building uses to the risk zones.

TABLE 10.—*Projected losses due to geologic problems in California, 1970–2000*

[Adapted from California Division of Mines and Geology, 1973, p. 4]

Geologic problem	Projected losses 1970–2000	Possible loss reduction	Cost of loss reduction	Benefit/cost ratio
Earthquake shaking	$21 billion	$10.5 billion	$2 billion	5
Loss of mineral resources	17 billion	15 billion	90 million	167
Flooding	6.5 billion	3.4 billion	2.7 billion	1.3
Erosion	600 million	400 million	250 million	1.5
Expansive soils	150 million	149 million	7.5 million	20
Subsidence	26 million	13 million	9 million	1.5

TABLE 11.—*A scale of acceptable risks*

Level of acceptable risk	Kinds of structures	Extra project cost probably required to reduce risk to an acceptable level
Extremely low[1]	Structures whose continued functioning is critical, or whose failure might be catastrophic: nuclear reactors, large dams, power intertie systems, plants manufacturing or storing explosives or toxic materials.	No set percentage (whatever is required for maximum attainable safety).
Slightly higher than under level 1[1]	Structures whose use is critically needed after a disaster: important utility centers; hospitals; fire, police, and emergency communication facilities; fire stations; and critical transportation elements such as bridges and overpasses; also smaller dams.	5-25 percent of project cost[2].
Lowest possible risk to occupants of the structure[3]	Structures of high occupancy, or whose use after a disaster would be particularly convenient: schools, churches, theaters, large hotels, and high-rise buildings housing large numbers of people, other places normally attracting large concentrations of people, civic buildings such as fire stations, secondary utility structures, extremely large commercial enterprises, most roads, alternative or noncritical bridges and overpasses.	5-15 percent of project cost[4].
An "ordinary" level of risk to occupants of the structure[3],[5]	The vast majority of structures: most commercial and industrial buildings small hotels and apartment buildings, and and single family residences.	1-2 percent of project cost, in most cases (2-10 percent of project cost in a minority of cases).[4]

[1] Failure of a single structure may affect substantial populations.
[2] These additional percentages are based on the assumption that base cost is the total cost of the building or other facility when ready for occupancy. In addition, it is assumed that the structure would have been designed and built in accordance with current California practice. Moreover, the estimated additional cost presumes that the structures in this acceptable-risk category are to embody sufficient safety to remain functional after an earthquake.
[3] Failure of a single structure would affect primarily only the occupants.
[4] These additional percentages are based on the assumption that the base cost is the total cost of the building or facility when ready for occupancy. In addition, it is assumed that the structure would have been designed and built in accordance with current California practice. Moreover, the estimated additional cost presumes that structures in this acceptable-risk category are to be sufficiently safe to give reasonable assurance of preventing injury or loss of life during an earthquake, but otherwise not necessarily to remain functional.
[5] "Ordinary risk": Resist minor earthquakes without damage; resist moderate earthquakes without structural damage, but with some non-structural damage; resist major earthquakes of the intensity or severity of the strongest experienced in California, without collapse, but with some structural as well as nonstructural damage. In most structures, it is expected that structural damage, even in a major earthquake, could be limited to repairable damage (Danehy, 1969).

TABLE 12.—*Risk zones for settlement and ground failure*

[Established by subsurface conditions in the baylands of Santa Clara County. Adapted from Woodward-Clyde and Assoc. and McClure and Messinger (1970), p. 10.]

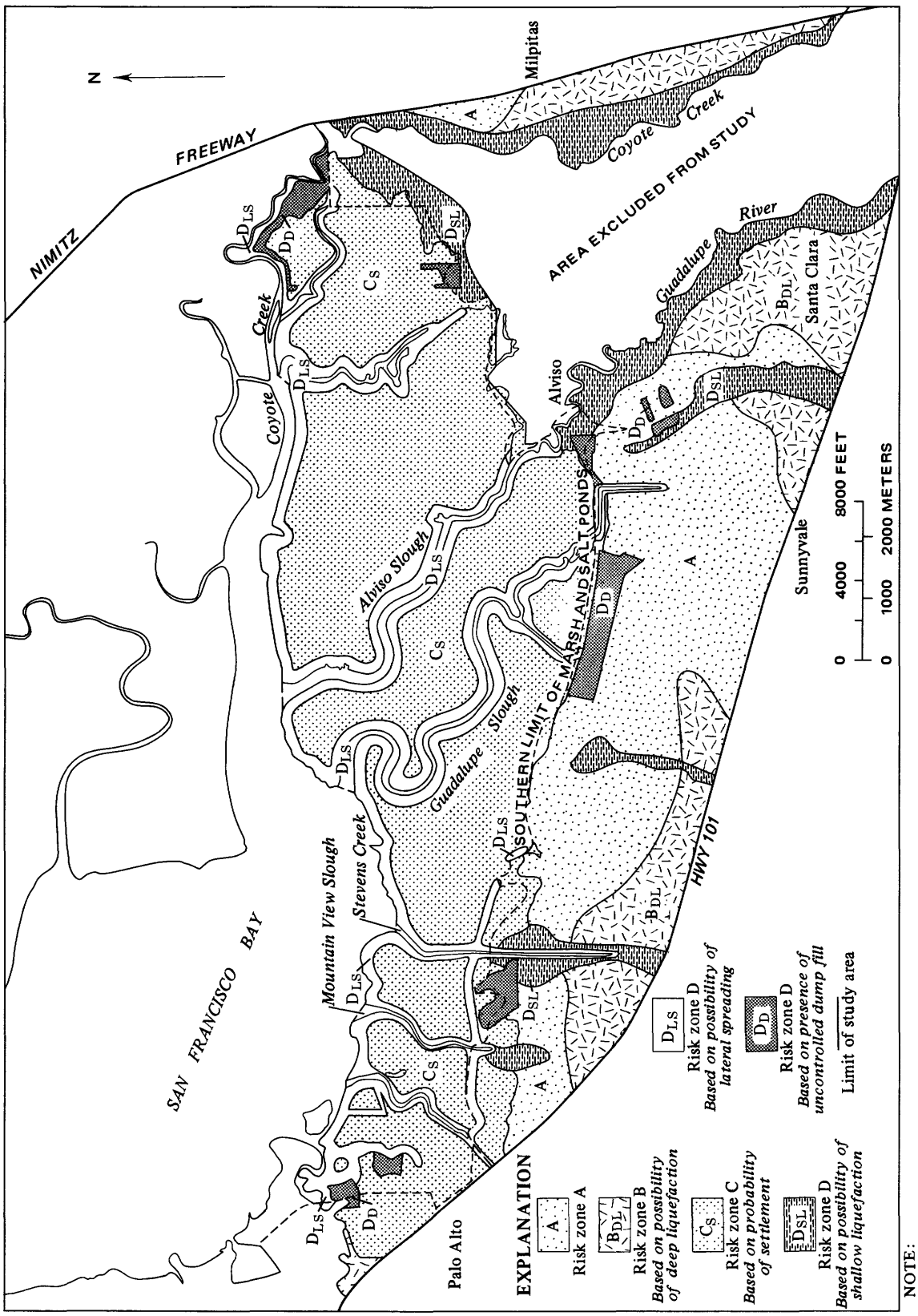
Risk zone	Surface effect	Subsurface cause
A	Little risk of settlement or ground failure	---
B_{DL}	Significant settlement	Liquefaction of confined granular layer in alluvium (seismic loading).
C_S	Moderate to substantial settlement and(or) differential settlement	Consolidated of bay mud or soft clay (static unloading).
D_D	Substantial settlement and(or) differential settlement	Consolidation of uncontrolled dump fill or sanitary land fill (static loading).
D_{SL}	Failure of ground surface	Liquefaction of granular surface layer (seismic loading).
D_{LS}	Failure of ground surface	Lateral spreading toward free face (seismic loading).

The plan adopts these uses with the stipulation that any developer in the baylands provide data from test boring and sample testing in depth to demonstrate that a proposed development site is not in a higher risk zone than shown. Establishing an Advisory Review Board was recommended to advise public agencies on the adequacy of engineering investigations, design, and construction methods in the baylands.

On the basis of the plan, the county adopted an ordinance requiring a soils report for all major subdivisions unless specifically exempted. Geologic reports and site investigations are required for all subdivisions on or adjacent to potentially hazardous areas as depicted on official county hazard maps. The map of risk zones for land-use planning (fig. 54) is one of the official hazard maps. Geologic reports are normally required for development in risk zones C and D and may be required in risk zones A and B.

A key feature of the successful integration of geologic considerations into plan development and administration in the Santa Clara County Baylands program is the use of the appropriate expertise at each stage of the planning process. In the baylands study, an engineering geologist gathered available geologic data, and together with a structural engineer, divided the study area into zones on the basis of the expected surface effects of geologic conditions. They then worked cooperatively to determine the range of land uses and building types that could be accommodated in each zone with reasonable safety on the basis of:

(1) The possible types of geologic risks such as settlement, liquefaction, lateral spreading, ground shaking, tsunamis and fault rup-



NOTE:
The delineation of risk zones is based on limited subsurface information. Risk zone designations could change as more detailed subsurface information becomes available.

FIGURE 54.—Risk zones for land-use planning, Santa Clara County baylands. From Woodward-Clyde and Associates and McClure and Messinger (1970, part II, fig. 4).

TABLE 13.—*Land and building uses for various risk zones*

[Adapted from Santa Clara County Planning Policy Committee, 1972, p. 22]

Land and building uses	Risk zones (see fig. 54)			
	A	B	C	D
Group A buildings:				
Hospital and nursing homes	X	--	--	--
Auditoriums and theaters	X	--	--	--
Schools	X	--	--	--
Transportation and airports	X	--	--	--
Public and private offices	X	--	--	--
Major Utility	X	--	--	--
Other building uses	X	--	--	--
Group B buildings:				
Residential-multiple units	X	X	--	--
Residential, 1 and 2 family	X	X	--	--
Small Commercial	X	X	--	--
Small public	X	X	--	--
Small schools, one story	X	X	--	--
Utilities	X	X	--	--
Group C buildings:				
"Industrial park" commercial	X	X	X	--
Light and heavy industry	X	X	X	--
Small public, if mandatory	X	X	X	--
Airport maintenance	X	X	X	--
Group D buildings:				
Water-oriented industry	X	X	X	--
Wharves and docks	X	X	X	--
Warehouses	X	X	X	--
Group D open space:				
Agriculture, marinas, public and private open spaces, marshlands and saltponds, and small appurtenant buildings	X	X	X	X

ture; (2) The ability to identify land areas where these types of geologic risks are possible; (3) The ability to assign either qualitative or quantitive limits on the possible effects of these risks; (4) The types of land and building uses and their socio-economic importance; (5) The behavior of buildings and other improvements under static and seismic conditions; (6) The ability of "normal" practices of investigation, design, construction, inspection, and enforcement to develop recommendations and procedures to provide adequate levels of protection; (7) The ability to develop and implement special investigation, design, construction, inspection, and enforcement procedures where normal procedures are considered inadequate. (Santa Clara County Planning Policy Committee, 1972, p. 27).

Using the interpretations and recommendations of the engineering geologist and structural engineer, plus other relevant information, the planner developed land-use policies and recommendations and defined procedures for obtaining more detailed geologic investigations, if needed, at the time of an application for a zoning change, land division, grading permit or building permit. After adoption of the policies and procedures, a geologist was added to the County staff to assist planners and engineers in administering the policies and review procedures.

The relation between planning phase and the use of geologic expertise in the Santa Clara County Baylands study provides a model applicable to other planning areas with known or suspected geologic hazards. However, the sequence as described assumes the availability of basic geologic data. The process of incorporating geologic considerations into land-use planning starts with basic geologic maps or more specialized maps such as the map of flatland deposits and continues through successive refinements of the basic geologic data and interpretations to relate geologic conditions to particular land uses and structural types.

SUMMARY

Geologic information about flatland areas is of particular importance in land-use planning because most urban development occurs in relatively flat terrain. Geologic studies can help identify potential problems such as flooding, stream-channel changes, salt-water intrusion, subsidence, settlement, shrink and swell, and various earthquake-induced hazards. In addition, geologic studies can locate many natural resources including ground-water recharge and storage areas, agricultural soils, and deposits of sand, salt, gravel, and clay. A planning jurisdiction can then direct future growth to reduce risk from natural hazards, avoid excessive development costs, and preserve essential resources.

The maps of flatland deposits included with this report (pls. 1, 2, and 3) illustrate an innovative approach to geologic mapping. Unconsolidated alluvial deposits occurring in areas with slopes of less than 15 percent are differentiated largely on the basis of composition and age. These characteristics are important in determining the engineering properties of the deposits, particularly the potential for seismic wave amplification and liquefaction. With the aid of existing soils data, topographic maps, aerial photographs, and limited fieldwork, geologists completed the mapping of flatland deposits of the entire 7,281 square mile (19, 316 km^2) San Francisco Bay region in only three years.

The maps were prepared specifically for use in land-use planning. Each map unit is described in terms of its geologic characteristics, engineering properties, resource potential, and any special problems related to the safety and cost of land development.

In the past, planners have used modern soils series maps prepared primarily by the U.S. Soil Conservation Service to identify the problems and resources discussed here. Where available, these maps are an excellent source of information, particularly to evaluate land capability for agriculture, erosion potential,

and tendencies of the soil to corrode or expand. However, the approach used here adds a new dimension to the usual soils data by considering greater depth of deposits and the processes by which they formed. This added dimension is especially important in geologically active areas such as the west coast, but it can also be useful elsewhere in the country. The geologic approach to mapping flatland surficial deposits is essential in seismically active areas in order to evaluate ground shaking and the possibility of ground failure. In addition, geologic information is needed to assess potential for groundwater storage and recharge, and problems of settlement and subsidence. These are major concerns throughout the country.

Since formative processes are emphasized, geologic description of alluvial deposits explicitly includes geologic-hydrologic relations. These relations are important in understanding the direction and nature of long-term changes in the natural environment that can affect the use of land.

The map of flatland deposits, at a scale of 1:125,000, provides a regional overview of flatland characteristics. Areawide information at this scale provides an excellent framework for developing a data-collection program at the regional and local levels. It allows a planning agency to focus on those areas with identified problems or resource potential, and those areas where land uses are most likely to change. The public and private benefits of specific identification of resource and hazard areas before land development occurs are substantial because it is almost always easier and less expensive to address site problems before development than to try to correct them afterward.

As discussed in the sections on planning approaches to flatland problems and resources, geologic information is important throughout the planning process. Information on flatland geology, along with data on hillside geology and other earth-science and environmental information, is needed to:

1. Evaluate the relative physical capability of land to accommodate proposed uses;
2. Develop land-use policies and plans at the regional and local levels responsive to the physical problems and potentials of the land;
3. Define appropriate soils and geologic investigations needed for project design and review;
4. Establish procedures to review soils and geologic reports, environmental impact assessments, and other information submitted for project review;
5. Prepare and administer land-use and development regulations implementing adopted policies and plans.

A qualified earth scientist, on or available to, the planning staff to assist in interpreting and applying geologic data is essential. Wisely used, geologic information can lead to safer, less costly, and more environmentally sensitive use of our valuable, but limited, land resources.

REFERENCES CITED

Association of Bay Area Governments, 1966, Preliminary regional plan for the San Francisco Bay region: Berkeley, California, 52 p.

_____ 1970, Regional Plan 1970:1900: Berkeley, California, 32 p.

_____ 1972, Regional open space plan, phase II: Berkeley, California, 15 p.

_____ 1975, Areas of critical environmental concern, report to the Regional Planning Committee: Berkeley, California, 83 p.

Atwater, B. F., Hedel, C. W., Helley, E. J., 1976, Late Quaternary depositional history, Holocene sea-level changes, and vertical crusted movement, southern San Francisco Bay, California: U.S. Geol. Survey. Prof. Paper 1014, 15 p.

Bailey, E. H., and Harden, D. R., 1975, Mineral Resources of the San Francisco Bay region, California—Present availability and planning for the future: U.S. Geol. Survey open-file report, 182 p.

Bishop, D. G., 1974, The Dunedin earthquake, 9 April 1974, Part 2 local effects: New Zealand Natl. Socl. Earthquake Eng. Bull., v. 7, no. 3, p. 123-129.

Bonilla, M. G., 1965, Geologic map of the San Francisco South quadrangle, California: U.S. Geol. Survey open-file map, scale 1:24,000.

Borcherdt, R. D., Gibbs, J. F., and Lajoie, K. R., 1975, Prediction of maximum earthquake intensities in the southern San Francisco Bay region, California for large earthquakes on the San Andreas and Hayward faults: U.S. Geol. Survey Misc. Field Studies Map MF-709, Scale 1:125,000.

Borcherdt, R. D., Joyner, W. B., Warrick, R. E., and Gibbs, J. F., 1975, Response of local geologic units to ground shaking, *in* Borcherdt, R. D., editor, Studies for seismic zonation of the San Francisco Bay region: U.S. Geol. Survey Prof. Paper 941-A, p. A52-A67.

Brewer, James, 1973, Bay land sinks, tenants moved: San Francisco Chronicle, p. 1., Sept. 14 issue.

Burnett, J. L., and Barneyback, R. S., Jr., 1975, Sand and gravel, *in* Bailey, E. H., and Harden, D. R., Mineral resources of the San Francisco Bay region, California—Present availability and planning for the future: U.S. Geol. Survey open-file report, 182 p.

California Council on Intergovernmental Relations, 1973, General plan guidelines: Sacramento, CA., (noncontinuous paging).

California Division of Mines and Geology, 1966, Geology of northern California: California Div. Mines and Geology Bull. 190, 507 p.

_____ 1973, Urban geology master plan for California: California Div. Mines and Geology Bull. 198, 112 p.

California Office of Planning and Research, 1974, Prime agricultural lands report: Sacramento, Calif., not paged.

California State Legislature, 1965, McAteer-Petris act, government code, title 7.2, sections 66600-66660, 12 p.

_____ 1972, Alquist-Priolo special studies zones act, as amended 1975: Public resources code, sec. 2621-2625.

Danehy, E. A., editor, 1969, Urban environmental geology in the San Francisco Bay region: Assoc. Engineering Geologists, San Francisco Section, Spec. Pub., 162 p.

Dean, J. B., 1975, A panacea that wasn't: Cry California: San Francisco, California, California Tomorrow, v. 10, no. 3, p. 18-23.

Gibbs, J. F., and Borcherdt, R. D., 1974, Effects of local geology on ground motion in the San Francisco Bay region [abs.]: Geol. Soc. America Abs. with Programs, v. 6, no. 3, p. 284.

Gilbert, G. K., 1971, Hydraulic-mining debris in the Sierra Nevada: U.S. Geol. Survey Prof. Paper 105, 154 p.

Goldman, H. B., 1969, Geology of San Francisco Bay, *in* Geologic and engineering aspects of San Francisco Bay fill: California Div. Mines and Geology Spec. Rept. 97, p. 11-27.

Hall, N. T., 1966, Late Cenozoic stratigraphy between Mussel Rock and Fleishhacker Zoo: Mineral Information Service, v. 19, no. 11, p. 522-525.

Hart, E. W., 1975, Limestone and shells, *in* Bailey, E.H., and Horden, D.R., Mineral resources of the San Francisco Bay region, California—present availability and planning for the future: U.S. Geol. Survey open-file report, 182 p.

Hazelwood, R. M., 1974, Preliminary report of seismic refraction survey along the east side of the San Francisco Bay, Alameda County, California: U.S. Geol. Survey open-file report, 10 p.

Higgins, C. G., 1952, The lower course of the Russian River, California: California Univ. Pubs. in Geol. Sci., v. 29, no. 5, 83 p.

Joint Committee on Seismic Safety, 1974, Meeting the earthquake challenge, part 1, a comprehensive approach to seismic safety: Sacramento, California, California State Legislature, 32 p.

Laird, R.T., Perkins, J.B., Bainbridge, D.A., Baker, J.B., Boyd, R.T., Huntsman, Daniel, Zucker, M.B., and Staub, Paul, 1979, Quantitative land capability analysis: U.S. Geol. Survey Professional Paper 945, 115 p.

Lajoie, K. R., and Helley, E. J., 1975, Differentiation of Sedimentary Deposits for Purposes of Seismic Zonation, *in* Borcherdt, R. D., ed., Studies for seismic zonation of the San Francisco Bay region: U.S. Geol. Survey Prof. Paper 941-A, p. A39-A51.

Lee, C. H., and Praszker, Michael, 1969, Bay mud developments and related structural foundations, *in* Geologic and engineering aspects of San Francisco Bay fill: California Div. Mines and Geology Spec. Rept. 97, p. 41-87.

Limerinos, J. T., Lee, K. W., and Lugo, P. E., 1973, Flood-prone areas in the San Francisco Bay region, California: U.S. Geol. Survey open-file report, p. 37-73, scale 1:125,000.

McCulloch, D. S., Peterson, D. H., Carlson, P. R., and Conomos, T. J., 1970, A preliminary study of the effects of water circulation in the San Francisco Bay estuary: U.S. Geol. Survey Circ. 637-A, B, 35 p.

Medvedev, S. V., 1965, Engineering seismology: U.S. Geol. Survey rept., 256 p.; available from the Nat. Tech. Inf. Service, U.S. Dept. Commerce, Springfield, Va., NTIS no. TT65-50011.

Meehan, R. L., Dukes, M. T., and Shires, P. O., 1975, A case history of expansive claystone damage: Am. Soc. Civil Engineers Proc., Jour. Geotech. Engineering Div., v. 101, no. Gt9, p. 933-948.

Metcalf, Woodridge, 1959, Native trees of the San Francisco Bay region, California: Berkeley, University of California Press, Natural History Guides, no. 4, 70 p.

Metropolitan Transportation Commission, 1975, Metropolitan Transportation Commission, 5 years of progress 1970-1975: Berkeley, Calif., 16 p.

Milliman, S. D., and Emery, K. O., 1968, Sea levels during the past 35,000 years: Science, v. 162, p. 1121.

Napa County, 1968, Ordinance, no. 274 amending zoning ordinance no. 186: Napa, Calif.

Nichols, D. R., and Wright, N. A., 1971, Preliminary map of historic margins of marshlands, San Francisco Bay, California: U.S. Geol. Survey open-file map, scale 1:125,000.

Overview Corp., 1973, How to implement open space plans for the San Francisco Bay area: Berkeley, Calif., 172 p.

Oxburgh, E. R., 1974, The plain man's guide to plate tectonics: Geologists' Assoc. Proc. (Colchester, England), v. 85, pt. 3, p. 299-358.

Page, J. M., and Wire, J. C., 1969, How geology serves the water needs of an instant metropolis—northern Santa Clara Valley, *in* Urban environmental geology in the San Francisco Bay region: Assoc. Eng. Geologists, San Francisco Sec., Spec. Pub., p. 105-124.

Pestrong, Raymond, 1972, San Francisco Bay tidelands: California Geology, v. 25, no. 2, p. 27-40.

Poland, J. F., 1969, Land subsidence in the western United States: Office of Emergency Preparedness, Geologic Hazards and Problems Section, Proc., p. 77-96.

———1971, Land subsidence in the Santa Clara Valley, Alameda, San Mateo and Santa Clara Counties, California: U.S. Geol. Survey Misc. Field Studies Map, MF-336, scale 1:125,000.

Price, W. H., 1966, Grading and surface area—significance of tests and properties of concrete and concrete-making materials: Soc. Testing and Materials, Spec. Tech. Pub., 169-A, p. 404-414.

Rantz, S. E., 1971, Precipitation depth-duration-frequency relations for the San Francisco Bay region, California, *in* Geological Survey research 1971: U.S. Geol. Survey Prof. Paper 750-C, p. C237-C241.

San Francisco Bay Conservation and Development Commission, 1969, San Francisco Bay plan: San Francisco, California, 41 p., and maps.

———1974, Safety of fills: guidelines for bay plan revision, Bay Plan Evaluation Project: San Francisco, California, 23 p.

Santa Clara County, 1974, Ordinance No. NS-1203.31 relating to soils and geology reports: San Jose, California, 11 p.

Santa Clara County Planning Policy Committee, 1972, A policy plan for the baylands of Santa Clara County, Santa Clara County Planning Dept.: San Jose, California, 76 p.

Sarna-Wojcicki, A. M., 1971, Correlation of late Cenozoic pyroclastic deposits in the central Coast Ranges of California: California Univ. Berkeley, Ph.D. thesis, 170 p.

Schlocker, Julius, 1971, Generalized geologic map of the San Francisco Bay region: U.S. Geol. Survey open-file map, scale 1:500,000.

Smith, A. C., 1968, Introduction to the natural history of the San Francisco Bay region: Berkeley, University of California Press, Natural History Guide no. 1, 70 p.

Steinbrugge, K. V., 1969, Seismic risk to buildings and structures on filled lands in the San Francisco Bay, *in* Geologic and engineering aspects of San Francisco Bay fill: California Div. Mines and Geology Spec. Rept. 97, p. 103-115.

Stinson, M. C., 1975, Peat, *in* Bailey, E. H., and Harden, D. R., Mineral resources of the San Francisco Bay region, California—present availability and planning for the future: U.S. Geol. Survey open-file report, 182 p.

Tolman, C. F., and Poland, J. F., 1940, Ground water, salt-water infiltration and ground-surface recession in Santa Clara Valley, Santa Clara County, Calif.: Am. Geophys. Union Trans. pt. 1, p. 23--35.

Turner, M. D., 1951, The building stone and aggregate industry of the San Francisco Bay counties, *in* Geologic guidebook of the San Francisco Bay counties: California Div. Mines and Geology Bull., 154, p. 235-238.

U.S. Congress, 1969, National environmental policy act, public law 91-190, 5 p.

_____ 1972, Federal water pollution control act amendments of 1972, section 208, public law 92-500, 89 p.

_____ 1974, Housing and community development act, section 701, public law 93-383.

U.S. Department of Housing and Urban Development, 1975, Comprehensive planning assistance, rules and regulations, part 600: Federal Register, v. 40, no. 164, p. 36856-36865.

U.S. Soil Conservation Service, 1968; Soils of Santa Clara County: Washington, D.C., U.S. Government Printing Office, 227 p.

U.S. Soil Conservation Service, 1970, Know Your Soil: Agricultural Information Bull. no. 267, 16 p.

Ver Planck, W. E., 1951, Salines in the Bay area, *in* Geologic guidebook of the San Francisco Bay Counties: California Div. Mines and Geology, Bull. 154, p. 219-222.

Warrick, R. E., 1974, Seismic investigation of a San Francisco Bay mud site: Seismol. Soc. America Bull., v. 64, no. 2, p. 375-385.

Webster, D. A., 1973, Map showing areas bordering the southern part of San Francisco Bay where a high-water table may adversely affect land use: U.S. Geol. Survey Misc. Field Studies Map MF-530.

Weir, W. W., 1950, Subsidence of peat lands of the Sacramento-San Joaquin Delta, California: Hilgardia, v. 20, no. 3, p. 37-55.

Williams, J. C., and Monroe, H. C., 1967, A field guide to the natural history of the San Francisco Bay area: Berkeley, California, McCutchers Pub. Corp., 270 p.

Wood, H. O., 1908, Distribution of apparent intensity in San Francisco, *in* The California earthquake of April 18, 1906, Report of the State Earthquake Commission: Carnegie Inst. Washington Pub. 87, p. 220-245.

Woodward-Clyde and Associates, and McClure and Messinger, 1970, Geology and structural engineering, parts I and II, prepared for Planning Policy Committee Santa Clara County, Oakland, Calif., 112 p. (pub. rept.)

Youd, T. L., Nichols, D. R., Helley, E. J., and Lajoie, K. R., 1973, Liquefaction potential of unconsolidated sediments in the southern San Francisco Bay region, California: U.S. Geol. Survey open-file report, 23 p.

_____ 1975, Liquefaction potential, *in* Studies for seismic zonation of the San Francisco Bay region: U.S. Geol. Survey Prof. Paper 941-A, p. A68-A74.

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

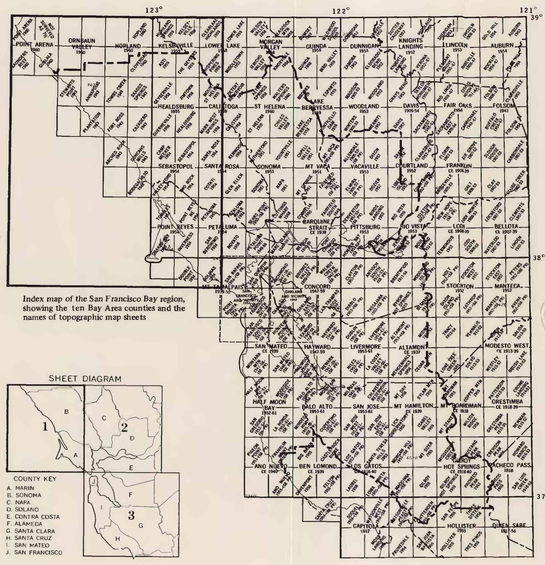
PROFESSIONAL PAPER 943
PLATE 1

CORRELATION OF MAP UNITS

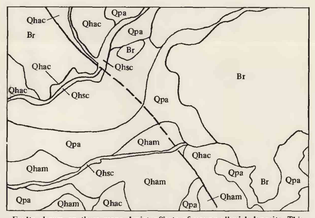
ALLUVIAL DEPOSITS	ESTUARINE DEPOSITS	MARINE DEPOSITS	UNDIFFERENTIATED DEPOSITS		
Qhsc Qhac Qham Qhaf Qhafs	Qhbm	Qhs	Qu	Holocene (10,000 years before present)	QUATERNARY
Qps	Qps			Pleistocene (1.8 million years before present)	QUATERNARY
		Qpmt Qpmc			
			Br	Pliocene	TERTIARY
					PRE-TERTIARY

DESCRIPTION OF MAP UNITS

Qhsc	STREAM CHANNELS – Open alluvial channels with movable beds, mapped where scale permits
Qhac	COARSE-GRAINED ALLUVIUM – Unconsolidated, moderately sorted permeable sand and silt with coarse sand and gravel; more abundant toward fan heads
Qham	MEDIUM-GRAINED ALLUVIUM – Unconsolidated moderately sorted moderately permeable fine sand, silt, and clayey silt with a few thin beds of coarse sand
Qhaf	FINE-GRAINED ALLUVIUM – Unconsolidated plastic moderately to poorly sorted carbonaceous silt and clay
Qhafs	FINE-GRAINED SALT – AFFECTED ALLUVIUM – Unconsolidated plastic moderately to poorly sorted carbonaceous silt and clay. Irregularly bedded with carbonate nodules
Qhbm	BAY MUD – Unconsolidated water-saturated dark plastic carbonaceous clay and silty clay
Qhs	BEACH AND DUNE SAND DEPOSITS – Loose well-sorted fine- to medium-grained sand
Qpa	LATE PLEISTOCENE ALLUVIUM – Weakly consolidated slightly weathered poorly sorted irregularly interbedded clay, silt, sand, and gravel
Qps	PLEISTOCENE BEACH AND DUNE SAND DEPOSITS (MERRIT SAND) – Loose well-sorted fine to medium sand
	EARLY PLEISTOCENE ALLUVIUM – Moderately consolidated deeply weathered poorly sorted irregularly interbedded clay, silt, sand, and gravel
Qpmt	MARINE TERRACE DEPOSITS – Weakly consolidated slightly weathered sand and gravel
Qpmc	COLMA FORMATION – Pale, loose or friable well-sorted fine- to medium-grained sandstone with subordinate gravel, sandstone, siltstone, and claystone
Qu	UNDIVIDED QUATERNARY DEPOSITS – Not recognizable as discrete map units because original form obliterated by urbanization
Br	UNDIVIDED BEDROCK – Older than Pleistocene



Index map of the San Francisco Bay region, showing the ten Bay Area counties and the names of topographic map sheets



Faults shown on these maps depict offsets of young alluvial deposits. This interpretation is based on the geologic mapping techniques described in the text. Faults are mapped on the basis of anomalies in alluvial deposits that are inconsistent with surficial processes, fault-related geomorphic features, seismic activity, or surface creep. In some instances faulting older than the deposits may have provided a basin of deposition and hence give an apparent offset of the young alluvial deposits. Fault lines are dashed where evidence is not clear or urbanization has obliterated fault features

Base from U.S. Geological Survey, San Francisco Bay Region, Sheet 1, 1970
50,000-foot grid based on California coordinate system, zone 2
5000-meter Universal Transverse Mercator grid ticks, zone 10

SCALE 1:125 000

2 1 0 2 4 6 8 10 MILES

2 1 0 2 4 6 8 10 KILOMETERS

CONTOUR INTERVAL 200 FEET
DATUM IS MEAN SEA LEVEL

U.S. Interior – Geological Survey, Reston, VA. – 1977 – G77250

Geology by D. B. Burke, E. J. Helley, K. R. LaJoie, J. C. Tinsley, and G. E. Weber, 1972 – 74

GEOLOGIC MAP OF THE FLATLAND DEPOSITS OF THE NORTHWESTERN PART OF THE SAN FRANCISCO BAY REGION

This map was printed from negatives prepared by photographic color separation of the author's hand-colored original.

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

PROFESSIONAL PAPER 943
PLATE 2

SHEET DIAGRAM

COUNTY KEY
A. MARIN
B. SONOMA
C. NAPA
D. SOLANO
E. CONTRA COSTA
F. ALAMEDA
G. SANTA CLARA
H. SANTA CRUZ
I. SAN MATEO
J. SAN FRANCISCO

Base from U.S. Geological Survey, San Francisco Bay Region, sheet 2, 1970
50,000-foot grid based on California coordinate system, zone 2
5000-meter Universal Transverse Mercator grid ticks, zone 10

SCALE 1:125 000

2 1 0 2 4 6 8 10 MILES

2 1 0 2 4 6 8 10 KILOMETERS

CONTOUR INTERVAL 200 FEET
DATUM IS MEAN SEA LEVEL

Geology by D. B. Burke, E. J. Helley, K. R. LaJoie, J. C. Tinsley, and G. E. Weber, 1972 – 74

GEOLOGIC MAP OF THE FLATLAND DEPOSITS OF THE NORTHEASTERN PART OF THE SAN FRANCISCO BAY REGION

This map was printed from negatives prepared by photographic color separation of the author's hand-colored original.

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

PROFESSIONAL PAPER 943
PLATE 3

SHEET DIAGRAM

COUNTY KEY
A. MARIN
B. SONOMA
C. NAPA
D. SOLANO
E. CONTRA COSTA
F. ALAMEDA
G. SANTA CLARA
H. SAN MATEO
I. SAN FRANCISCO
J. SAN FRANCISCO

Base from U.S. Geological Survey, San Francisco Bay Region, sheet 3, 1970
50,000-foot grid based on California coordinate system, zone 2
5000-meter Universal Transverse Mercator grid ticks, zone 10

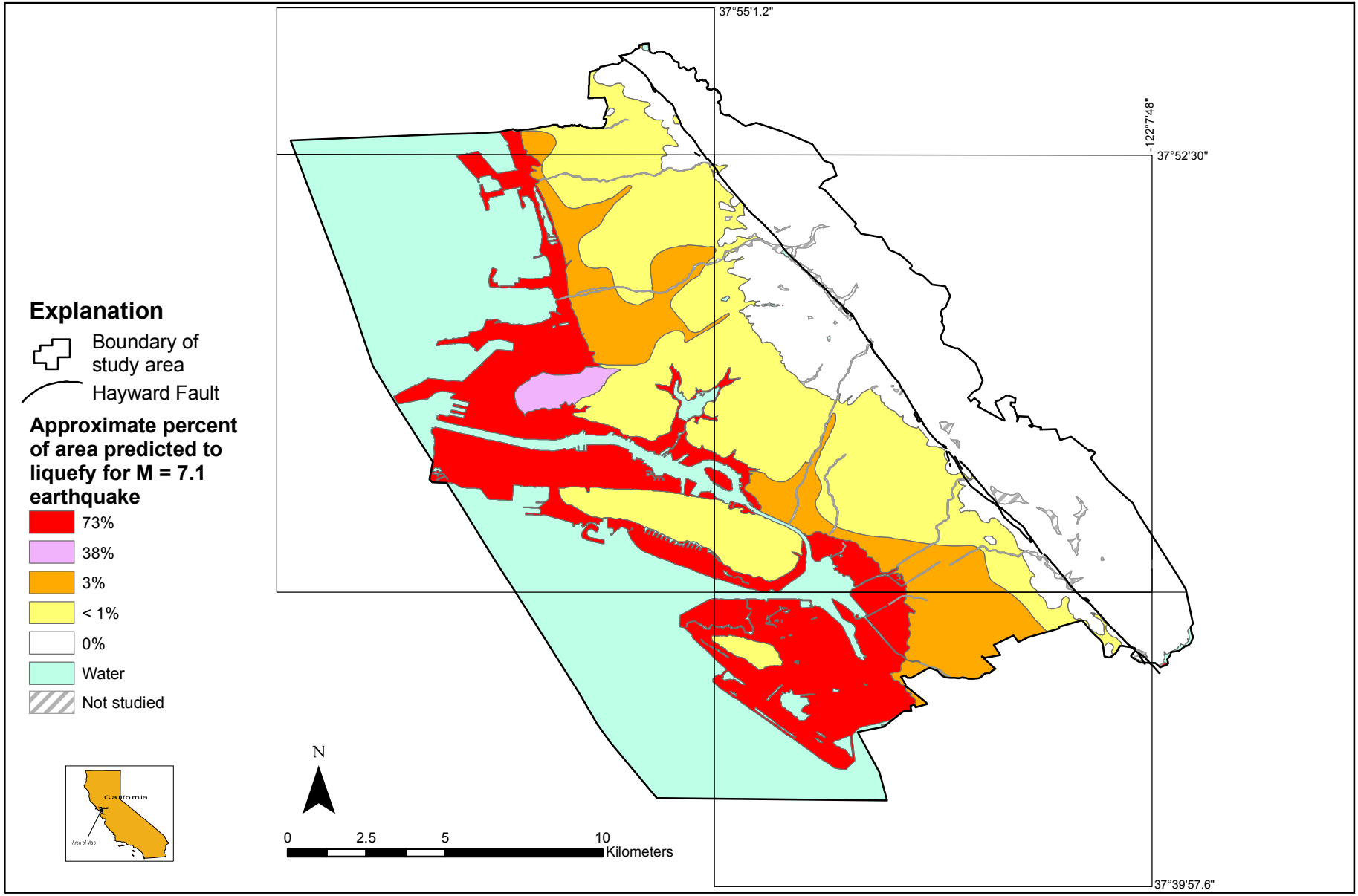
SCALE 1:125 000
2 1 0 2 4 6 8 10 MILES
2 1 0 2 4 6 8 10 KILOMETERS
CONTOUR INTERVAL 200 FEET
DATUM IS MEAN SEA LEVEL

Geology by D. B. Burke, E. J. Helley, K. R. LaJoie, J. C. Tinsley, and G. E. Weber, 1972 - 74

GEOLOGIC MAP OF THE FLATLAND DEPOSITS OF THE SOUTHERN PART OF THE SAN FRANCISCO BAY REGION

This map was printed from negatives prepared by photographic color separation of the author's hand-colored original.

U.S. Department of the Interior
U.S. Geological Survey



Map Projection: Geographic NAD27

Liquefaction Hazard Map of Alameda, Berkeley, Emeryville, Oakland, and Piedmont, California: A Digital Database

by
Thomas L. Holzer, Michael J. Bennett, Thomas E. Noce,
Amy C. Padovani and John C. Tinsley, III

This report is preliminary and has not been reviewed for conformity with U.S. Geological Survey editorial standards or with the North American Stratigraphic Code. Any use of trade, product, or firm names is for descriptive purposes only and does not imply endorsement by the U.S. Government.

This map was printed on an electronic plotter directly from digital files. Dimensional calibration may vary between electronic plotters and between X and Y directions on the same plotter, and paper may change size due to atmospheric conditions; therefore, scale and proportions may not be true on plots of this map.

For sale by U.S. Geological Survey, Information Services, Box 25286, Federal Center, Denver, CO 80225. 1-888-ASK-USGS

U.S. DEPARTMENT OF THE INTERIOR

U.S. GEOLOGICAL SURVEY

Liquefaction Hazard and Shaking Amplification Maps of Alameda, Berkeley, Emeryville, Oakland, and Piedmont, California: A Digital Database

by

Thomas L. Holzer, Michael J. Bennett, Thomas E. Noce,
Amy C. Padovani, and John C. Tinsley, III

Open-File Report 02-296
Version 1.1

2002, revised 2005

This report is preliminary and has not been reviewed for conformity with U.S. Geological Survey editorial standards or with the North American Stratigraphic Code. Any use of trade, product, or firm names is for descriptive purposes only and does not imply endorsement by the U.S. Government.

This database, identified as "Liquefaction Hazard and Shaking Amplification Maps of Alameda, Berkeley, Emeryville, Oakland, and Piedmont, California: A Digital Database," has been approved for release and publication by the Director of the USGS. Although this database has been reviewed and is substantially complete, the USGS reserves the right to revise the data pursuant to further analysis and review. This database is released on condition that neither the USGS nor the U.S. Government may be held liable for any damages resulting from its use.

INTRODUCTION

This Open-File Report is a digital database for hazard maps of liquefaction effects and shaking amplification in the Oakland, California, area. This accompanying pamphlet serves to introduce and describe the digital data. Paper maps are not included in the Open-File Report; instead PDF plot files are included that can be used to plot images of the hazard maps.

This digital database is based on a previously published map of surficial geology by Helley and Graymer (1997) as modified by R. Witter (digital communication, 2003) together with 210 newly acquired seismic cone penetration test (SCPT) soundings supplemented by unpublished commercial borings. The database identifies areas that have potential (1) to produce surface manifestations of liquefaction, for example, sand boils, ground cracks, and lateral spreading, and (2) to amplify ground shaking from earthquakes. The scale of the source map limits the spatial resolution (scale) of the database to 1:24,000 and smaller for the liquefaction map and 1:50,000 and smaller for the shaking amplification map; plotting at larger scales will not yield greater real detail. These maps depict the hazard at a regional scale and should not be used for site-specific design. Subsurface conditions can vary abruptly and borings are required to address the hazard at a given location. The liquefaction hazard map also does not account for local ground improvements that have been made to mitigate against the occurrence of liquefaction.

LIQUEFACTION HAZARD

The liquefaction hazard map predicts the approximate percentage of each designated area that will have surface manifestations of liquefaction during an M7.1 earthquake on the Hayward fault. An earthquake of this magnitude is expected if the whole Hayward fault ruptures in a single event (Working Group on California Earthquake Probabilities, 1999). This event dominates the deaggregated hazard near the eastern shore of San Francisco Bay (http://earthquake.usgs.gov/hazmaps/interactive/). The estimated annual probability for this earthquake is 0.00191 per year, and no such event has occurred since 1740 (Working Group on California Earthquake Probabilities, 1999). However, other smaller events may occur. For example, an M6.6 associated with a rupture of the northern segment of the Hayward fault has an estimated annual probability of 0.00258 per year. For these smaller events, liquefaction will be less extensive than for the M7.1 earthquake considered in this report.

The prediction of liquefaction is based on the liquefaction potential index (LPI) (Toprak and Holzer, 2003). LPI is a weighted integration of one minus the factor of safety against liquefaction within the uppermost 20 m of sediment at a specific location. The previous study by Toprak and Holzer (2003) investigated the correlation of LPI with surface manifestations of liquefaction during the 1989 Loma Prieta, California, earthquake and found that surface manifestations typically occurred where LPI values exceed 5. LPI values were computed at the 210 locations where CPT soundings were conducted in the communities of Alameda, Berkeley, Emeryville, and Oakland. Distributions of LPI values were calculated for each of the major surficial geologic units mapped by Helley and Graymer (1997) as modified by R. Witter. For each geologic unit in the study area, the percentage of the LPI values that exceed 5 for a M7.1 Hayward fault earthquake indicates the approximate percentage of the area in which liquefaction effects can be expected (See Holzer and others, in press).

Because of the major difference in liquefaction susceptibility between Holocene and Pleistocene alluvial fan deposits, areas where unsaturated Holocene alluvial fan deposits overlie Pleistocene alluvial fan deposits were identified by comparing the depth to the water table with the thickness of the Holocene alluvial fan deposits. In areas where the Holocene alluvial fan deposits are completely above the water table, the liquefaction hazard is derived from the underlying Pleistocene alluvial fan deposits. Thus, the boundary between the saturated and unsaturated Holocene alluvial fan deposits distinguishes between areas with different degrees of hazard. Areas shown on the map as "not studied" are narrow valleys where Helley and Graymer (1997) as modified by R. Witter mapped Holocene deposits, but in which it was not feasible to conduct sufficient soundings to document sediment thickness and liquefaction susceptibility.

SHAKING AMPLIFICATION

The shaking amplification map is based only on shear-wave velocity measurements conducted during the SCPT soundings. It uses the 2000 National Earthquake Hazards Reduction Program (NEHRP) V_{s30} site classification scheme to categorize the potential for shallow soils to amplify ground shaking (Building Seismic Safety Council, 2001). Although the scheme relies primarily on a time-averaged shear-wave velocity to a depth of 30 m (V_{s30}) to classify the soils at a site (Table 1), site classes E and F can be determined by other soil properties, such as thickness. This classification is used to determine appropriate amplification factors for use in engineering design, with type E soils having the largest amplification factor (Building Seismic Safety Council, 2001).

For the shaking amplification map presented here, only V_{S30} was considered when classifying a site. The regional distribution of V_{S30} was estimated by dividing the study area into three approximately northwest-southeast regions. The western region is west of the predevelopment shoreline of San Francisco Bay where the upper 30 m typically consists of artificial fill placed over younger bay mud, which in turn overlies either fine-grained Pleistocene sediment or Merritt sand. The central region lies immediately northeast of the predevelopment shoreline where the upper 30 m typically consists of Holocene alluvial fan deposits overlying Pleistocene alluvial fan deposits. The eastern region is underlain by bedrock. To map the NEHRP V_{S30} site classification in the western and central regions, maps showing the thickness of Holocene sediment and artificial fill were prepared and then the V_{S30} at points on a regular grid with 50-m spacing was computed based on average velocities of each geologic unit. With the exception of the younger bay mud, a constant average shear-wave velocity of each geologic unit was computed from the velocities measured during the cone penetration testing. The velocity of the younger bay mud increases linearly with depth, so a depth-dependent equation was used to compute the travel time through this layer in the estimation of V_{S30}.

The map in the southwestern region may underestimate values of V_{S30} in some areas because it was assumed that the Holocene sediment beneath the artificial fill at each control point was younger bay mud. This unit has the lowest shear-wave velocity of all of the geologic units. Special studies are required in these areas to determine if V_{S30} values are indeed lower than 180 m/s, the prerequisite for a type E classification. Because points where V_{S30} was estimated were 50 m apart, modern stream valleys with Holocene fluvial deposits less than approximately 50-m wide were not mapped and classified.

Table 1. Ground-amplification V_{S30} site classes (adapted from Building Seismic Safety Council (2000)).

Site Class	Description	V_{S30}(m/s) Minimum	Maximum
A	Hard Rock (Eastern US only)	1500	
B	Rock	760	1500
C	Very Dense Soil and Soft Rock	360	760
D	Stiff Soils	180	360
E	Soft Soils		180

Locations of and data from the CPT soundings, including the shear-wave travel times, are available on the World Wide Web at the following URL: http://quake.usgs.gov/prepare/cpt/. For more information on the mapping procedure, the reader is referred to Holzer and others (2005a). For an analysis of the shear wave velocities of the geologic units including velocity gradients, the reader is referred to Holzer and others (2005b).

ACKNOWLEDGMENTS

The field investigations with the CPT soundings that provided the subsurface data used in this report were facilitated by the cooperation of Coleen Bell and David Skinner of the City of Oakland; Capt Larry Picinic and Flavio Barrantes of the City of Alameda; Maurice Kaufman, John Flores, and Hank Van Dyke of the City of Emeryville, Arrieta Chakos, Diana Aikenhead, Roger Miller, Jay Wilson, Rene Cardineaux of the City of Berkeley, and Gerald Serventi and Karl Kuhlmann of the Port of Oakland. Selcuk Toprak, Suzanna Brooks, and Eric Hand of the USGS provided help with data reduction and analysis. We also are grateful to the

California Geological Survey and the Port of Oakland for providing subsurface data. Carl Wentworth of the USGS provided valuable guidance with GIS and the preparation of this report. Carl Wentworth and Manuel Bonilla provided thorough and thoughtful reviews
of the report.

DATABASE CONTENTS AND PRESENTATION

The report consists of digital files representing the 8 parts of the database, some of which are presented in more than one format. The names of the files are unique designators based on the report identifier, of02-296, followed by part numbers and an extension indicating file type. Some of the files have been have been bundled and compressed with WinZip for convenience. The report file (of02-296_1.1.pdf) is provided as a Portable Document Format (.pdf) file and is also packaged with the database files in WinZip compressed form. The revision history file (version_history.pdf) is presented as a Portable Document Format (.pdf) file bundled in the database .zip files, as well as an individual download. The six .pdf map images may be downloaded individually or as a complete set in a single .zip file (of02-296_all_maps.zip). The liquefaction and shaking amplification databases are also packaged separately in compressed form with WinZip (.zip). The files and their identities are as follows:

1. Open-File Pamphlet: The text of the open-file pamphlet (this text, in Portable Document Format), which describes the database.

a. of02-296_1.1.pdf PDF file, 104 KB.

2. Liquefaction Map Images: The image files representing the liquefaction hazard map as a Portable Document Format file (.pdf). Files with an (-sg) extension contain the major streets and highways displayed on the map.

a. of02-296_2liq.pdf Portable Document Format, 528 KB

b. of02-296_2liq-sg.pdf Portable Document Format, 727 KB

3. Shaking Amplification Map Images: The image files representing the shaking amplification map as a Portable Document Format file (.pdf). Files with an (-sg) extension contain the major streets and highways displayed on the map.

a. of02-296_3sa.pdf Portable Document Format, 305 KB

b. of02-296_3sa-sg.pdf Portable Document Format, 303 KB

4. CPT Location Map Images: The image files representing the location of 210 SCPT soundings on the liquefaction map (scptliq) and the shaking amplification map (scptsa) Portable Document Format files (.pdf).

a. of02-296_4scptliq.pdf Portable Document Format, 532 KB

b. of02-296_4scptsa.pdf Portable Document Format, 309 KB

5. Liquefaction Map Database Package: The zipped file containing the open file pamphlet, revision list, and the data component files of the liquefaction hazard map, in ArcGIS format. The ArcGIS format files consist of shapefiles for the Hayward fault, the study area boundary, the liquefaction hazard, the latitude and longitude lines, the CPT locations, the streets and the major freeways. Additionally there are 3 .mxd files, named according to the unique identifier discussed above that were created using ArcMap 9.1, and the projection file.

a. of02-296_5liq.zip WinZip file, 1.3 MB

6. Shaking Amplification Map Database Package: The zipped files containing the open file pamphlet, revision list, and the data component files of the shaking amplification map, in ArcGIS format. The ArcGIS format files consist of shapefiles for the Hayward fault, the study area boundary, the latitude and longitude lines, the water boundary, the grid of shaking amplification values, the CPT locations, the streets and the major freeways. Additionally there are 3 .mxd files, named according to the unique identifier discussed above that were created using ArcMap 9.1, and the projection file.

a. of02-296_6sa.zip WinZip file, 3.9 MB

7. All map Images: The liquefaction map images, the shaking amplification map images, and the SCPT location map images (6 in total), in .pdf format, compressed into one .zip file.

a. of02-296_all_maps.zip WinZip file 2.8 MB

8. Revision List: A list of the parts of the report (including bundled packages of parts), indication of the current version number for the report and in which version each part was last revised, followed by a chronologic list describing any revisions (see REVISIONS, below).

a. Version_history.pdf Portable Document Format, 15 KB

OBTAINING THE DIGITAL FILES

The database and image files can be downloaded from the Western Region Geologic Information Web Server.

1. The files for this report are stored on the publication server of the U.S. Geological Survey. The Internet address of this open file report is:

http://pubs.usgs.gov/of/2002/of02-296/

PROCESSING THE FILES

The database files require initial processing before they are usable if they are bundled compressed files. These files were intended for PC platforms. For other formats contact the senior author at tholzer@usgs.gov.

OPENING THE WINZIP FILES

Some of the files are packaged as WinZip (.zip files). Thus, WinZip or another similar utility is required to uncompress the files. Once extracted from the compressed files, the data files can be imported into ArcGIS. Several ArcMap .mxd files, created using ArcMap 9.1, are provided. It is important that the embedded file structure in each .zip file be maintained upon extraction for the .mxd files to work properly. The necessary utility for uncompressing and extracting from zipped format (WinZip) is available on-line. This commercial package runs on PCs. An evaluation copy of WinZip can be downloaded from: http://www.winzip.com/downwzeval.htm

REVISIONS

Changes to any part of this report (parts are the numbered items described above in 'Database Contents' and listed in the revision list (Version_history.txt) may be made in the future if needed. This could involve, for example, fixing files that don't work properly, revising details, adding new file formats, or adding other components to the report.

The report began at version 1.0. This report is version 1.1. Previous versions are archived and available for download. Any revisions will be specified in the revision list and will result in the recording of a new version number for the report. Small changes will be indicated by decimal increments and larger changes by integer increments in the version number. Revisions will be announced and maintained on the Web page for this report on the Western Region Geologic Publications Web Server. Consult the revision list there to determine if a revision is significant for your purposes.

SPATIAL RESOLUTION

The digital database should not be used in ways that violate the spatial resolution of the data. Although the digital form of the data removes the physical constraint imposed by the scale of a paper map, the detail and accuracy inherent in map scale are also present in the digital data. Use of the liquefaction and shaking amplification databases, respectively, at scales larger than 1:24,000 and 1:50,000, will not yield greater real detail although it may reveal fine-scale irregularities below the intended resolution of the database. Similarly, where this database is used in combination with other data of higher resolution, the resolution of the combined output will be limited by the lower resolution of these data. The quadrangle boundaries in the images are accurate at 1:24,000.

DESCRIPTION OF THE SPATIAL DATABASE

The spatial database consists of ArcGIS formatted files. A description of the projection is listed below in table 2. The GIS files are in decimal degrees of longitude and latitude, prepared by projecting and converting the primary UTM coverages.

Table 2. Map Projection

Projection	GEOGRAPHIC
Units	DECIMAL DEGREES
Datum	NAD27
Spheroid	CLARKE1866
Parameters	NONE

REFERENCES CITED

Building Seismic Safety Council, 2001. 2000 edition, NEHRP recommended provision for seismic regulation for new buildings and other structures, FEMA-368, Part 1(Provisions) and Part 2 (Commentary). Washington, D.C., Federal Emergency Management Agency.

Helley, E.J., and Graymer, R.W., 1997, Quaternary geology of Alameda County, and parts of Contra Costa, Santa Clara, San Mateo, Stanislaus, and San Joaquin Counties, California: A digital database: U.S. Geological Survey Open-File Report 97-97, http://geopubs.wr.usgs.gov/open-file/of97-97/ .

Holzer, T.L., Bennett, M.J., Noce, T.E., Padovani, A.C., and Tinsley, J.C., III, in press, Liquefaction hazard mapping with LPI in the greater Oakland, California, area: Earthquake Spectra, v. 22, no. 3.

Holzer, T.L., Bennett, M.J., Noce, T.E., Tinsley, J.C., III, 2005b, Shear-wave velocity of surficial geologic sediments in Northern California: Statistical distributions and depth dependence: Earthquake Spectra, v. 21, no. 1, p.161-177.

Holzer, T.L., Padovani, A.C., Bennett, M.J., Noce, T.E., and Tinsley, J.C., III, 2005a, Mapping NEHRP VS30 site classes: Earthquake Spectra, v. 21, no. 2, p. 353-370.

Toprak, S., and Holzer, T.L., 2003, Liquefaction potential index: Field assessment: Journal of Geotechnical and Geoenvironmental Engineering, v. 129, no. 4, p. 315-322.

Working Group on California Earthquake Probabilities, 1999, Earthquake probabilities in the San Francisco Bay Region: 2000 to 2030 - A summary of findings: U.S. Geological Survey Open File Report 99-517, Online Version 1.0 is obtainable at: http://geopubs.wr.usgs.gov/open-file/of99-517/

26 September 2013
Project 731609201

Mr. Joe Ernst
East Bay Partners I, LLC
c/o Thompson Dorfman Partners, LLC
39 Forest Street, Suite 201
Mill Valley, California 94941

Subject: Review of Geotechnical Reports
Sherwin-Williams Site
1450 Sherwin Avenue
Emeryville, California

Dear Mr. Ernst:

This letter report summarizes our review of geotechnical reports prepared for the site of the old Sherwin-Williams paint facility in Emeryville, California. We have discussed the scope of services with you and understand the purposes of our review are to provide you with an independent evaluation of the geotechnical conditions and to evaluate the applicability of the conclusions and recommendations provided in the geotechnical reports. We understand that plans are to redevelop the site for office, commercial and residential use. We reviewed the following two geotechnical reports provided by you:

- "Summary of Geotechnical Results and Conceptual Geotechnical Engineering Recommendations for the Sherwin-Williams Company, Emeryville, CA Manufacturing Facility," Technical Memorandum by CDM, June 10, 2005.
- "2012 Update – Geotechnical Results and Conceptual Geotechnical Engineering Recommendations, Sherwin-Williams Company, Emeryville, CA Manufacturing Site," by CDM Smith, November 7, 2012.

In addition, we were provided with a preliminary plan of the proposed development of the site, and we reviewed the general geology of the vicinity.

1.0 SITE CONDITIONS

The site is located at 1450 Sherwin Avenue in Emeryville. It is bound by Sherwin Avenue on the southeast, Horton Street on the northeast, railroad tracks on the southwest and buildings on the northwest. A Sherwin-Williams paint factory once occupied the site. All but one of the factory buildings has been demolished. The building that remains is located at the northwest corner of Horton Street and Sherwin Avenue. The site encompasses approximately 8.6 acres. Ground surface elevations range from about 12 to 22 feet Mean Sea Level Datum[1] (MSL). The preliminary development plan is shown on Figure 1; the various portions of the development have been designated as Parcels A, B, C and D. Plans are to renovate the existing structure on Parcel A for office use and construct mid-rise mixed residential and commercial space on Parcels B and C. A high-rise residential building is planned for Parcel D. None of the buildings will have a basement. The CDM report of 2005 theorizes that the existing building is on

[1] Based on ground surface elevation contours presented on Figure 3 of CDM report of June 10, 2005.

a shallow foundation, but no actual data is presented to verify that statement. At present it is not known what, if any, new foundation elements will be required for the renovation and strengthening (if needed) of the building on Parcel A.

Based on our review of available documents, the paint manufacturing activities resulted in soil contamination that has been remediated; per Department of Toxic Substances Control (DTSC) Order No. 05/0-00- with notice of completion issued 23 January 2013. The remediation consists of installation of an impermeable barrier (slurry wall) around a portion of the site, installation and operation of extraction wells, and the removal of contaminated soil and replacement with engineered fill. As part of the latter, it appears portions of the slurry wall have been removed. Several new extraction wells reportedly were installed. These and other remediation activities are documented in reports other than the foregoing. The approximate locations of the remaining slurry wall are shown on Figure 1. The most significant remediation effort that occurred between the publications of the two CDM reports was the removal of approximately 14,000 cubic yards of contaminated material and replacement of it with clean fill. The approximate area where the removal and replacement took place is shown on Figure 1. No documentation of the quality of compaction is included in the 2012 report.

1.1 Seismic Hazards

The site is within a liquefaction hazard zone as designated by the California Geologic Survey[2]. Neither report adequately addresses site liquefaction potential or related hazards such as loss of bearing, settlement and lateral spreading.

1.2 Subsurface Conditions

The CDM reports characterize the subsurface profile as consisting of at least five layers, which we summarize as follows:

Layer 1 – Fill that is predominantly silty clayey gravel with sand. Layer 1 contains organics and glass, concrete and brick debris.

Layer 2 – Black sandy clay that is soft, contains organics and is expansive. This layer apparently is related to deposition and erosion by Temescal Creek.

Layer 3 – Medium dense to dense clayey sand and clayey gravel

Layer 4 – Medium stiff to very stiff sandy clay

Layer 5 – Medium dense to very dense sand and gravel.

It was noted that Layer 2 does not exist everywhere on the site.

Groundwater was encountered at depths between 10 and 14 feet below the ground surface. However, it is noted in the reports that groundwater extraction was being performed at the time measurements were taken.

---

2 State of California Seismic Hazard Zones, Oakland West Quadrangle, Official Map, Released February 14, 2003.

2.0 FOUNDATIONS

Foundation recommendations in the CDM reports for the planned buildings are presented for different building height categories. Low and mid-rise buildings are grouped in one category and high-rise in another. We infer from the reports that the building on Parcel A is a low-rise buildings, those on Parcels B and C would be classified as mid-rise, and the building proposed for Parcel D is a high-rise. Our comments regarding the CDM recommendations follow.

2.1 Parcels A, B C

It was recommended that the foundation for low- to mid-rise buildings be conventional spread footings or mats that take support in Layer 3; Layers 1 and 2 were determined to be unsuitable. The recommended allowable bearing pressure is 5,000 pounds per square foot (psf). Ground surface contours and contours of the bottom of the undesirable layers, Layer 2 and Layer 1 where Layer 2 does not exist, were provided so depths of footings can be estimated. The elevations were based on MSL. Our interpretation of the required footing depths are as follows:

Building Parcel	Approximate Ground Surface Elevation (ft.)	Approximate Elevation of Top of Layer 3 (ft.)	Approximate Depth to Bearing Stratum (ft.)
A	16 to 21	-10	26 to 31
B	13 to 16	0 to -18	13 to 32
C	12 to 14	-10 to -20	22 to 34

1. All elevations reference Mean Sea Level (MSL) datum.

Based on the foregoing table, it is our opinion that it is impractical to excavate to the top of the bearing layer, as proposed by CDM for the purposes of installing either spread footings or mat foundations. Consequently, we do not believe, without additional foundation elements or ground improvement, that this recommendation is appropriate. An additional concern for the Parcel B building is that it will span from an area of clean fill (reportedly place and compacted in 2011/2012 but not documented) to an area where unsuitable soil is present to 22 to 30 feet below ground surface. It is our opinion that spread footings might be used if they are supported on foundation elements that extend through Layers 1 and 2 and can transfer building loads to Layer 3.

Two techniques are particularly suited for the site and proposed development. These include drilled displacement columns (DDC) and soil cement mixing (SMX) columns. These techniques are different in their implementation but the effects are essentially to improve the ground locally and to carry the loads of the buildings to deeper, stronger strata below the unsuitable layers. This approach would allow for the use of footings at column and bearing wall locations and structural slab in between.

SMX columns and DDC are installed under design-build contracts by specialty contractors. Columns will need to be designed using a sufficient replacement ratio of cement mixtures to soil or to strengthen the soil and adequately transfer the loads to a competent bearing layer. More detailed discussions of these techniques are presented below.

2.1.1 Soil Cement Mixing

SMX columns are created by treating soil in-place with cement grout using mixing shafts consisting of continuous flight augers, or a technique called jet-grouting. Soil-cement mixing may be installed in a variety of patterns including cellular blocks, a grid pattern, or columns. Typical soil-cement columns have a minimum diameter or width of three feet. Typical minimum replacement ratios (ratio of treated soil to building footprint) are on the order of 30 to 50 percent. The structures can then be supported on a shallow foundation bearing on the improved soil.

2.1.2 Drilled Displacement Columns

DDCs are constructed by using a displacement auger to create a soil shaft that is filled with CLSM (Controlled Low Strength Material) injected under pressure as the displacement auger is withdrawn from the hole. Installation of DDCs produces minimal soil cuttings because the soil is displaced during column installation. DDCs vary from 18 to 36 inches in diameter; the selected diameter is based on building loads and number of columns per bearing location. Strengths of the CLSM typically range from 100 to 500 psi at 28 days, depending on the foundation load requirements.

Based on the information presented in the CDM reports, it is our preliminary opinion that the buildings may be supported on isolated or continuous spread footings bearing on SMX columns or DDCs. On the basis of our experience, we estimate spread footings bearing on SMX columns or DDCs may be designed using an allowable bearing capacity of about 5,000 psf for dead plus live loads.

An alternative to this approach would be to support the Parcel B and C buildings on piles as discussed for Parcel D in the following section.

2.2 Parcel D

The building proposed for Parcel D is envisioned as a residential tower up to 100 feet high. CDM recommends that the building be supported on either driven pre-cast, pre-stressed concrete piles or drilled cast-in-place drilled shafts. Both 12-inch and 14-inch square concrete piles are mentioned with allowable capacities of up to 200 and 250 kips, respectively. Drilled shaft capacities of up to 400 kips are indicated. Either foundation type would gain support in Layers 3, 4 and 5 with lengths of 80 to 100 feet. For these pile types, no lateral capacities were presented in the CDM reports. Because of the liquefaction potential of Layer 1 (yet to be evaluated), we judge lateral load resistance may be problematic.

Our experience indicates that 12-inch square pre-cast, pre-stressed concrete piles are not structurally viable if high lateral load resistance is required, which would be likely for the proposed building. Further, drilled shafts below the groundwater level, in granular soil, tend to be difficult and expensive to install

because of techniques required to prevent caving and to place concrete under water. Therefore we conclude that of the pile types mentioned in the CDM reports, only 14-inch concrete piles are viable. The capacity estimated is reasonable for this pile.

Other options which we suggest be considered include auger cast displacement piles and drilled-in pipe piles. Both pile types are design/build elements, but have comparable capacities to driven piles, at comparable costs, and have the advantage of low noise and vibration. Any pile type installed may need the approval of the Department of Toxic Substances Control (DTSC) and other regulatory agencies. It is not clear from reviewing the CDM reports if this approval has been sought and given. In our experience auger cast displacement piles can be more favorably viewed by regulators than other pile types because the concrete is placed under pressure and provides a seal against water migration along the sides of the pile.

3.0 ADDITIONAL STUDIES

We recommend that additional studies be under taken prior to the final geotechnical design of project. The following items and tasks should be performed so that a detailed geotechnical report can be issued:

- Information regarding the existing foundations of the Parcel A building
- Evaluation of liquefaction potential and related seismic hazards
- Update of seismic parameters per current building code
- Documentation and test results for fill placed during remediation
- Additional field exploration of subsurface conditions in the vicinity of Parcels C and D
- Obtain regulatory approval for pile foundations

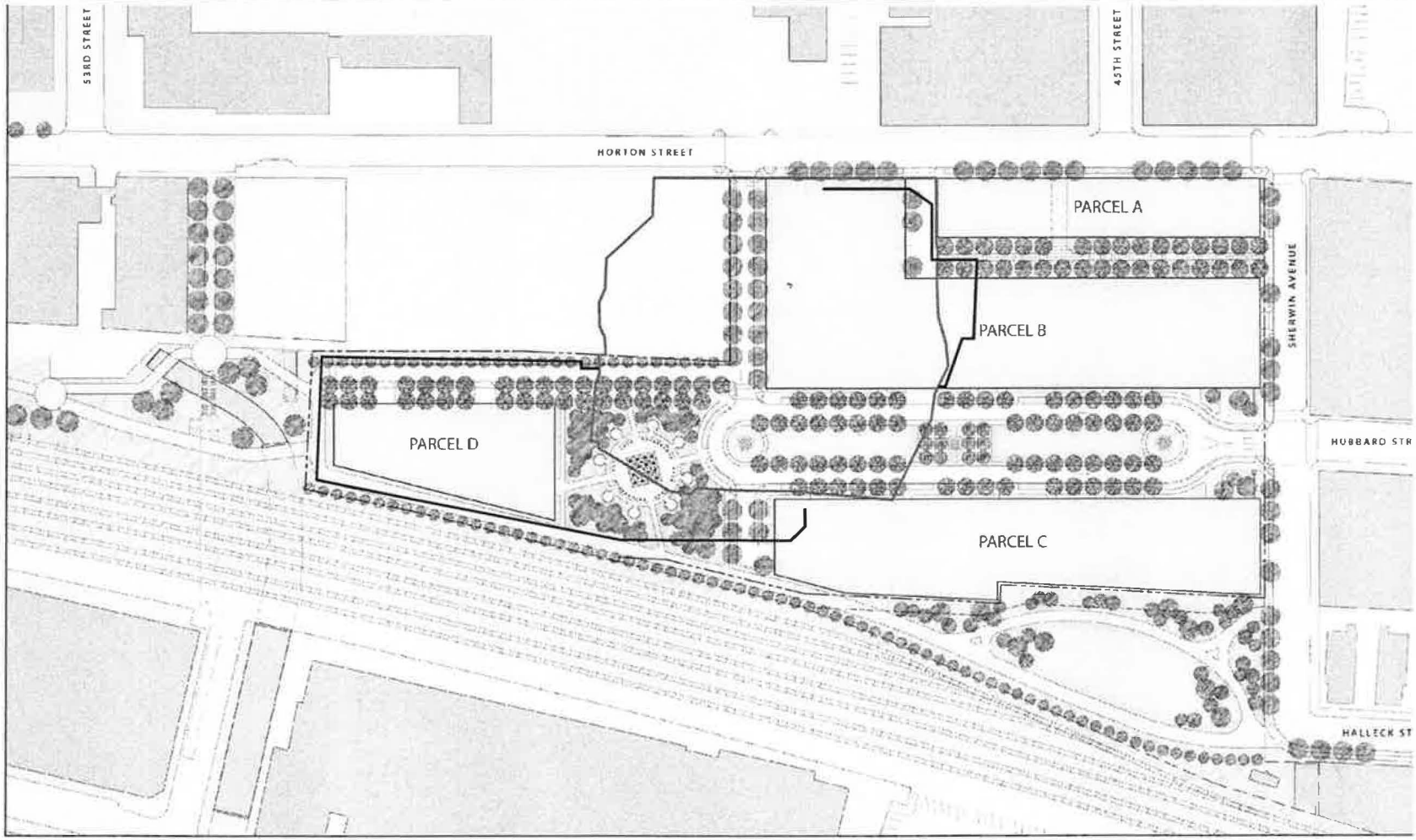
We trust the foregoing is adequate for your present needs; please contact us if we can be of further assistance.

Sincerely yours,
TREADWELL & ROLLO, A LANGAN COMPANY

Richard D. Rodgers, G.E. #732
Managing Principal

731609201.01_RDR_Sherwin-Williams Site

Attachment: Site Plan



Explanation

Approximate alignment of remaining slurry wall.[1]

Approximate area of soil removal and replacement with engineered fill.[1]

Notes

1. Based on Figure 2 of CDM Smith report dated November 7, 2012

0 180 Feet

Approximate scale

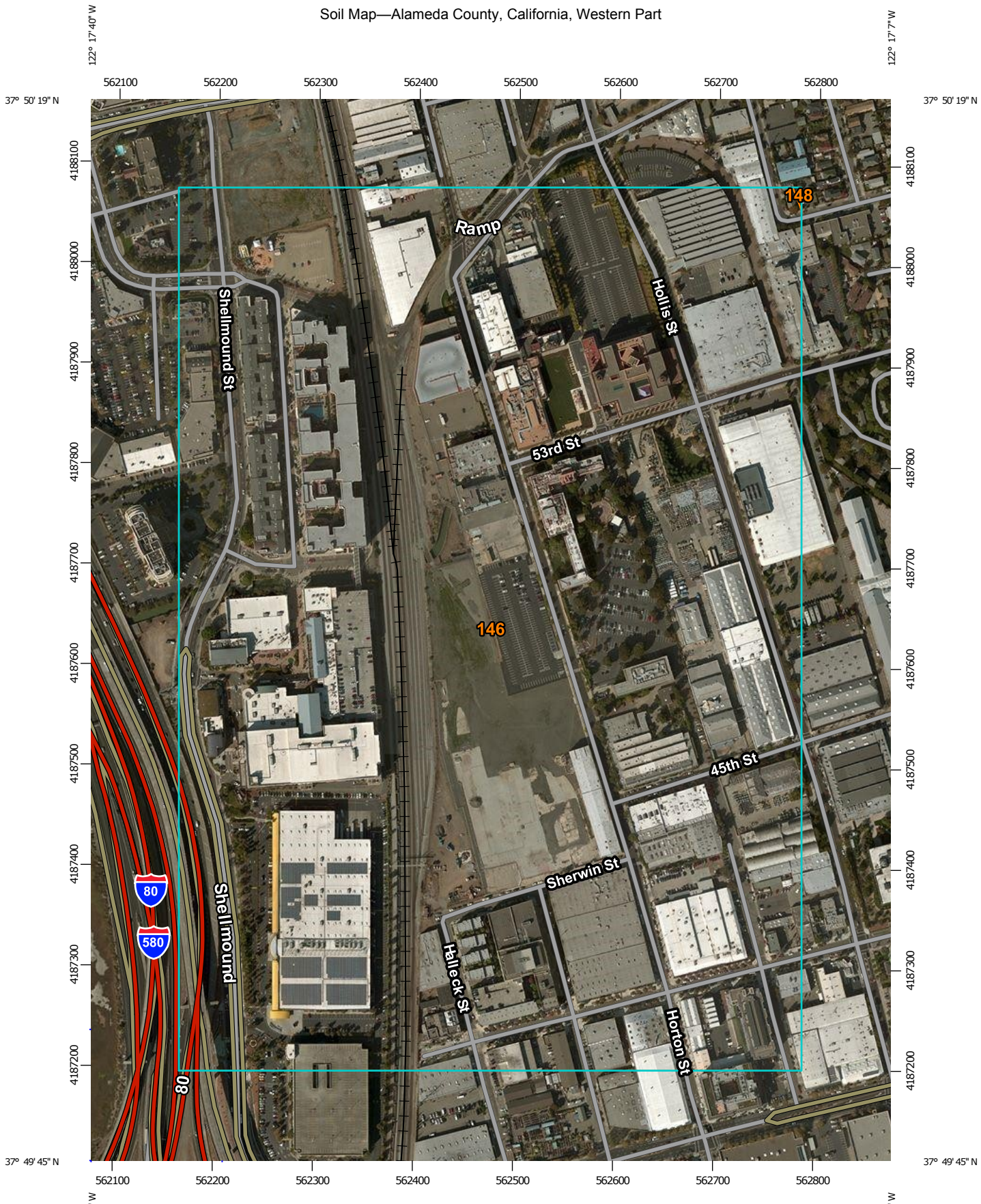
SHERWIN-WILLIAMS SITE
1450 Sherwin Avenue
Emeryville, California

SITE PLAN

Date 09/16/13 | Project No. 731609201 | Figure 1

Treadwell&Rollo
A LANGAN COMPANY

\\langan.com\data\SF\data\731609201\project data - 731609201\22-design files\geotech\731609201-B-SP101.dwg 9/11/13



Map Scale: 1:5,150 if printed on A portrait (8.5" x 11") sheet.

N

Meters
0 50 100 200 300

Feet
0 250 500 1000 1500

Map projection: Web Mercator Corner coordinates: WGS84 Edge tics: UTM Zone 10N WGS84

MAP LEGEND

Area of Interest (AOI)
- Area of Interest (AOI)

Soils
- Soil Map Unit Polygons
- Soil Map Unit Lines
- Soil Map Unit Points

Special Point Features
- Blowout
- Borrow Pit
- Clay Spot
- Closed Depression
- Gravel Pit
- Gravelly Spot
- Landfill
- Lava Flow
- Marsh or swamp
- Mine or Quarry
- Miscellaneous Water
- Perennial Water
- Rock Outcrop
- Saline Spot
- Sandy Spot
- Severely Eroded Spot
- Sinkhole
- Slide or Slip
- Sodic Spot
- Spoil Area
- Stony Spot
- Very Stony Spot
- Wet Spot
- Other
- Special Line Features

Water Features
- Streams and Canals

Transportation
- Rails
- Interstate Highways
- US Routes
- Major Roads
- Local Roads

Background
- Aerial Photography

MAP INFORMATION

The soil surveys that comprise your AOI were mapped at 1:24,000.

Warning: Soil Map may not be valid at this scale.

Enlargement of maps beyond the scale of mapping can cause misunderstanding of the detail of mapping and accuracy of soil line placement. The maps do not show the small areas of contrasting soils that could have been shown at a more detailed scale.

Please rely on the bar scale on each map sheet for map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL: http://websoilsurvey.nrcs.usda.gov
Coordinate System: Web Mercator (EPSG:3857)

Maps from the Web Soil Survey are based on the Web Mercator projection, which preserves direction and shape but distorts distance and area. A projection that preserves area, such as the Albers equal-area conic projection, should be used if more accurate calculations of distance or area are required.

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Alameda County, California, Western Part
Survey Area Data: Version 11, Sep 3, 2015

Soil map units are labeled (as space allows) for map scales 1:50,000 or larger.

Date(s) aerial images were photographed: Oct 7, 2013—Nov 1, 2013

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Map Unit Legend

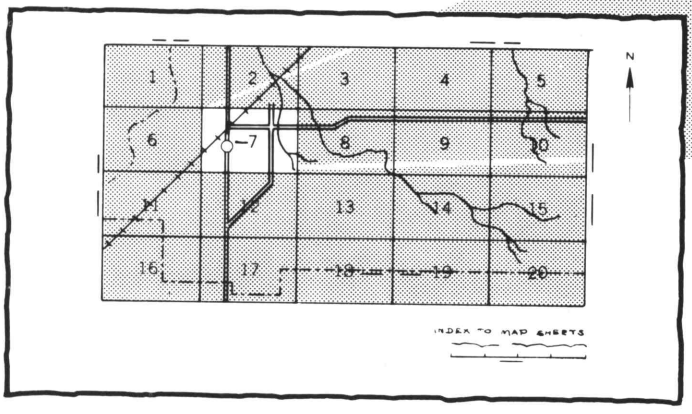
Alameda County, California, Western Part (CA610)			
Map Unit Symbol	**Map Unit Name**	**Acres in AOI**	**Percent of AOI**
146	Urban land	135.7	100.0%
148	Urban land-Clear Lake complex	0.0	0.0%
Totals for Area of Interest		**135.7**	**100.0%**

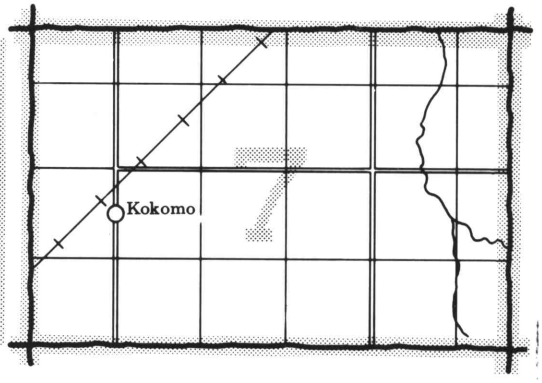
SOIL SURVEY OF
ALAMEDA COUNTY, CALIFORNIA, WESTERN PART

United States Department of Agriculture
Soil Conservation Service
in cooperation with
University of California Agricultural Experiment Station

HOW TO USE

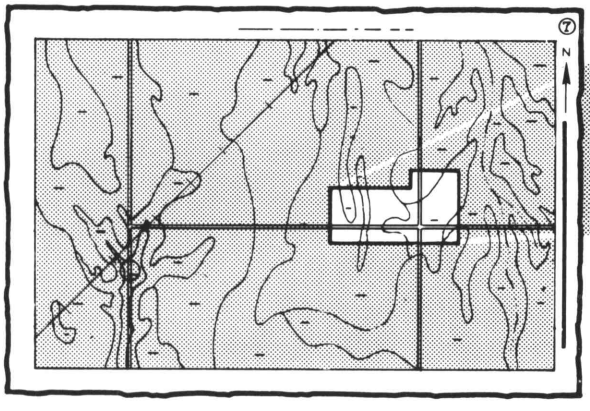
1. Locate your area of interest on the "Index to Map Sheets" (the last page of this publication).

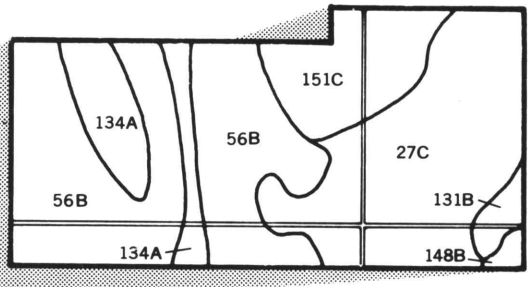




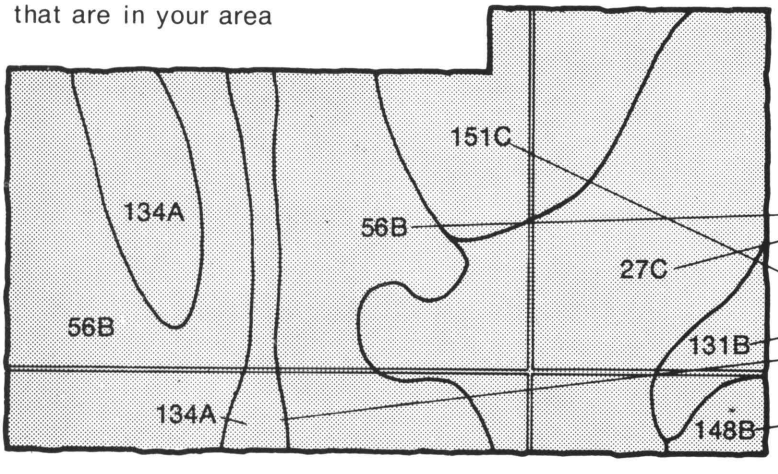
2. Note the number of the map sheet and turn to that sheet.

3. Locate your area of interest on the map sheet.





4. List the map unit symbols that are in your area

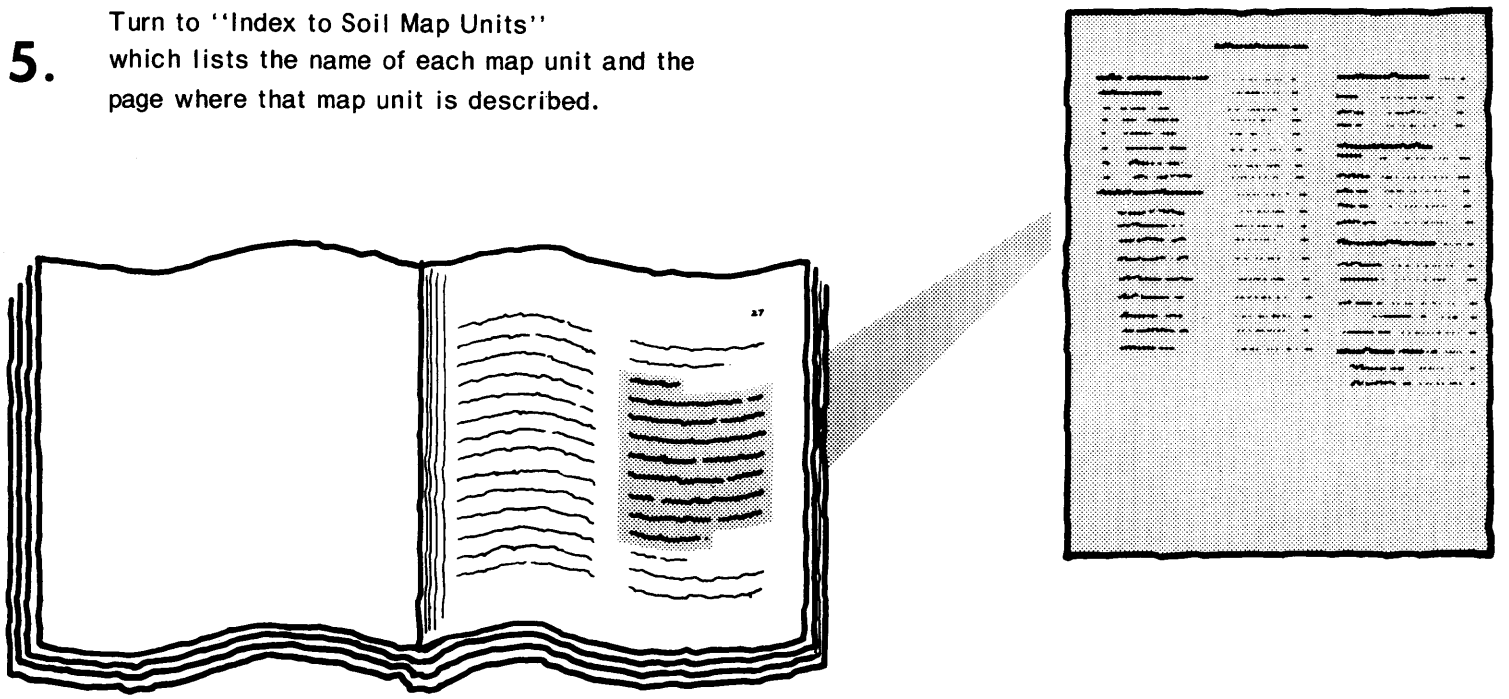


Symbols

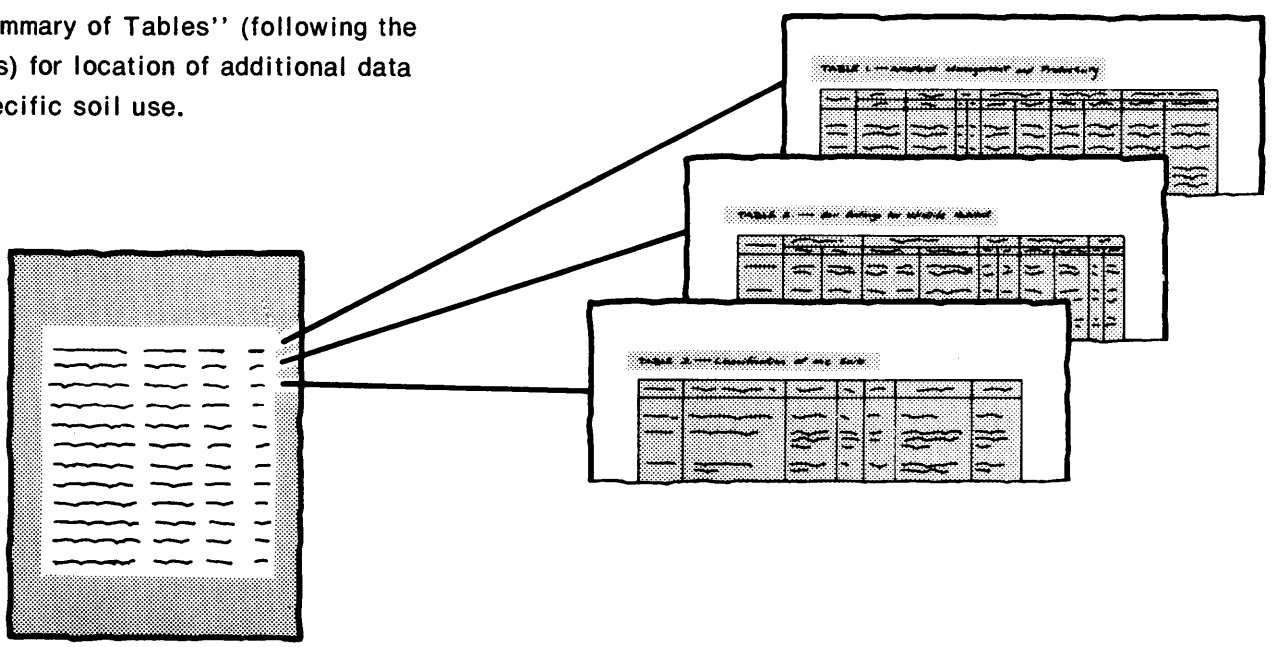
- 27C
- 56B
- 131B
- 134A
- 148B
- 151C

THIS SOIL SURVEY

5. Turn to "Index to Soil Map Units" which lists the name of each map unit and the page where that map unit is described.



6. See "Summary of Tables" (following the Contents) for location of additional data on a specific soil use.



7. Consult "Contents" for parts of the publication that will meet your specific needs. This survey contains useful information for farmers or ranchers, foresters or agronomists; for planners, community decision makers, engineers, developers, builders, or homebuyers; for conservationists, recreationists, teachers, or students; for specialists in wildlife management, waste disposal, or pollution control.

This is a publication of the National Cooperative Soil Survey, a joint effort of the United States Department of Agriculture and agencies of the States, usually the Agricultural Experiment Stations. In some surveys, other Federal and local agencies also contribute. The Soil Conservation Service has leadership for the Federal part of the National Cooperative Soil Survey. In line with Department of Agriculture policies, benefits of this program are available to all, regardless of race, color, national origin, sex, religion, marital status, or age.

Major fieldwork for this soil survey was completed in 1975. Soil names and descriptions were approved in April 1975. Unless otherwise indicated, statements in the publication refer to conditions in the survey area in 1975. This survey was made cooperatively by the Soil Conservation Service and the University of California Agricultural Experiment Station. It is part of the technical assistance furnished to the Alameda County Resource Conservation District.

Soil maps in this survey may be copied without permission, but any enlargement of these maps could cause misunderstanding of the detail of mapping and result in erroneous interpretations. Enlarged maps do not show small areas of contrasting soils that could have been shown at a larger mapping scale.

Contents

	Page
Index to soil map units	iv
Summary of tables	v
Preface	vii
General nature of the area	1
Climate	1
Physiography, relief, and drainage	1
History and development	2
Transportation	2
Industry	2
Farming	2
How this survey was made	3
General soil map for broad land use planning	3
Map unit descriptions	3
1. Reyes-Urban land	3
2. Clear Lake-Omni-Urban land	4
3. Xeropsamments-Urban land-Baywood	4
4. Xerorthents-Maymen-Millsholm	4
5. Danville-Botella	5
6. Tierra-Urban land	5
7. Sycamore-Yolo	5
Soil maps for detailed planning	6
Soil descriptions	6
Use and management of the soils	30
Capability classification	31
Land resource areas	32
Engineering	32
Building site development	33
Sanitary facilities	33
Water management	34
Recreation	35
Wildlife habitat	35
Soil properties	36
Engineering properties	37
Physical and chemical properties	37
Soil and water features	38

	Page
Classification of the soils	39
Soil series and morphology	40
Altamont series	40
Azule series	40
Baywood series	41
Baywood Variant	42
Botella series	42
Clear Lake series	43
Climara series	43
Contra Costa series	44
Danville series	44
Diablo series	45
Gaviota series	45
Laugenour series	46
Los Gatos series	46
Los Osos series	47
Marvin series	47
Maymen series	48
Millsholm series	48
Montara series	49
Omni series	49
Pescadero series	49
Pleasanton series	50
Reyes series	51
Rincon series	51
Sycamore series	52
Tierra series	52
Vallecitos series	53
Willows series	53
Yolo series	54
Formation of the soils	54
Landscape	54
Climate	55
Geomorphic units	55
References	56
Glossary	56
Tables	63

Issued March 1981

Index to soil map units

	Page
100—Altamont clay, 5 to 15 percent slopes	6
101—Altamont clay, 15 to 30 percent slopes	7
102—Altamont clay, 30 to 50 percent slopes	7
103—Azule clay loam, 9 to 30 percent slopes	8
104—Azule clay loam, 30 to 50 percent slopes	8
105—Baywood Variant, sand	9
106—Botella loam, 0 to 2 percent slopes	9
107—Clear Lake clay, 0 to 2 percent slopes, drained	10
108—Clear Lake clay, 2 to 9 percent slopes, drained	10
109—Climara clay, 30 to 50 percent slopes	11
110—Contra Costa clay loam, 30 to 50 percent slopes	11
111—Danville silty clay loam, 0 to 2 percent slopes	12
112—Danville silty clay loam, 2 to 9 percent slopes	12
113—Diablo clay, 9 to 15 percent slopes	12
114—Diablo clay, 15 to 30 percent slopes	13
115—Diablo clay, 30 to 50 percent slopes	13
116—Gaviota-Rock outcrop complex, 15 to 50 percent slopes	14
117—Laugenour loam, drained	14
118—Los Gatos-Los Osos complex, 30 to 50 percent slopes	15
119—Los Gatos-Los Osos complex, 50 to 75 percent slopes	15
120—Los Osos silty clay loam, 9 to 30 percent slopes	16
121—Los Osos silty clay loam, 30 to 50 percent slopes	16
122—Los Osos-Millsholm complex, 9 to 30 percent slopes	16
123—Los Osos-Millsholm complex, 30 to 50 percent slopes	17
124—Los Osos-Millsholm complex, 50 to 75 percent slopes	18
125—Marvin silt loam, saline-alkali	18
126—Maymen loam, 30 to 75 percent slopes	19
127—Maymen-Los Gatos complex, 30 to 75 percent slopes	19
128—Millsholm silt loam, 30 to 50 percent slopes	20
129—Millsholm silt loam, 50 to 75 percent slopes	20
130—Montara-Rock outcrop complex, 30 to 75 percent slopes	20
131—Omni silty clay loam, drained	20
132—Omni silty clay loam, strongly saline	21
133—Pescadero clay, drained	21
134—Pescadero clay, ponded	21
135—Pits, gravel	22
136—Pleasanton gravelly loam, 0 to 5 percent slopes	22
137—Reyes clay	22
138—Reyes clay, ponded	22
139—Reyes clay, drained	22
140—Rincon clay loam, 0 to 2 percent slopes	23
141—Riverwash	23
142—Quarry	23
143—Sycamore silt loam, drained	23
144—Sycamore silt loam, clay substratum	24
145—Tierra loam, 0 to 5 percent slopes	24
146—Urban land	24
147—Urban land-Baywood complex	24
148—Urban land-Clear Lake complex	25
149—Urban land-Danville complex	25
150—Urban land-Tierra complex, 2 to 5 percent slopes	26
151—Urban land-Tierra complex, 5 to 15 percent slopes	26
152—Urban land-Tierra complex, 15 to 30 percent slopes	26
153—Vallecitos-Rock outcrop complex, 30 to 50 percent slopes	27
154—Willows clay, drained	27
155—Xerorthents, clayey	27
156—Xeropsamments, fill	28
157—Xerorthents-Altamont complex, 30 to 50 percent slopes	28
158—Xerorthents-Los Osos complex, 30 to 50 percent slopes	29
159—Xerorthents-Millsholm complex, 30 to 50 percent slopes	29
160—Xerorthents-Millsholm complex, 50 to 75 percent slopes	29
161—Yolo silt loam, 0 to 2 percent slopes	30

Summary of tables

Page

Acreage and proportionate extent of the soils (Table 3) 68
Acres. Percent.

Average monthly and annual precipitation data (Table 2) 67
Month. Station.

Building site development (Table 4) 69
Shallow excavations. Dwellings without basements. Dwellings with basements. Small commercial buildings. Local roads and streets.

Classification of the soils (Table 12) 103
Soil name. Family or higher taxonomic class.

Engineering properties and classifications (Table 9) 91
Depth. USDA texture. Classification—Unified, AASHTO. Fragments greater than 3 inches. Percentage passing sieve number—4, 10, 40, 200. Liquid limit. Plasticity index.

Physical and chemical properties of soils (Table 10) 96
Depth. Permeability. Available water capacity. Soil reaction. Salinity. Shrink-swell potential. Erosion factors—K, T.

Recreational development (Table 7) 83
Camp areas. Picnic areas. Playgrounds. Paths and trails.

Sanitary facilities (Table 5) 74
Septic tank absorption fields. Sewage lagoon areas. Trench sanitary landfill. Area sanitary landfill. Daily cover for landfill.

Soil and water features (Table 11) 100
Hydrologic group. Flooding—Frequency, Duration, Months. High water table—Depth, Kind, Months. Bedrock—Depth, Hardness.

Temperature data from five weather stations (Table 1) 64
Month. Temperature—Highest, Mean maximum, Mean, Mean minimum, Lowest.

Water management (Table 6) 79
Pond reservoir areas. Embankments, dikes, and levees. Drainage. Irrigation. Grassed waterways.

Wildlife habitat potentials (Table 8) 87
Potential for habitat elements—Grain and seed crops, Grasses and legumes, Wild herbaceous plants, Shrubs, Wetland plants, Shallow-water areas. Potential as habitat for—Openland wildlife, Wetland wildlife, Rangeland wildlife.

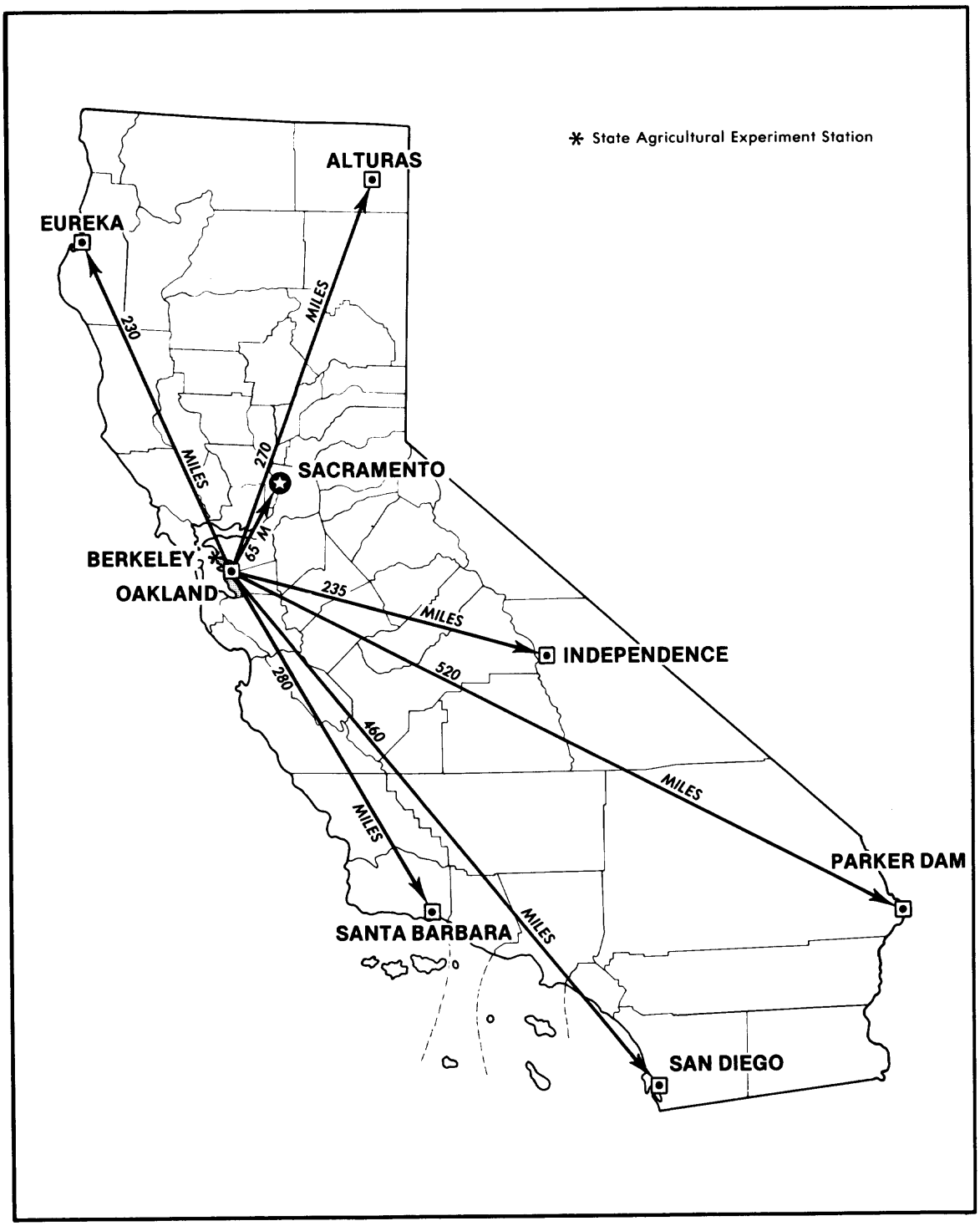
Preface

This soil survey contains much information useful in land-planning programs in Alameda County, Western Part. Of prime importance are the predictions of soil behavior for selected land uses. Also highlighted are limitations or hazards to land uses that are inherent in the soil, improvements needed to overcome these limitations, and the impact that selected land uses will have on the environment.

This soil survey has been prepared for many different users. Farmers, ranchers, foresters, and agronomists can use it to determine the potential of the soil and the management practices required for food and fiber production. Planners, community officials, engineers, developers, builders, and home buyers can use it to plan land use, select sites for construction, develop soil resources, or identify any special practices that may be needed to insure proper performance. Conservationists, teachers, students, and specialists in recreation, wildlife management, waste disposal, and pollution control can use the soil survey to help them understand, protect, and enhance the environment.

Great differences in soil properties can occur even within short distances. Soils may be seasonally wet or subject to flooding. They may be shallow to bedrock. They may be too unstable to be used as a foundation for buildings or roads. Very clayey or wet soils are poorly suited to use as septic tank absorption fields. A high water table makes a soil poorly suited to basements or underground installations.

These and many other soil properties that affect land use are described in this soil survey. Broad areas of soils are shown on the general soil map; the location of each kind of soil is shown on detailed soil maps. Each kind of soil in the survey area is described, and much information is given about each soil for specific uses. Additional information or assistance in using this publication can be obtained from the local office of the Soil Conservation Service or the Cooperative Extension Service.



Location of Alameda County, Western Part, in California.

SOIL SURVEY OF ALAMEDA COUNTY, CALIFORNIA, WESTERN PART

By Lawrence E. Welch

Soils surveyed by Lawrence E. Welch, Clifford Landers, Paul Nazar, and William Harris,
Soil Conservation Service

United States Department of Agriculture, Soil Conservation Service, in cooperation with
University of California Agricultural Experiment Station

ALAMEDA COUNTY, WESTERN PART, is in the San Francisco drainage basin. The survey area is bounded on the west by San Francisco Bay and on the east by foothills and uplands of the Diablo Range. The area is 225 square miles, or about 144,120 acres in size. Elevation ranges from sea level to about 2,000 feet.

Most of the survey area is urban land. Oakland, the largest city in Alameda County, is the county seat. Agriculture is limited mainly to the southern part of the survey area. A few large vegetable farms are in an area east of Coyote Hills.

General nature of the area

This section provides general information about the survey area. Climate; physiography, relief, and drainage; history and development; transportation; industry; and farming are discussed.

Climate

The survey area has a marine climate characterized by very little change in temperature. Temperatures are moderate, and crops can be grown throughout the year. Rain falls mainly in winter. There is little or no rain in summer. Summer crops require irrigation, but winter crops or early-maturing grain crops require little or no irrigation.

The mean annual temperature ranges from 56.5 degrees F at Oakland Airport to 58.5 degrees at Alvarado. Temperatures reach 90 degrees or higher on about 4 days a year. Temperature data from five weather stations is shown in Table 1.

The average frost-free season is 293 days or more. The number of frost-free days (32 degrees F or higher) at Hayward is 306; at Newark, 293; and at Oakland, 333.

The average annual precipitation ranges from 13.64 inches at Newark to 25.42 inches near Hayward. In general, the amount of precipitation increases inland from the bay as the elevation increases. Most precipitation falls between October and April. Localized showers are infrequent. Storms are moderate in duration and intensity, but, at times, precipitation is heavy enough to cause flooding. Snow and hail are rare. Table 2 provides average monthly and annual precipitation data.

The relative humidity in winter is about 85 to 90 percent at night and 60 to 70 percent in the afternoon. It is less in spring, but increases at night in summer. Humidity is lowest in fall. It ranges from 50 percent during the day to 70 percent at night.

Strong winds are unusual in this survey area. The wind speed is less than 6 miles per hour more than 50 percent of the time and exceeds 12 miles per hour only 10 percent of the time. The strongest winds are usually associated with winter storms. Winds from the north and east are sometimes accompanied by cold temperatures in winter and spring. Westerly winds in summer are generated by the cool marine air flowing to the warmer interior. These winds are strongest early in summer, mainly late in the afternoon and in the evening.

Physiography, relief, and drainage

The survey area consists of three physiographic units: nearly level deltas and flood plains at sea level to an elevation of 200 feet; upland terraces and terrace remnants at an elevation of 100 to 300 feet; and foothills and uplands, along the eastern boundary, at an elevation of 200 to 2,000 feet. The soils on foothills and uplands are strongly sloping to very steep.

The survey area is drained mainly by Alameda Creek, which enters the area at Niles, and by San Leandro Creek, which enters the area at San Leandro. The flow of water in these creeks is regulated by reservoirs that are east of the survey area. Numerous intermittent streams that flow for short periods in winter also drain the area.

History and development

In the late eighteenth century, Spanish explorers and missionaries opened the survey area to settlement. As early as 1795, the Spaniards called the area that encompasses the southern part of the survey area "Alameda," and the stream running through it, "Rio de la Alameda." "Alameda" is derived from the Spanish word that means "grove of poplar trees." Mission San Jose de Guadalupe, which became one of the most prosperous and populous of the California missions, was established in 1797. In 1820, Rancho San Antonio was granted to Don Luis Peralta. This domain included the areas along the eastern shore of San Francisco Bay where the cities of Albany, Berkeley, Emeryville, Piedmont, Oakland, Alameda, and San Leandro are now. Other large Spanish land grants in the survey area were Rancho San Leandro and Rancho San Lorenzo.

American territorial claims in 1847 and the gold rush of 1849 promoted the settlement of the survey area. In 1852, tracts of land were staked out at the present site of the city of Oakland. Seventeen years later the first transcontinental railroad arrived in Oakland. The city's population increased from 1,543 in 1860 to 10,500 in 1870.

Alameda County was organized in 1853 from parts of Contra Costa and Santa Clara Counties. The population was 93,864 in 1890 and 908,209 in 1960.

Transportation

The bayshore cities in the county are natural terminals for long-distance transportation lines. Three transcontinental railways—Southern Pacific, Santa Fe, and Western Pacific—have terminals directly connected to port facilities. These major railroads, in addition to truck lines, provide transportation to all Pacific Coast cities and to interior valley areas.

The Port of Oakland has more than 19 miles of deepwater frontage. Before World War II, this port served more than 100 steamship lines engaged in coastal, intercoastal, and foreign trade.

The Metropolitan Oakland International Airport is 6 miles south of the center of Oakland. It is more than 1,000 acres in size. An additional 1,000 acres, adjacent to the airport, is reserved for harbor and airport industrial development. The airport accommodates intercontinental airlines. There are seven other airports in Alameda County. Two of these airports are municipally controlled, two are operated by the military, and three are privately owned.

The San Francisco-Oakland Bay Bridge provides passage for busses, trucks, and private automobiles. The San Mateo Bridge and the Dumbarton Bridge connect the southern part of Alameda County with San Mateo County and with the coastal highway.

The major paved highways in the area make Alameda County a center for bus and truck traffic. Alameda County has 219 miles of State highways and 562 miles of county roads, 227 miles of which are primary roads.

Industry

The food processing industry—mainly the canning of fruits, vegetables, and fish—ranks first in the economy of Alameda County. Most of the foods that are canned are produced outside of the survey area. The most important of these foods are peaches, pears, mixed fruits, apricots, spinach, tomatoes, and potatoes. Wineries produce table and dessert wines as well as vermouth and champagne.

The manufacturing of machinery is the second largest industry. The fabricated metals industry and the transportation equipment industry are also important to the county's economy. More than 100 chemical firms employ 5,000 workers, and primary metals production firms employ about the same number. Other important industries are printing and publishing, sand and gravel extraction, and the production of glass, paper, and allied products and electrical machinery.

Electricity for industry is provided by a system of hydroelectric plants, supplemented by steam electric-generating plants in key cities.

Natural gas is piped into Alameda County from the local fields and from fields in Texas, New Mexico, and Canada. Fuel oil and gasoline are available from the local refineries of four major oil companies.

A twin aqueduct, 93 miles long, brings soft mountain water from the Sierra Nevada to the area.

Farming

In the past, the southern part of the survey area supplied many vegetable crops to the cities surrounding San Francisco Bay. Today, the amount of farmland has been reduced because of the increase in residential and industrial development in the area. A few large areas east of the Coyote Hills are intensively cropped to vegetables. The most common cropping system includes head lettuce in summer and cauliflower in winter. Tomatoes are sometimes grown instead of head lettuce. Small acreages of fruit and nut crops, nursery products, and cut flowers are scattered throughout the southern part of the survey area.

Most of the water used for agriculture comes from wells. The hazard of salt water intrusion from San Francisco Bay has been reduced by importing water and diverting it into old gravel pits adjacent to Alameda Creek to recharge the ground water reservoir.

How this survey was made

Soil scientists made this survey to learn what kinds of soil are in the survey area, where they are, and how they can be used. The soil scientists went into the area knowing they likely would locate many soils they already knew something about and perhaps identify some they had never seen before. They observed the steepness, length, and shape of slopes; the size of streams and the general pattern of drainage; the kinds of native plants or crops; the kinds of rock; and many facts about the soils. They dug many holes to expose soil profiles. A profile is the sequence of natural layers, or horizons, in a soil; it extends from the surface down into the parent material, which has been changed very little by leaching or by the action of plant roots.

The soil scientists recorded the characteristics of the profiles they studied, and they compared those profiles with others in counties nearby and in places more distant. Thus, through correlation, they classified and named the soils according to nationwide, uniform procedures.

After a guide for classifying and naming the soils was worked out, the soil scientists drew the boundaries of the individual soils on aerial photographs. These photographs show buildings, field borders, roads, and other details that help in drawing boundaries accurately. The soil map at the back of this publication was prepared from aerial photographs.

The areas shown on a soil map are called map units. Some map units are made up of one kind of soil, others are made up of two or more kinds of soil, and a few have little or no soil material. Map units are discussed in the sections "General soil map for broad land use planning" and "Soil maps for detailed planning."

While a soil survey is in progress, samples of soils are taken as needed for laboratory measurements and for engineering tests. The soils are field tested, and interpretations of their characteristics may be modified during the course of the survey. New interpretations are added to meet local needs, mainly through field observations of different kinds of soil in different uses under different levels of management. Also, data are assembled from other sources, such as test results, records, field experience, and state and local specialists.

But only part of a soil survey is done when the soils have been named, described, interpreted, and delineated on aerial photographs and when the laboratory data and other data have been assembled. The mass of detailed information then needs to be organized so that it is usable to farmers, engineers, planners, developers and builders, home buyers, and others.

Where soil boundaries extend into urban areas, pavement and buildings restrict the examination of the soils at close intervals. In the cities of Oakland and Berkeley, for example, the original soil properties have been obscured in many places by cutting and filling for urban development. Areas of identifiable soils are mapped in complex with Urban land. The mapped soil boundaries represent the best possible estimate of soil patterns under these circumstances.

The soil maps showing the urban areas are suitable for extensive general planning. Onsite inspection is needed for some intensive uses of Urban land and may be necessary in other areas as well, for example, where soil properties need to be identified at very close intervals.

General soil map for broad land use planning

The general soil map at the back of this publication shows map units that have a distinct pattern of soils, relief, and drainage. Each map unit is a unique natural landscape. Typically, a map unit consists of one or more major soils and some minor soils. It is named for the major soils. The soils making up one unit can occur in other units but in a different pattern.

The general soil map provides a broad perspective of the soils and landscapes in the survey area. It provides a basis for comparing the potential of large areas for general kinds of land use. Areas that are, for the most part, suited to certain kinds of farming or to other land uses can be identified on the map. Likewise, areas of soils having properties that are distinctly unfavorable for certain land uses can be located.

Because of its small scale, the map does not show the kind of soil at a specific site. Thus, it is not suitable for planning the management of a farm or field or for selecting a site for a road or building or other structure. The kinds of soil in any one map unit differ from place to place in slope, depth, stoniness, drainage, or other characteristics that affect their management.

Map unit descriptions

1. Reyes-Urban land

Nearly level, very poorly drained clays on tidal flats, and Urban land

This map unit consists of soils that formed in alluvium on tidal flats adjacent to the bay. The slopes are less than 2 percent. The natural vegetation consists primarily of salt-tolerant grasses and brush. Elevation is near sea level. The average annual precipitation ranges from 14 to 18 inches, the mean annual temperature is 57 degrees F, and the frost-free season is 300 to 320 days.

This map unit makes up 23 percent of the survey area. Reyes soils make up about 70 percent of this map unit and Urban land about 25 percent. Omni silty clay loam, strongly saline, and Pescadero clay, ponded, make up the rest.

Reyes soils are very deep and very poorly drained. The surface layer is olive gray, strongly alkaline clay about 6 inches thick. The underlying material, to a depth of 42 inches, is mottled dark greenish gray and black, strongly alkaline clay. Below that it is dark greenish gray, strongly alkaline silty clay. These soils contain polysulfides below a depth of about 6 inches.

Urban land consists of areas that are covered by industrial and commercial buildings, streets, and other structures. Many of these areas consist of heterogeneous fill made up of crushed rock and soil material.

Reyes soils are used mainly for commercial salt production. They can also be used as wildlife habitat and dryland pasture.

2. Clear Lake-Omni-Urban land

Nearly level to moderately sloping, poorly drained clays and silty clay loams, and Urban land; on the basin rim

This map unit consists of soils that formed in alluvium derived mainly from sedimentary rock. The slopes range from 0 to 9 percent but are mainly 0 to 2 percent. The soils are on the basin rim that parallels the bay. The natural vegetation consists of annual grasses, forbs, and scattered oaks. Elevation ranges from 5 to 200 feet. The average annual precipitation ranges from 14 to 20 inches, the mean annual temperature is 57 degrees F, and the frost-free season is 300 to 330 days.

This map unit makes up 17 percent of the survey area. Clear Lake soils make up about 45 percent of this map unit; Omni soils, 17 percent; and Urban land, 13 percent. Marvin and Pescadero soils and Xerorthents, clayey, make up the rest.

Clear Lake soils are very deep. The surface layer is very dark gray, neutral to moderately alkaline clay about 37 inches thick. The underlying material is dark gray and grayish brown calcareous clay and silty clay and extends to a depth of more than 60 inches. Flood-control structures have lowered the water table to a depth of 48 inches or more in most places.

Omni soils are very deep. The surface layer is grayish brown, moderately alkaline silty clay loam and silty clay about 15 inches thick. The subsoil extends to a depth of 52 inches; it is mottled, dark gray and light olive brown, moderately alkaline clay. The substratum is mottled, light olive brown silty clay loam and extends to a depth of 60 inches or more. Flood-control structures have lowered the water table to a depth of 5 feet or more.

Urban land consists of areas that are covered by houses, industrial buildings, parking lots, and other structures. The soil material has been altered or mixed during urban development. The characteristics of the original soil material were probably similar to those of the Clear Lake soils.

Areas of this map unit are mainly used for urban development. Some areas of the Clear Lake and Omni soils are used for dryland grain and pasture.

3. Xeropsamments-Urban land-Baywood

Nearly level to moderately sloping, somewhat excessively drained sands and loamy sands, and Urban land; on the coastal plain

This map unit consists of soils that formed in sandy eolian deposits on mounds and ridges that derived from beach deposits and in sandy material dredged from beaches. The slopes range from 0 to 9 percent. The natural vegetation consists of annual grasses, forbs, and scattered oaks. Elevation ranges from sea level to 60 feet. The average annual precipitation ranges from 16 to 18 inches, the mean annual temperature is 57 degrees F, and the frost-free season is 300 to 330 days.

This map unit makes up 8 percent of the survey area. Xeropsamments make up about 53 percent of this map unit; Urban land, 20 percent; and Baywood soils, 15 percent. Omni and Willows soils make up the rest.

Xeropsamments consist of very deep sandy material that was dredged from beaches. These areas are protected from tidal action by levees.

Urban land consists of areas that are covered by houses, industrial buildings, parking lots, and other structures. The soil material has been altered or mixed during urban development. The characteristics of the original soil material were probably similar to those of the Baywood soils.

Baywood soils are very deep. The surface layer is grayish brown and brown, slightly acid loamy sand about 32 inches thick. The underlying material is pale brown and light yellowish brown, slightly acid loamy sand. It extends to a depth of 60 inches or more.

Areas of this map unit are used mainly for urban development. Much of the acreage is already covered by residential and commercial buildings, parking lots, and airfields.

4. Xerorthents-Maymen-Millsholm

Steep to very steep, well drained and somewhat excessively drained soils that have various textures; on foothills

This map unit consists of soils that formed mainly in material that weathered from interbedded sedimentary rock and some intrusive rock. The slopes range from 30 to 75 percent. The natural vegetation consists of annual grasses, forbs, and oaks. Some areas have dense stands of eucalyptus, coyote bush, and deer wood and an understory of annual grasses and forbs. Elevation ranges from 5 to 2,000 feet. The average annual precipitation ranges from 15 to 26 inches, the mean annual temperature is 56 degrees F, and the frost-free season is 300 to 320 days.

This map unit makes up about 17 percent of the survey area. Xerorthents make up about 28 percent of this map unit; Maymen soils, 20 percent; and Millsholm soils, 20 percent. Los Osos, Diablo, Altamont, Los

Gatos, Contra Costa, Gaviota, Montara, and Vallecitos soils and Quarries make up the rest.

Xerorthents are well drained and somewhat excessively drained. These soils have few or no identifiable horizons because they have been altered by cutting and filling for urban development. The texture is clay, silty clay, clay loam, silty clay loam, loam, or silt loam; but in some areas, coarse fragments of sandstone or shale make up as much as 50 percent of the soil mass. Bedrock is exposed in many of the cut areas.

Maymen soils are shallow and somewhat excessively drained. The surface layer and subsoil are light brownish gray, strongly acid loam. Shale is at a depth of about 19 inches.

Millsholm soils are shallow and well drained. The surface layer is grayish brown, medium acid silt loam about 6 inches thick. The subsoil is light olive brown, medium acid silt loam. Shale is at a depth of 20 inches.

These soils are used mainly as sites for houses and parks. A few areas of Maymen and Millsholm soils are rangeland.

5. Danville-Botella

Nearly level to moderately sloping, well drained loams and silty clay loams; on low terraces and alluvial fans

This map unit consists of soils that formed in very deep alluvium derived primarily from sedimentary rock. The slopes range from 0 to 9 percent but are mainly 0 to 2 percent. The natural vegetation consists of annual grasses, forbs, and scattered oaks. Elevation ranges from 10 to 300 feet. The average annual precipitation ranges from 14 to 20 inches; the mean annual temperature is 57 degrees F, and the frost-free season is 300 to 330 days.

This map unit makes up about 16 percent of the survey area. Danville soils make up about 50 percent of the map unit and Botella soils about 16 percent. Clear Lake, Omni, and Rincon soils and Urban land make up the rest.

Danville soils are very deep and well drained. The surface layer is grayish brown and dark gray, slightly acid silty clay loam about 21 inches thick. The subsoil is grayish brown, slightly acid silty clay and heavy silty clay loam that extends to a depth of about 61 inches. The substratum is grayish brown, neutral silty clay loam and extends to a depth of 80 inches or more.

Botella soils are very deep and well drained. The surface layer is grayish brown, neutral loam about 9 inches thick. The subsoil is dark grayish brown and dark brown, neutral light clay loam that extends to a depth of 33 inches. The substratum is brown, mildly alkaline clay loam and yellowish brown, moderately alkaline silt loam and extends to a depth of 60 inches or more.

These soils are used mainly for urban development. A few areas are used for vegetable crops.

6. Tierra-Urban land

Nearly level to moderately steep, moderately well drained loams, and Urban land; on upland terraces

This map unit consists of soils that formed in weakly consolidated alluvium on old dissected terraces. These soils and Urban land are on the foot slopes parallel to the bay. The natural vegetation consists primarily of plants that are used for landscaping. The slopes range from 0 to 30 percent. Elevation ranges from 100 to 250 feet. The average annual precipitation ranges from 15 to 20 inches, the mean annual temperature is 57 degrees F, and the frost-free season is 300 to 320 days.

This map unit makes up about 7 percent of the survey area. Tierra soils make up about 47 percent of this map unit and Urban land, about 44 percent. Azule and Danville soils make up the rest.

The Tierra soils are very deep and moderately well drained. The surface layer is grayish brown, slightly acid loam about 11 inches thick. The subsurface layer is gray, slightly acid loam 1 inch thick. The subsoil is very dark grayish brown, grayish brown, and brown, neutral clay and extends to a depth of about 32 inches. The substratum is variegated yellowish brown and brown, neutral sandy clay loam and extends to a depth of 60 inches or more.

Urban land consists of areas that are covered by houses, industrial buildings, parking lots, and other urban structures. The soil material has been altered or mixed during urban development. The characteristics of this original soil material were probably similar to those of the Tierra soils.

Areas of this map unit are used almost entirely for urban development. A few areas of Tierra soils are grazed.

7. Sycamore-Yolo

Nearly level, well drained and poorly drained silt loams, on flood plains and alluvial fans

This map unit consists of soils that formed in very deep alluvium that derived from sedimentary rock. The slopes are 0 to 2 percent. The natural vegetation consists of annual grasses, forbs, and scattered oaks. Elevation ranges from 10 to 200 feet. The average annual precipitation ranges from 14 to 18 inches, the mean annual temperature is 57 degrees F, and the frost-free season is 300 to 320 days.

This map unit makes up 12 percent of the survey area. The Sycamore soils make up about 48 percent of the map unit and Yolo soils, 35 percent. Botella, Danville, and Omni soils and gravel pits make up the rest.

Sycamore soils are very deep and poorly drained. The surface layer is light brownish gray, moderately alkaline silt loam about 18 inches thick. The subsoil is mottled, grayish brown and light olive gray, moderately alkaline silt loam and extends to a depth of 44 inches. The

substratum is mottled, light olive gray, moderately alkaline, heavy silt loam and extends to a depth of 60 inches or more. In most areas, the water table has been lowered to a depth of 6 feet or more.

Yolo soils are very deep and well drained. The surface layer is grayish brown, neutral silt loam about 8 inches thick. The underlying material is brown, mildly alkaline, and moderately alkaline silt loam and extends to a depth of 60 inches or more.

These are among the most productive soils in the survey area. They are used primarily for vegetable crops.

Soil maps for detailed planning

The map units shown on the detailed soil maps at the back of this publication represent the kinds of soil in the survey area. They are described in this section. The descriptions together with the soil maps can be useful in determining the potential of a soil and in managing it for food and fiber production; in planning land use and developing soil resources; and in enhancing, protecting, and preserving the environment. More information for each map unit, or soil, is given in the section "Use and management of the soils."

Preceding the name of each map unit is the symbol that identifies the soil on the detailed soil maps. Each map unit description includes general facts about the soil and a brief description of the soil profile. In each description, the principal hazards and limitations are indicated, and the management concerns and practices needed are discussed.

The map units on the detailed soil maps represent an area on the landscape made up mostly of the soil or soils for which the unit is named. Most of the delineations shown on the detailed soil map are phases of soil series.

Soils that have profiles that are almost alike make up a *soil series*. Except for allowable differences in texture of the surface layer or of the underlying substratum, all the soils of a series have major horizons that are similar in composition, thickness, and arrangement in the profile. A soil series commonly is named for a town or geographic feature near the place where a soil of that series was first observed and mapped. The Altamont series, for example, was named for the town of Altamont in Alameda County.

Soils of one series can differ in texture of the surface layer or in the underlying substratum and in slope, erosion, stoniness, salinity, wetness, or other characteristics that affect their use. On the basis of such differences, a soil series is divided into phases. The name of a *soil phase* commonly indicates a feature that affects use or management. For example, Altamont clay, 5 to 15 percent slopes, is one of several phases within the Altamont series.

Some map units are made up of two or more dominant kinds of soil. Such map units are called soil complexes, soil associations, and undifferentiated groups.

A *soil complex* consists of areas of two or more soils that are so intricately mixed or so small in size that they cannot be shown separately on the soil map. Each area includes some of each of the two or more dominant soils, and the pattern and proportion are somewhat similar in all areas. Xerorthents-Altamont complex, 30 to 50 percent slopes, is an example.

Most map units include small, scattered areas of soils other than those that appear in the name of the map unit. Some of these soils have properties that differ substantially from those of the dominant soil or soils and thus could significantly affect use and management of the map unit. These soils are described in the description of each map unit. Some of the more unusual or strongly contrasting soils that are included are identified by a special symbol on the soil map.

Most mapped areas include places that have little or no soil material and support little or no vegetation. Such places are called *miscellaneous areas*; they are delineated on the soil map and given descriptive names. Riverwash is an example. Some of these areas are too small to be delineated and are identified by a special symbol on the soil map.

The acreage and proportionate extent of each map unit are given in table 3, and information on properties, limitations, and capabilities for many soil uses is given for each kind of soil in other tables. (See "Summary of tables.") Many of the terms used in describing soils are defined in the Glossary.

Soil descriptions

100—Altamont clay, 5 to 15 percent slopes. This is a deep, well drained soil that formed in material that weathered from interbedded soft shale and fine-grained sandstone or from soft conglomerate. This soil is on the foothills near Mission San Jose. Elevation ranges from 200 to 1,000 feet. The average annual precipitation is 16 inches and the mean annual temperature is 57 degrees F. The average frost-free season ranges from 300 to 320 days.

Typically, the surface layer is dark brown and brown, slightly acid to mildly alkaline clay about 28 inches thick. The next layer is finely mixed dark brown and dark yellowish brown, calcareous clay about 9 inches thick. The underlying material is yellowish brown, calcareous clay and extends to a depth of 50 inches. It is underlain by highly fractured and weathered fine-grained sandstone and shale.

Included in mapping are small areas of Diablo clay and Climara clay. Also included are a few small areas of a grayish brown, calcareous clay that is 20 to 40 inches

deep to soft sedimentary rock. Small areas of Rincon clay loam are along small drainageways.

Permeability is slow. The available water capacity is 5.0 to 9.5 inches. The root zone is 40 to 60 inches deep. Runoff is medium, and the hazard of erosion is moderate.

Most areas of this soil are in natural vegetation. These areas are commonly left idle and are only of esthetic value. The existing vegetation needs to be protected from fire and other destructive forces. If this soil is left bare, it is subject to erosion, and areas downslope are subject to sedimentation.

In a few areas, this soil is used for urban development.

This soil has many limitations for use as building sites. The shrink-swell potential is high; as a result, foundations can shift and crack. Building pads should be shaped to provide drainage away from the building site, thus keeping the soil beneath the foundation dry and reducing the hazards of differential settlement and shrink-swell. The high shrink-swell potential and low strength affect the construction of roads and streets. Suitable base material is needed. In sloping areas, interceptor drains should be provided to keep moisture from moving beneath the roads.

The steep banks that result from shaping this soil for use as building sites are highly erodible. They should be seeded to a fast-growing cover as soon as possible to reduce the hazard of erosion. The use of straw mulch or jute netting helps to reduce the erosion hazard during establishment of the grass cover. If runoff from higher areas is a problem, diversions at the head of these slopes may be needed.

The water intake rate and permeability are slow, therefore, lawns should be watered slowly so that the amount of water lost as runoff is reduced. Shrubs and trees can be drip irrigated to encourage deep rooting. Lawn grasses grow best if about 1 pound of elemental nitrogen per 1,000 square feet is applied every 8 weeks, from April through October. Some ornamental plants respond to sulfur and to iron and aluminum chelates. The addition of organic matter to the soil can improve the rate of water intake, aeration, and soil tilth.

Capability unit IIIe-5(15), nonirrigated.

101—Altamont clay, 15 to 30 percent slopes. This is a deep, well drained soil that formed in material that weathered from shale and fine-grained sandstone or from soft conglomerate. This soil is on the foothills near Mission San Jose. Elevation ranges from 200 to 1,000 feet. The average annual precipitation is 16 inches, and the mean annual temperature is 57 degrees F. The average frost-free season ranges from 300 to 320 days.

Typically, the surface layer is dark brown and brown, slightly acid to moderately alkaline clay about 28 inches thick. The next layer is finely mixed dark brown and dark yellowish brown, calcareous clay about 9 inches thick. The underlying material is yellowish brown, calcareous clay and extends to a depth of 50 inches. It is underlain by highly fractured and weathered, fine-grained sandstone and shale.

Included in mapping are small areas of grayish brown, moderately alkaline clay that is 20 to 40 inches deep to sedimentary rock. Also included are small areas of Climara clay and Rincon clay loam.

Permeability is slow. The available water capacity is 5.0 to 9.5 inches. The root zone is 40 to 60 inches deep. Runoff is rapid, and the hazard of erosion is moderate to high.

Most areas of this soil are in natural vegetation. These areas are commonly left idle and are only of esthetic value. The existing vegetation needs to be protected from fire and other destructive forces.

This soil has limitations for use as building sites. The shrink-swell potential is high; as a result, foundations can shift and crack. Building pads should be shaped to provide drainage away from the building site, thus keeping the soil beneath the foundation dry and reducing the hazards of differential settlement and shrink-swell. The high shrink-swell potential and low strength affect the construction of roads and streets. Suitable base material is needed. In sloping areas, interceptor drains should be provided to keep moisture from moving beneath the roads.

The steep banks that result from shaping this soil for use as building sites are highly erodible. They should be seeded to a fast-growing cover as soon as possible to reduce the hazard of erosion. The use of straw mulch or jute netting helps to reduce the erosion hazard during establishment of the cover. If runoff from higher areas is a problem, diversions may be needed at the head of these slopes.

The water intake rate and permeability are slow, therefore, lawns should be watered slowly to reduce runoff. Shrubs and trees can be drip irrigated to encourage deep rooting. Lawn grasses grow best if about 1 pound of elemental nitrogen per 1,000 square feet is applied every 8 weeks, from April through October. Some ornamental plants respond to sulfur and to iron and aluminum chelates. The addition of organic matter to the soil can improve the rate of water intake, aeration, and soil tilth.

Capability unit IVe-5(15), nonirrigated.

102—Altamont clay, 30 to 50 percent slopes. This is a deep, well drained soil that formed in material weathered from interbedded soft shale and fine-grained sandstone or from soft conglomerate. This soil is on foothills at an elevation of 200 to 1,000 feet. The average annual precipitation is 16 inches, and the mean annual temperature is 57 degrees F. The average frost-free season ranges from 300 to 320 days.

Typically, the surface layer is dark brown and brown, slightly acid to mildly alkaline clay about 28 inches thick. The next layer is finely mixed dark brown and dark yel-

lowish brown, calcareous clay about 9 inches thick. The underlying material is yellowish brown, calcareous clay and extends to a depth of 50 inches. It is underlain by highly fractured and weathered fine-grained sandstone and shale.

Included in mapping are small areas of grayish brown, moderately alkaline clay that is 20 to 40 inches deep to sedimentary rock. Also included are small areas of Climara clay, Rincon clay loam, and landslips.

Permeability is slow. The available water capacity is 5.0 to 9.5 inches. The root zone is 40 to 60 inches deep. Runoff is rapid, and the hazard of erosion is high.

Most areas of this soil are in natural vegetation. These areas are commonly left idle and are only of esthetic value. The existing vegetation needs to be protected from fires and other destructive forces.

In a few small areas, this soil is used for urban development.

This soil has many limitations for use as building sites. The shrink-swell potential is high; as a result, foundations can shift and crack. Building pads should be shaped to provide drainage away from the building site, thus keeping the soil beneath the foundation dry and reducing the hazards of differential settlement and shrink-swell. The high shrink-swell potential and low strength affect the construction of roads and streets. Solid base material is needed. In sloping areas, interceptor drains should be provided to keep moisture from moving beneath the roads.

The steep banks that result from shaping this soil for use as building sites are highly erodible. Retaining walls may be needed in addition to a fast-growing vegetative cover to reduce the hazards of erosion. The use of straw mulch or jute netting helps to reduce the hazard of erosion during establishment of the cover. If runoff from higher areas is a problem, diversions may be needed at the head of these slopes.

The water intake rate and permeability are slow; therefore, lawns should be watered slowly to reduce runoff. Lawn grasses grow best if about 1 pound of elemental nitrogen per 1,000 square feet is applied every 8 weeks, from April through October. Shrubs and trees can be drip irrigated to encourage deep rooting. Some ornamental plants respond to sulfur and to iron and aluminum chelates. Adding organic matter to the soil can improve the rate of water intake, aeration, and soil tilth.

Capability subclass VIe(15), nonirrigated.

103—Azule clay loam, 9 to 30 percent slopes. This is a moderately deep, well drained soil that formed in material that weathered from consolidated alluvial sediment, soft shale, or fine-grained sandstone. This soil is on foothills. Elevation ranges from 100 to 500 feet. The average annual precipitation is 20 inches, and the mean annual temperature is 57 degrees F. The average frost-free season ranges from 300 to 320 days.

Typically, the surface layer is grayish brown, slightly acid clay loam about 6 inches thick. The subsoil extends to a depth of 25 inches. It is grayish brown and dark grayish brown, slightly acid clay that grades to grayish brown and light yellowish brown, slightly acid clay. It is underlain by light yellowish brown consolidated alluvial sediment.

Included in mapping are small areas of Los Osos silty clay loam and Tierra loam.

Permeability is slow. The available water capacity is 3.5 to 7.0 inches. The root zone is 24 to 40 inches deep. Runoff is medium to rapid. The hazard of erosion is moderate to high.

This soil is used mainly as sites for houses. In some areas it is used for grazing.

The natural vegetation should be protected from fire. If the areas in natural vegetation are used as rangeland, they should not be grazed before the grasses are 4 to 6 inches high, and enough residue should be left on the surface after the grazing season to reduce the hazard of erosion and help prevent weed infestation.

This soil has many limitations for use as building sites. The shrink-swell potential is high; as a result, foundations can shift and crack. Building pads should be shaped to provide drainage away from the building site, thus keeping the soil beneath the foundation dry and reducing the hazards of differential settlement and shrink-swell. The high shrink-swell potential and low strength affect the construction of roads and streets. Suitable base material is needed. In sloping areas, interceptor drains should be provided to keep moisture from moving beneath the roads.

The steep banks that result from shaping this soil for use as building sites are highly erodible. They should be seeded to a fast-growing cover as soon as possible to reduce the hazard of erosion. The use of straw mulch or jute netting helps to reduce the hazard of erosion during establishment of the cover. If runoff from higher areas is a problem, diversions may be needed at the head of these slopes.

Since the water intake rate and permeability are slow, lawns should be watered slowly to reduce runoff. Shrubs and trees can be drip irrigated to encourage deep rooting. Lawn grasses grow best if 1 pound of elemental nitrogen per 1,000 square feet is applied every 8 weeks, from April through October. Some ornamental plants respond to sulfur and to iron and aluminum chelates. Adding organic matter to the soil can improve the rate of water intake, aeration, and soil tilth.

Capability unit IVe-3(15), nonirrigated.

104—Azule clay loam, 30 to 50 percent slopes. This is a moderately deep, well drained soil that formed in material that weathered from consolidated alluvial sediment, soft shale, or fine-grained sandstone. The average annual precipitation is 20 inches, and the mean annual

temperature is 57 degrees F. The average frost-free season ranges from 300 to 320 days.

Typically, the surface layer is grayish brown, slightly acid clay loam about 6 inches thick. The subsoil extends to a depth of 25 inches. It is grayish brown and dark grayish brown, slightly acid clay that grades to grayish brown and light yellowish brown, slightly acid clay. It is underlain by light yellowish brown consolidated alluvial sediment.

Included in mapping are small areas of Los Osos silty clay loam and Los Gatos loam.

Permeability is slow. The available water capacity is 3.5 to 7.0 inches. The root zone is 24 to 40 inches deep. Runoff is rapid, and the hazard of erosion is high.

This soil is used mainly as sites for houses. In some areas it is used for grazing.

The natural vegetation should be protected from fire. If the areas in natural vegetation are used for grazing, they should not be grazed before grasses are 4 to 6 inches high, and enough residue should be left on the surface after the grazing season to reduce the hazard of erosion and to help prevent weed infestation.

This soil has many limitations for use as building sites. The shrink-swell potential is high; as a result, foundations can shift and crack. Building pads should be shaped to provide drainage away from the building site, thus keeping soil beneath the foundation dry and reducing the hazards of differential settlement and shrink-swell. The high shrink-swell potential and low strength also affect the construction of roads and streets. Suitable base material is needed. In sloping areas, interceptor drains should be provided to keep moisture from moving beneath the roads.

The steep banks that result from shaping this soil for use as building sites are highly erodible. Supporting walls are often needed to hold fill material in place. The banks should be seeded to a fast-growing cover as soon as possible to reduce the hazard of erosion. The use of straw mulch or jute netting helps to reduce the hazard of erosion during establishment of the cover. If runoff from higher areas is a problem, diversions may be needed at the head of these slopes.

Since the water intake rate and permeability are slow, lawns should be watered slowly to reduce runoff. Shrubs and trees can be drip irrigated to encourage deep rooting. Lawn grasses grow best if 1 pound of elemental nitrogen per 1,000 square feet is applied every 8 weeks, from April through October. Some ornamental plants respond to sulfur and to iron and aluminum chelates. Adding organic matter to the soil can improve the rate of water intake, aeration, and soil tilth.

Capability subclass VIe(15), nonirrigated.

105—Baywood Variant, sand. This is a very deep, somewhat poorly drained soil that formed in sandy sediment on old coastal plains. Elevation ranges from 5 to 15 feet. The slopes are less than 2 percent. The average annual precipitation is 17 inches, and the mean annual temperature is 57 degrees F. The average frost-free season ranges from 300 to 330 days.

Typically, the upper part of the surface layer is dark grayish brown, mildly alkaline sand about 14 inches thick. The lower part is mottled, very dark grayish brown, mildly alkaline sand about 7 inches thick. The underlying material is mottled, brown, neutral sand to a depth of 32 inches. Below that it is yellowish brown, neutral sand that extends to a depth of 60 inches or more.

Included in mapping are small areas of Xeropsamments, fill, and Baywood loamy sand.

Permeability is rapid. The available water capacity is 3 to 5 inches. The root zone for water-tolerant plants is 60 inches deep. The water table restricts the root zone for water-sensitive plants to a depth of 40 or 50 inches. Runoff is very slow. Soil blowing is a hazard if the soil is left bare.

In most areas this soil is used for urban development. A few areas are farmed.

The water table limits the use of this soil for urban development. This limitation can be overcome by installing drainage systems or by designing buildings and streets to overcome the wetness problem.

Because of the low available water capacity and rapid permeability, plants used in landscaping should be watered lightly and frequently. Plants respond to nitrogen and to iron and aluminum chelates.

Farmed areas are double cropped. A common cropping sequence includes head lettuce in summer and cauliflower in winter. Nitrogen and phosphorus are needed for maximum yields. Irrigation water should be applied frequently and in light amounts to prevent the leaching of nutrients and the elevation of the water table.

Capability unit IIIw-4(14), nonirrigated and irrigated.

106—Botella loam, 0 to 2 percent slopes. This is a very deep, well drained soil on low terraces and alluvial fans. This soil formed in alluvium that derived from sedimentary rock. Elevation ranges from 10 to 200 feet. The average annual precipitation is 17 inches, and the mean annual temperature is 57 degrees F. The average frost-free season ranges from 300 to 320 days.

Typically, the surface layer is grayish brown, neutral loam about 9 inches thick. The subsoil extends to a depth of 33 inches. It is dark grayish brown and dark brown, neutral, light clay loam. The substratum is brown and yellowish brown, mildly alkaline to moderately alkaline silt loam and extends to a depth of 60 inches or more.

Included in mapping are small areas of Danville silty clay loam, Omni silty clay loam, drained, and Yolo silt loam.

Permeability is moderately slow. The available water capacity is 9 to 11 inches. The root zone is more than 60 inches deep. Surface runoff is slow, and the hazard of erosion is slight.

In most areas this soil is used for urban development. In some areas it is used for vegetable crops.

This soil has some limitations for urban development. Because of low strength and the moderate shrink-swell potential, foundations for houses and roads need to be specially designed. Building pads should be shaped to provide drainage away from the building site, thus keeping the soil beneath the building dry and reducing the hazard of differential settlement.

Most plants used for landscaping do well on this soil and will respond to nitrogen and phosphate fertilizer. For maximum growth, lawns need 1 pound of elemental nitrogen per 1,000 square feet every 8 weeks, from April through October. Irrigation water should be applied at a slow rate to encourage deep rooting. Shrubs and trees should be drip irrigated to encourage deep rooting.

Head lettuce and cauliflower are the major crops. They are double cropped using head lettuce in summer and cauliflower in winter. In a few areas, tomatoes are grown instead of head lettuce. Returning crop residue to the soil helps to maintain tilth and improve the rate of water intake. Minimum tillage reduces soil compaction. Water should be applied only in the amount that meets the needs of the crop; over-irrigation wastes water and leaches nutrients from the soil. Nitrogen is needed for good crop growth. The average yield per acre of head lettuce is 550 cartons; cauliflower, 460 cartons; and tomatoes, 25 tons.

Capability unit IIIc-1(14), nonirrigated; capability class I(14), irrigated.

107—Clear Lake clay, 0 to 2 percent slopes, drained. This is a very deep, poorly drained soil that formed in alluvium in basins. Elevation ranges from 10 to 200 feet. The average annual precipitation is 17 inches, and the mean annual temperature is 57 degrees F. The average frost-free season ranges from 300 to 330 days.

Typically, the surface layer is very dark gray, neutral and moderately alkaline clay about 37 inches thick. The underlying material is calcareous, dark gray and grayish brown clay and silty clay to a depth of 60 inches or more.

Included in mapping are small areas of Omni silty clay loam, drained; Willows clay, drained; and Pescadero clay, drained.

Permeability is slow. The available water capacity is 7.0 to 9.5 inches. The root zone for water-tolerant plants is 60 or more inches deep, but it is restricted to a depth of 48 to 60 inches for water-sensitive plants. Drainage has been improved by reclamation and flood control structures, and the water table is now at a depth of 48 to 60 inches. Runoff is slow, and there is no hazard of erosion.

This soil is used for urban development. A few areas are used as dryland pasture and for volunteer hay.

This soil has limitations that must be overcome before construction is feasible. The shrink-swell potential is high; as a result, foundations can shift and crack. Building pads should be shaped to provide drainage away from the building site, thus keeping the soil beneath the foundation dry and reducing the hazards of differential settlement and shrink-swell. The high shrink-swell potential and low strength affect the construction of roads and streets. Suitable base material is needed. The slow permeability and the high water table are limitations for septic tank absorption fields and can contribute to failure of septic systems.

Since the water intake rate and permeability are slow, lawns should be watered slowly to reduce runoff. Lawn grasses grow best if 1 pound of elemental nitrogen per 1,000 square feet is applied every 8 weeks, from April through October. Shrubs and trees can be drip irrigated to encourage deep rooting. Plants that require good drainage and aeration should not be planted. Some ornamental plants respond to sulfur and to iron and aluminum chelates. Adding organic matter to the soil improves the rate of water intake, aeration, and soil tilth.

If areas of this soil are used as pasture, grazing should be delayed until the grasses are 4 to 6 inches high and until the soil is dry. If this soil is grazed when wet, it is subject to churning and puddling. Enough residue should be left on the surface after the grazing season to prevent deterioration of the soil and to prevent the infestation of weeds.

Capability unit IIIs-5(14), nonirrigated; IIs-5(14), irrigated.

108—Clear Lake clay, 2 to 9 percent slopes, drained. This is a very deep, poorly drained soil that formed in alluvium. Elevation ranges from 10 to 200 feet. The average annual precipitation is 17 inches, and the mean annual temperature is 57 degrees F. The average frost-free season ranges from 300 to 320 days.

Typically, the surface layer is very dark gray, neutral to moderately alkaline clay about 37 inches thick. The underlying material is dark gray and grayish brown, calcareous clay and silty clay to a depth of 60 inches or more.

Included in mapping are small areas of Danville silty clay loam, Omni silty clay loam, drained, and Rincon clay loam.

Permeability is slow. The available water capacity is 7.0 to 9.5 inches. Drainage has been improved by flood control structures and natural stream cutting. The root zone is more than 60 inches deep. The water table is below a depth of 60 inches. Runoff is medium, and the hazard of erosion is slight to moderate.

This soil is used primarily for urban development. A few areas are used as dryland pasture and for volunteer hay.

This soil has many limitations for use as building sites. The shrink-swell potential is high; as a result, foundations can shift and crack. Building pads should be shaped so that water is drained away from the building site, thus keeping the soil beneath the foundation dry

and reducing the hazards of differential settlement and shrink-swell. The high shrink-swell potential and low strength affect the construction of roads and streets. Suitable base material is needed. In sloping areas, interceptor drains should be provided to keep moisture from moving beneath the roads. Revegetation is needed to control erosion if this soil is disturbed during construction.

Since the water intake rate and permeability are slow, lawns should be watered slowly to reduce runoff. Shrubs and trees can be drip irrigated to encourage deep rooting. Lawn grasses grow best if 1 pound of elemental nitrogen per 1,000 square feet is applied every 8 weeks, from April through October. Some ornamental plants respond to sulfur and to iron and aluminum chelates. Adding organic matter to the soil can improve the rate of water intake, aeration, and soil tilth.

If areas of this soil are used as pasture, the soil should not be grazed before grasses are 4 to 6 inches high, and enough residue should be left on the surface after the grazing season to reduce weed infestation and the hazard of erosion.

Capability unit IIIe-5(14), nonirrigated; IIe-5(14), irrigated.

109—Climara clay, 30 to 50 percent slopes. This is a moderately deep, well drained soil that formed in material that weathered from ultrabasic rock on uplands. Elevation ranges from 100 to 750 feet. The average annual precipitation is 20 inches, and the mean annual temperature is 57 degrees F. The average frost-free season ranges from 300 to 310 days.

Typically, the surface layer is black, neutral and mildly alkaline clay 27 inches thick. The underlying material is variegated very dark brown, olive brown, and olive, moderately alkaline, calcareous clay to a depth of 33 inches. Below that, there is soft, weathered ultrabasic rock. Hard ultrabasic rock is at a depth of 40 inches.

Included in mapping are small areas of Altamont clay, Diablo clay, and Montara clay loam. Also included are small areas of a dark grayish brown clay that is 20 to 40 inches deep to bedrock and a few areas that have bedrock outcrops or landslips.

Permeability is slow. The available water capacity is 2.5 to 6.0 inches. The root zone is 20 to 40 inches deep. Runoff is rapid, and the hazard of erosion is high.

This soil is used primarily for urban development. Some small areas are used for grazing and for recreation. They should be protected from fire, excessive foot traffic, and overgrazing to reduce erosion and sedimentation.

This soil has many limitations for use as building sites. The shrink-swell potential is high; as a result, foundations can shift and crack. Building pads should be shaped so that water is drained away from the building site, thus helping to keep the soil beneath the foundation dry and reducing the hazards of differential settlement and shrink-swell. The high shrink-swell potential and low strength affect the construction of roads and streets. Suitable base material is needed. In sloping areas, interceptor drains should be provided to keep moisture from beneath the roads.

The steep banks that result from shaping this soil for use as building sites are highly erodible. Walls generally are needed to hold fill material in place. Exposed areas should be seeded to a fast-growing cover as soon as possible to reduce the hazard of erosion. The use of straw mulch or jute netting helps to reduce the hazard of erosion during establishment of the cover. If runoff from higher areas is a problem, diversions may be needed at the head of these slopes.

Since the water intake rate and permeability are slow, lawns should be watered slowly to reduce runoff. Shrubs and trees can be drip irrigated to encourage deep rooting. Lawn grasses grow best if 1 pound of elemental nitrogen per 1,000 square feet is applied every 8 weeks, from April through October. Some ornamental plants respond to sulfur and to iron and aluminum chelates. Adding organic matter to the soil can improve the rate of water intake, aeration, and soil tilth.

Capability subclass VIe(15), nonirrigated.

110—Contra Costa clay loam, 30 to 50 percent slopes. This is a moderately deep, well drained soil that formed in material that weathered from metabasic and metasedimentary rock. This soil is in the Coyote Hills. Elevation ranges from 5 to 290 feet. The average annual precipitation is 15 inches, and the mean annual temperature is 57 degrees F. The average frost-free season ranges from 300 to 320 days.

Typically, the surface layer is brown, neutral clay loam about 24 inches thick. The subsoil extends to a depth of 35 inches. It is reddish brown, neutral heavy clay loam in the upper part and yellowish red, neutral gravelly clay in the lower part. Fractured, partly weathered, metasedimentary rock is at a depth of 35 inches.

Included in mapping are small areas of Vallecitos gravelly loam; a few areas of a moderately deep, dark reddish brown clay loam; and a few areas of soils that are more than 35 percent angular pebbles.

Permeability is slow. The available water capacity is 3.0 to 7.5 inches. The root zone is 20 to 40 inches deep. Runoff is rapid, and the hazard of erosion is high.

This soil is used for recreation. It is in natural vegetation. The vegetation needs to be protected from fire and excessive foot traffic to reduce the hazard of erosion and to maintain its scenic value. Trails are difficult to build because of the steep slope and the clay loam surface texture. They should be constructed across the slope or along ridges to reduce the hazard of erosion.

This soil is poorly suited to use as septic tank filter fields because of the steep slope, the depth to bedrock, and the slow permeability of the subsoil.

Capability subclass VIe(15), nonirrigated.

111—Danville silty clay loam, 0 to 2 percent slopes. This is a very deep, well drained soil that formed on low terraces in alluvium that derived mainly from sedimentary rock. Elevation ranges from 20 to 300 feet. The average annual precipitation is 17 inches, and the mean annual temperature is 57 degrees F. The average frost-free season ranges from 300 to 320 days.

Typically, the surface layer is grayish brown and dark gray, slightly acid silty clay loam about 21 inches thick. The subsoil extends to a depth of 61 inches. It is grayish brown, slightly acid silty clay and heavy silty clay loam. The substratum is grayish brown, neutral silty clay loam and extends to a depth of more than 60 inches.

Included in mapping are small areas of Botella loam; Clear Lake clay, drained; and Rincon clay loam.

Permeability is slow. The available water capacity is 8.5 to 10.5 inches. The root zone is more than 60 inches deep. Runoff is slow, and there is no hazard of erosion.

This soil is used for urban development. In a few areas it is used for grain and vegetable crops.

This soil has certain limitations that must be overcome before the construction of buildings is feasible. The shrink-swell potential is high; as a result, foundations can shift and crack. Building pads should be shaped so that water is drained away from the building site, thus keeping the soil beneath the foundation dry and reducing the hazards of differential settlement and shrink-swell. The high shrink-swell potential and low strength affect the construction of roads and streets. Suitable base material is needed. In sloping areas, interceptor drains should be provided to keep moisture from beneath the roads. Structural measures for erosion control may be needed.

The water intake rate and permeability are slow; therefore, lawns should be watered slowly to reduce runoff. Shrubs and trees can be drip irrigated to encourage deep rooting. Lawn grasses grow best if 1 pound of elemental nitrogen per 1,000 square feet is applied every 8 weeks, from April through October. Adding organic matter to the soil can improve the rate of water intake, aeration, and soil tilth.

Capability unit IIIs-3(14), nonirrigated; IIs-3(14), irrigated.

112—Danville silty clay loam, 2 to 9 percent slopes. This is a very deep, well drained soil that formed in alluvium that derived mainly from sedimentary rock. It is on low terraces and alluvial fans. Elevation ranges from 20 to 300 feet. The average annual precipitation is 17 inches, and the mean annual temperature is 57 degrees F. The frost-free season ranges from 300 to 320 days.

Typically, the surface layer is grayish brown and dark gray, slightly acid silty clay loam about 21 inches thick. The subsoil extends to a depth of 61 inches. It is grayish brown, slightly acid silty clay and heavy silty clay loam. The substratum is grayish brown, neutral silty clay loam and extends to a depth of more than 60 inches.

Included in mapping are small areas of Botella loam, Tierra loam, and Rincon clay loam.

Permeability is slow. The available water capacity is 8.5 to 10.5 inches. The root zone is more than 60 inches deep. Runoff is slow to medium, and the hazard of erosion is slight to moderate.

This soil is used for urban development; however, certain limitations must be overcome before buildings can be constructed. The shrink-swell potential is high; as a result, foundations can shift and crack. Building pads should be shaped so that water is drained away from the building site, thus keeping the soil beneath the foundation dry and reducing the hazards of differential settlement and shrink-swell. The high shrink-swell potential and low strength affect the construction of roads and streets. Suitable base material is needed. In sloping areas, interceptor drains should be provided to keep moisture from beneath the roads. If this moderately sloping soil is disturbed during construction, it may need to be revegetated to control erosion.

The water intake rate and permeability are slow; therefore, lawns should be watered slowly to reduce runoff. Shrubs and trees can be drip irrigated to encourage deep rooting. Lawn grasses grow best if 1 pound of elemental nitrogen per 1,000 square feet is applied every 8 weeks, from April through October. Adding organic matter to the soil can improve the rate of water intake, aeration, and soil tilth.

Capability unit IIIe-3(14), nonirrigated; IIe-3(14), irrigated.

113—Diablo clay, 9 to 15 percent slopes. This is a deep, well drained soil that formed in material that weathered from soft, fine-grained sandstone or shale. Elevation ranges from 200 to 800 feet. The average annual precipitation is 16 inches, and the mean annual temperature is 57 degrees F. The frost-free season is 300 to 320 days.

Typically, the upper part of the surface layer is dark gray, neutral and mildly alkaline clay and silty clay about 15 inches thick. The lower part is variegated gray and olive gray, mildly alkaline silty clay about 17 inches thick. The next layer is light olive gray, mildly alkaline silty clay about 10 inches thick. The underlying material is variegated light olive gray and olive gray, moderately alkaline silty clay loam to a depth of 50 inches. Below that is calcareous shale.

Included in mapping are small areas of Altamont clay and Clear Lake clay, drained.

Permeability is slow. The available water capacity is 5.5 to 11.0 inches. The root zone is 40 to 60 inches deep. Runoff is medium, and the hazard of erosion is moderate.

In most areas this soil is in natural vegetation. Some of these areas are grazed. A few are used for urban development.

The vegetation should be protected from fire and other destructive forces. If this soil is exposed, it is subject to erosion, and sedimentation is a hazard. Grasses should be 4 to 6 inches high before they are grazed in fall, and enough residue should be left on the surface after the grazing season to reduce the hazard of erosion.

This soil has many limitations for use as building sites. The shrink-swell potential is high; as a result, foundations can shift and crack. Building pads should be shaped so that water is drained away from the building site, thus keeping the soil beneath the foundation dry and reducing the hazards of differential settlement and shrink-swell. The high shrink-swell potential and low strength affect the construction of roads and streets. Suitable base material is needed. In sloping areas, interceptor drains should be provided to keep moisture from beneath the roads.

The steep banks that result from shaping this soil for use as building sites are highly erodible. They should be seeded to a fast-growing cover as soon as possible to reduce the hazard of erosion. The use of straw mulch or jute netting helps to reduce the hazard of erosion during establishment of the cover. If runoff from higher areas is a problem, diversions may be needed at the head of these slopes.

The water intake rate and permeability are slow; therefore, lawns should be watered slowly to reduce runoff. Shrubs and trees can be drip irrigated to encourage deep rooting. Lawn grasses grow best if 1 pound of elemental nitrogen per 1,000 square feet is applied every 8 weeks, from April through October. Some ornamental plants respond to sulfur and to iron and aluminum chelates. Adding organic matter to the soil can improve the rate of water intake, aeration, and soil tilth.

Capability unit IIIe-5(15), nonirrigated.

114—Diablo clay, 15 to 30 percent slopes. This is a deep, well drained soil that formed in material that weathered from soft, fine-grained sandstone or shale. Elevation ranges from 200 to 800 feet. The average annual precipitation is 16 inches, and the mean annual temperature is 57 degrees F. The average frost-free season ranges from 300 to 320 days.

Typically, the upper part of the surface layer is dark gray, neutral and mildly alkaline clay and silty clay about 15 inches thick. The lower part is variegated gray and olive gray, mildly alkaline silty clay about 17 inches thick. The next layer is light olive gray, mildly alkaline silty clay about 10 inches thick. The underlying material is variegated light olive gray and olive gray, moderately alkaline silty clay loam and extends to a depth of 50 inches. Below that is calcareous shale.

Included in mapping are small ares of Altamont clay and Clear Lake clay, drained.

Permeability is slow. The available water capacity is 5.5 to 11.0 inches. The root zone is 40 to 60 inches deep. Runoff is rapid, and the hazard of erosion is moderate to high.

In most areas this soil is used as sites for houses. Some areas are in natural vegetation.

To reduce the hazard of erosion and to maintain its scenic value, the existing vegetation should be protected from fire and other destructive forces.

This soil has many limitations for use as building sites. The shrink-swell potential is high; as a result, foundations can shift and crack. Building pads should be shaped so that water is drained away from the building site, thus keeping the soil beneath the foundation dry and reducing the hazards of differential settlement and shrink-swell. The high shrink-swell potential and low strength affect the construction of roads and streets. Walls may be needed to stabilize fill areas on the steepest slopes. Suitable base material is needed. On sloping areas, interceptor drains should be provided to keep moisture from beneath the roads.

The steep banks that result from shaping this soil for use as building sites are highly erodible. They should be seeded to a fast-growing cover as soon as possible to reduce the hazard of erosion. Using straw mulch or jute netting helps to reduce the erosion hazard during establishment of the cover. If runoff from higher areas is a problem, diversions may be needed at the head of these slopes.

The water intake rate and permeability are slow; therefore, lawns should be watered slowly to reduce runoff. Shrubs and trees can be drip irrigated to encourage deep rooting. Lawn grasses grow best if 1 pound of elemental nitrogen per 1,000 square feet is applied every 8 weeks, from April through October. Some ornamental plants respond to sulfur and to iron and aluminum chelates. Adding organic matter to the soil can improve the rate of water intake, aeration, and soil tilth.

Capability unit IVe-5(15), nonirrigated.

115—Diablo clay, 30 to 50 percent slopes. This is a deep, well drained soil that formed in material that weathered from fine-grained sandstone or shale in the foothills near Mission San Jose. It is at an elevation of 200 to 800 feet. The average annual precipitation is 17 inches, and the mean annual temperature is 57 degrees F. The average frost-free season is 300 to 320 days.

Typically, the upper part of the surface layer is dark gray, neutral and mildly alkaline clay and silty clay about 15 inches thick. The lower part is variegated gray and olive gray, mildly alkaline clay about 17 inches thick. The next layer is light olive gray, mildly alkaline silty clay about 10 inches thick. The underlying material is variegated light olive gray and olive gray, moderately alkaline, calcareous silty clay loam to a depth of 50 inches. Below that is calcareous shale.

Included in mapping are small areas of Altamont clay, Climara clay, and a moderately deep, grayish brown, neutral clay loam.

Permeability is slow. The available water capacity is 5.5 to 11.0 inches. The root zone is 40 to 60 inches deep. Runoff is rapid, and the hazard of erosion is high.

In most areas this soil is used for low-density housing. Many areas are in natural vegetation and have esthetic value. The vegetation should be protected from fire and excessive foot traffic to reduce the hazard of erosion.

This soil has many limitations for use as building sites. The shrink-swell potential is high; as a result, foundations can shift and crack. Building pads should be shaped so that water is drained away from the building site, thus keeping the soil beneath the foundation dry and reducing the hazards of differential settlement and shrink-swell. The high shrink-swell potential and low strength affect the construction of roads and streets. Suitable base material is needed. In sloping areas, interceptor drains should be provided to keep moisture from beneath the roads.

The steep banks that result from shaping this soil for building sites are highly erodible. Walls may be required to stabilize fill areas created by leveling for construction. The banks should be seeded to a fast-growing cover as soon as possible to reduce the hazard of erosion. Using straw mulch or jute netting helps to reduce the hazard of erosion during establishment of the grass cover. If runoff from higher areas is a problem, diversions may be needed at the head of these slopes.

The water intake rate and permeability are slow; therefore, lawns should be watered slowly to reduce runoff. Shrubs and trees can be drip irrigated to encourage deep rooting. Lawn grasses grow best if 1 pound of elemental nitrogen per 1,000 square feet is applied every 8 weeks, from April through October. Adding organic matter to the soil can improve the rate of water intake, aeration, and soil tilth.

Capability subclass VIe(15), nonirrigated.

116—Gaviota-Rock outcrop complex, 15 to 50 percent slopes. This map unit consists of moderately steep to steep soils and Rock outcrop on uplands at an elevation of about 200 to 1,500 feet. The average annual precipitation is about 20 inches, and the mean annual temperature is 57 degrees F. The average frost-free season ranges from 300 to 320 days. Gaviota soils make up about 70 percent of the complex; Rock outcrop, 20 percent. Included in mapping and making up about 10 percent of the complex are small areas of Millsholm silt loam and Maymen loam.

Gaviota soils are shallow and well drained. They formed in material that weathered from sandstone. Typically, the surface layer is brown, slightly acid and medium acid sandy loam and extends to a depth of 11 inches; it is underlain by sandstone bedrock.

Permeability is moderately rapid. Runoff is rapid, and the hazard of erosion is high.

Rock outcrop is large sandstone boulders and exposed sandstone bedrock. Runoff is very rapid.

Areas of this complex are used for urban development and recreation. Sanitary facilities are difficult to establish because of the shallow depth to rock, steep slopes, and Rock outcrop. Gaviota soils are poorly suited to most recreation uses because of steep slopes. The number of paths and trails should be kept to a minimum. Those established should be across the slope to reduce the hazard of erosion. Natural vegetation should be protected from fire to maintain its scenic value and to reduce the hazard of erosion.

Landscaped areas should be irrigated lightly and frequently to prevent loss of water and to reduce the hazard of erosion. Most plants respond to nitrogen and phosphate fertilizer. Large trees and shrubs are susceptible to windthrow.

Capability subclass VIIe(15), nonirrigated.

117—Laugenour loam, drained. This is a very deep and poorly drained soil that formed in recent alluvium adjacent to streams. Elevation ranges from 5 to 40 feet. The slopes are 0 to 2 percent. The average annual precipitation is about 16 inches, and the mean annual temperature is 57 degrees F. The average frost-free season is 300 to 320 days.

Typically, the upper part of the surface layer is grayish brown, moderately alkaline loam 8 inches thick. The lower part is mottled, grayish brown, moderately alkaline fine sandy loam about 15 inches thick. The underlying material is mottled, olive gray, moderately alkaline light loam to a depth of 40 inches. Below that, it is grayish brown and yellow, moderately alkaline silty clay loam to a depth of 60 inches or more.

Included in mapping are small areas of Sycamore silt loam, drained; Omni silty clay loam, drained; and a few small areas of a soil that is similar to this Laugenour soil but is underlain by silty clay between depths of 24 and 40 inches.

Permeability is moderately rapid to a depth of 40 inches and moderately slow below that depth. The available water capacity is 8.0 to 9.5 inches. Drainage has been improved by flood control structures that have lowered the water table to a depth of 40 to 60 inches. The root zone is 60 inches deep for water-tolerant plants, but in some areas it is restricted to a depth of 40 inches for water-sensitive plants. Runoff is slow, and there is no hazard of erosion.

In nearly all areas, this soil is used for urban development. Most areas are protected from flooding by channels and levees. The water table precludes the use of septic tank filter fields in most areas of this soil.

Most of the plants used for landscaping respond to nitrogen and phosphate fertilizer. Adding organic matter to the soil can help to improve tillage and increase the rate of water intake. Lawn grasses require 1 pound of elemental nitrogen per 1,000 square feet every 8 weeks, between April and November.

Capability unit IIIw-2(14), nonirrigated; IIw-2(14), irrigated.

118—Los Gatos-Los Osos complex, 30 to 50 percent slopes. This complex consists of soils on uplands at an elevation of 400 to 1,500 feet. The average annual precipitation is 20 inches, and the mean annual temperature is 57 degrees F. The average frost-free season ranges from 300 to 320 days. This complex is about 50 percent Los Gatos loam, which is mainly on north-facing slopes, and 35 percent Los Osos silty clay loam, which is mainly on south-facing slopes. The components of this map unit are so intricately intermingled that it was not practical to map them separately at the scaled used.

Included in mapping and making up about 15 percent of this complex are Maymen loam and some outcrops of bedrock along the ridges. Also included in seep areas is a very strongly acid soil.

The Los Gatos soil is a moderately deep, well drained soil that formed in material weathered from sedimentary rock. Typically, the surface layer is brown, neutral loam about 11 inches thick. The subsoil is brown and reddish brown, neutral and slightly acid loam and heavy loam and extends to a depth of 40 inches. It is underlain by sandstone bedrock.

The Los Gatos soil has moderately slow permeability. The available water capacity is 3.5 to 8.0 inches. The root zone is 24 to 40 inches deep. Runoff is rapid, and the hazard of erosion is high.

The Los Osos soil is a moderately deep, well drained soil that formed in material that weathered from sedimentary rock. Typically, the surface layer is grayish brown, medium acid silty clay loam about 8 inches thick. The subsoil is dark grayish brown, slightly acid silty clay loam and extends to a depth of 30 inches. It is underlain by weathered shale.

Permeability of the Los Osos soil is slow. The available water capacity is 3.5 to 6.5 inches. The root zone is 24 to 40 inches deep. Runoff is rapid, and the hazard of erosion is high.

The soils in this complex are used mainly for urban development. The steep slopes and shallowness to bedrock are limitations to the use of these soils as homesites and for local streets. Fill areas may require supporting walls. Cutbanks should be mulched and seeded with a fast-growing cover as soon as possible to reduce the hazard of erosion. The shrink-swell potential of Los Osos soils is high, and that of Los Gatos soils is moderate. As a result, foundations can shift and crack. Building pads should be shaped so that water is drained away from the building site, thus keeping the soil beneath the foundation dry and reducing the hazards of differential settlement and shrink-swell. The shrink-swell potential and low strength affect the construction of roads and streets. Suitable base material is needed. In sloping areas, interceptor drains should be provided to keep moisture from beneath the roads.

Most of the plants used in landscaping respond to nitrogen and phosphate fertilizer. Drip irrigation is the best method for watering shrubs and trees because it helps to reduce runoff.

In some areas these soils are in natural vegetation. The vegetation has esthetic value and should be protected from fire and excessive foot traffic.

Capability subclass VIe(15), nonirrigated.

119—Los Gatos-Los Osos complex, 50 to 75 percent slopes. This complex consists of very steep soils on upland slopes at an elevation of 400 to 1,500 feet. The average annual precipitation is 20 to 25 inches, and the mean annual temperature is 57 degrees F. The average frost-free season ranges from 300 to 320 days. This complex is about 50 percent Los Gatos loam, which is mainly on north-facing slopes, and 35 percent Los Osos silty clay loam, which is mainly on south-facing slopes. The components of this map unit are so intricately intermingled that it was not practical to map them separately at the scale used.

Included in mapping and making up about 15 percent of this complex are small areas of Millsholm silt loam and Maymen loam and some bedrock outcrops along ridges. Also included in seep areas is a very strongly acid soil.

The Los Gatos soil is moderately deep and well drained. It formed in material that weathered from sedimentary rock. Typically, the surface layer is brown, neutral loam about 11 inches thick. The subsoil is brown and reddish brown, neutral and slightly acid loam and heavy loam and extends to a depth of 40 inches. It is underlain by sandstone bedrock.

The Los Gatos soil has moderately slow permeability. The available water capacity is 3.5 to 8.0 inches. The root zone is 24 to 40 inches deep. Runoff is very rapid, and the hazard of erosion is very high.

The Los Osos soil is moderately deep and well drained. It formed in material that weathered from sedimentary rock. Typically, the surface layer is grayish brown, medium acid silty clay loam about 8 inches thick. The subsoil extends to a depth of 30 inches. It is dark grayish brown, slightly acid silty clay loam and heavy silty clay loam. Below that is weathered shale.

Permeability of the Los Osos soil is slow. The available water capacity is 3.5 to 6.5 inches. The root zone is 24 to 40 inches deep. Runoff is very rapid, and the hazard of erosion is very high.

The soils in this complex are used for recreation. Much of this complex is in natural vegetation that consists of thick stands of oak, California bay, poison oak, laurel, madrone, and some patches of coyote brush. The understory consists of scattered grasses and forbs. To maintain the scenic value of the area, vegetation should be protected from fire. The dense vegetation provides good habitat for wildlife.

Capability subclass VIIe(15), nonirrigated.

120—Los Osos silty clay loam, 9 to 30 percent slopes. This is a moderately deep, well drained soil that formed in material that weathered from sedimentary rock. It is on uplands at an elevation of 400 to 1,500 feet. The average annual precipitation is 20 inches, and the mean annual temperature is 57 degrees F. The average frost-free season ranges from 300 to 320 days.

Typically, the surface layer is grayish brown, medium acid silty clay loam about 8 inches thick. The subsoil extends to a depth of 30 inches. It is dark grayish brown, slightly acid silty clay loam and heavy silty clay loam. It is underlain by weathered shale.

Included in mapping are small areas of Los Gatos loam, Altamont clay, Climara clay, and Montara clay loam.

Permeability is slow. The available water capacity is 3.5 to 6.5 inches. The root zone is 24 to 40 inches deep. Runoff is medium to rapid, and the hazard of erosion is moderate to high.

This Los Osos soil is used mainly for urban development and recreation. A few areas are used as range.

This soil has many limitations for use as building sites. The shrink-swell potential is high; as a result, foundations can shift and crack. Building pads should be shaped so that water is drained away from the building site, thus keeping the soil beneath the foundation dry and reducing the hazards of differential settlement and shrink-swell. The high shrink-swell potential and low strength affect the construction of roads and streets. Suitable base material is needed. In sloping areas, interceptor drains should be provided to keep moisture from beneath the roads.

The steep banks that result from shaping this soil for use as building sites are highly erodible. Walls may be required to stabilize fill areas. The steep areas should be seeded to a fast-growing cover as soon as possible to reduce the hazard of erosion. Using straw mulch or jute netting helps to reduce the hazard of erosion during establishment of the grass cover. If runoff from higher areas is a problem, diversions may be needed at the head of these slopes.

The water intake rate and permeability are slow; therefore, lawns should be watered slowly to reduce runoff. Shrubs and trees can be drip irrigated to encourage deep rooting. Lawn grasses grow best if 1 pound of elemental nitrogen per 1,000 square feet is applied every 8 weeks, from April through October. Adding organic matter to the soil can improve the rate of water intake, aeration, and soil tilth. The natural vegetation has scenic value and should be protected from fire. Paths and trails should be laid out across the slope to prevent erosion.

If this soil is used as range, the hazard of erosion and weed infestation need to be controlled. Grasses should be 4 to 6 inches high before they are grazed, and enough residue should be left on the surface after the grazing season.

Capability unit IVe-3(15), nonirrigated.

121—Los Osos silty clay loam, 30 to 50 percent slopes. This is a moderately deep, well drained soil that formed in material that weathered from sedimentary rock. It is on uplands at an elevation of 400 to 1,500 feet. The average annual precipitation is 20 inches, and the mean annual temperature is 57 degrees F. The average frost-free season is 300 to 320 days.

Typically, the surface layer is grayish brown, medium acid silty clay loam about 8 inches thick. The subsoil extends to a depth of 30 inches. It is dark grayish brown, slightly acid silty clay loam and heavy silty clay loam. It is underlain by weathered shale.

Included in mapping are small areas of Los Gatos loam and Millsholm silt loam.

Permeability is slow. The available water capacity is 3.5 to 6.5 inches. The root zone is 24 to 40 inches deep. Runoff is rapid, and the hazard of erosion is high.

This Los Osos soil is used as sites for houses and for recreation. Areas of natural vegetation provide esthetic value.

This soil has many limitations for use as building sites. The shrink-swell potential is high; as a result, foundations can shift and crack. Building pads should be shaped so that water is drained away from the building site, thus keeping the soil beneath the foundation dry and reducing the hazards of differential settlement and shrink-swell. The high shrink-swell potential and low strength affect the construction of roads and streets. Suitable base material is needed. In sloping areas, interceptor drains should be provided to keep moisture from beneath the roads.

The steep banks that result from shaping this soil for use as buildling sites are highly erodible. Walls may be required to stabilize fill areas. The steep areas should be seeded to a fast-growing cover as soon as possible to reduce the hazard of erosion. Using straw mulch or jute netting helps to reduce the hazard of erosion during establishment of the grass cover. If runoff from higher areas is a problem, diversions may be needed at the head of these slopes.

The water intake rate and permeability are slow; therefore, lawns should be watered slowly to reduce runoff. Shrubs and trees can be drip irrigated to encourage deep rooting. Lawn grasses grow best if 1 pound of elemental nitrogen per 1,000 square feet is applied every 8 weeks, from April through October. Adding organic matter to the soil can improve the rate of water intake, aeration, and soil tilth.

This soil can be used as a site for paths and trails; however, because the slopes are very steep, the paths and trails need to be constructed across the slope to reduce the hazard of erosion. The vegetation in these areas should be protected from fire.

Capability subclass VIe(15), nonirrigated.

122—Los Osos-Millsholm complex, 9 to 30 percent slopes. This complex consists of strongly sloping and

moderately steep soils on uplands. Elevation ranges from 300 to 1,500 feet. The average annual precipitation is 20 inches, and the mean annual temperature is 57 degrees F. The average frost-free season is 300 to 320 days. This complex is about 60 percent Los Osos silty clay loam and 30 percent Millsholm silt loam. The components of this map unit are so intricately intermingled that it was not practical to map them separately at the scale used. Included in mapping, and making up about 10 percent of this complex, are Los Gatos loam and a few small areas of Rock outcrop.

The Los Osos soil is moderately deep and well drained. It formed in material that weathered from sedimentary rock. This soil is on side slopes. Typically, the surface layer is grayish brown, medium acid silty clay loam about 8 inches thick. The subsoil extends to a depth of 30 inches. It is dark grayish brown, slightly acid silty clay loam and heavy silty clay loam. It is underlain by weathered shale.

Permeability of the Los Osos soil is slow. The available water capacity is 3.5 to 6.5 inches. The root zone is 24 to 40 inches deep. Runoff is medium to rapid, and the hazard of erosion is moderate to high.

The Millsholm soil is shallow and well drained. It formed in material that weathered from sedimentary rock. This soil is on ridges. Typically, the surface layer is grayish brown, medium acid silt loam about 7 inches thick. The subsoil extends to a depth of 20 inches. It is light olive brown, medium acid silt loam and is underlain by shale bedrock.

Permeability of the Millsholm soil is moderate. The available water capacity is 1.5 to 3.5 inches. The root zone is 10 to 20 inches deep. Runoff is medium to rapid, and the hazard of erosion is moderate to high.

These soils are used mainly for urban development or recreation. A few areas are grazed.

These soils have many limitations for use as building sites. The Los Osos soil is subject to slippage if it becomes wet, especially if slopes are altered and the natural grade is increased. The shrink-swell potential is high; as a result, foundations can shift and crack. Building pads should be shaped so that water is drained away from the building site, thus keeping the soil beneath the foundation dry and reducing the hazards of differential settlement and shrink-swell. The high shrink-swell potential and low strength affect the construction of roads and streets. Suitable base material is needed. In sloping areas, interceptor drains should be provided to keep moisture from beneath roads. Because the Millsholm soil is shallow to bedrock, installing buried utility lines is difficult.

The steep banks that result from shaping these soils for use as building sites are highly erodible. They should be seeded to a fast-growing cover as soon as possible to reduce the hazard of erosion. Using straw mulch or jute netting helps to reduce the hazard of erosion during establishment of the grass cover. If runoff from higher areas is a problem, diversions may be needed at the head of these slopes.

Because the available water capacity is low, lawns should be watered frequently and lightly to reduce runoff. Shrubs and trees can be drip irrigated to encourage deeper rooting. Lawn grasses grow best if 1 pound of elemental nitrogen per 1,000 square feet is applied every 8 weeks, from April through October. Adding organic matter to the soil can improve the rate of water intake, aeration, and soil tilth.

If the soils in this complex are used for recreation, the best use is paths and trails, which should be constructed across the slope to reduce the hazard of erosion. Natural vegetation should be protected from fire and excessive foot traffic to control erosion and maintain the esthetic value of the site.

Capability unit IVe-3(15), nonirrigated.

123—Los Osos-Millsholm complex, 30 to 50 percent slopes. This complex consists of steep soils on uplands at an elevation between 300 and 1,500 feet. The average annual precipitation is 20 inches, and the mean annual temperature is 57 degrees F. The average frost-free season ranges from 300 to 320 days. This complex is about 60 percent Los Osos silty clay loam and 30 percent Millsholm silt loam. The components of this map unit are so intricately intermingled that it was not practical to map them separately at the scale used. Included in mapping, and making up about 10 percent of this map unit, are Los Gatos loam and a few small areas of Rock outcrop.

The Los Osos soil is moderately deep and well drained. It formed in material that weathered from sedimentary rock. This soil is on side slopes. Typically, the surface layer is grayish brown, medium acid silty clay loam about 8 inches thick. The subsoil extends to a depth of 30 inches. It is dark grayish brown, slightly acid silty clay loam and heavy silty clay loam. It is underlain by weathered shale.

Permeability of the Los Osos soil is slow. The available water capacity is 3.5 to 6.5 inches. The root zone is 24 to 40 inches deep. Runoff is rapid, and the hazard of erosion is high.

The Millsholm soil is shallow and well drained. It formed in material that weathered from sedimentary rock. This soil is on ridges. Typically, the surface layer is grayish brown, medium acid silt loam about 7 inches thick. The subsoil extends to a depth of 20 inches. It is light olive brown, medium acid silt loam. It is underlain by shale bedrock.

Permeability of the Millsholm soil is moderate. The available water capacity is 1.5 to 3.5 inches. The root zone is 10 to 20 inches deep. Runoff is rapid, and the hazard of erosion is high.

These soils are used mainly for urban development and recreation. In a few areas they are used as range.

These soils have many limitations for use as building sites. The Los Osos soil is subject to slippage if it is wet, especially if slopes have been altered and the natural grade has been increased. The shrink-swell potential is high; as a result, foundations can shift and crack. Building pads should be shaped so that water is drained away from the building site, thus keeping the soil beneath the foundation dry and reducing the hazards of differential settlement and shrink-swell. The high shrink-swell potential and low strength affect the construction of roads and streets. Suitable base material is needed. In sloping areas, interceptor drains should be provided to keep moisture from beneath the roads. Because the Millsholm soil is shallow to bedrock, installing buried utility lines is difficult.

The steep banks that result from shaping these soils for use as building sites are highly erodible. They should be seeded to a fast-growing cover as soon as possible to reduce the hazard of erosion. Using straw mulch or jute netting helps to reduce the hazard of erosion during establishment of the grass cover. If runoff from higher areas is a problem, diversions may be needed at the head of these slopes.

Because the available water capacity is low, lawns should be watered frequently and lightly to reduce runoff. Shrubs and trees can be drip irrigated to encourage deeper rooting. Lawn grasses grow best if 1 pound of elemental nitrogen per 1,000 square feet is applied every 8 weeks, from April through October. Adding organic matter to the soil can improve the rate of water intake, aeration, and soil tilth.

If used for recreation, the soils in this complex are best suited as sites for paths and trails that are established across the slope to reduce the hazard of erosion. Natural vegetation should be protected from fire and excessive foot traffic to control erosion and to maintain its esthetic value.

Capability subclass VIe(15), nonirrigated.

124—Los Osos-Millsholm complex, 50 to 75 percent slopes. This complex consists of very steep soils on uplands at an elevation between 300 and 1,500 feet. The average annual precipitation is 20 inches, and the mean annual temperature is 57 degrees F. The average frost-free season ranges from 300 to 320 days. This complex is about 50 percent Los Osos silty clay loam and 30 percent Millsholm silt loam. The components of this map unit are so intricately intermingled that it was not practical to map them separately at the scale used. Included in mapping, and making up about 20 percent of this map unit, are Los Gatos loam and Rock outcrop.

The Los Osos soil is moderately deep and well drained. It formed in material that weathered from sedimentary rock. This soil is on side slopes. Typically, the surface layer is grayish brown, medium acid silty clay loam about 8 inches thick. The subsoil is dark grayish brown, slightly acid silty clay loam and heavy silty clay loam and extends to a depth of 30 inches. It is underlain by weathered shale.

Permeability of the Los Osos soil is slow. The available water capacity is 3.5 to 6.5 inches. The root zone is 24 to 40 inches deep. Runoff is very rapid, and the hazard of erosion is very high.

The Millsholm soil is shallow and well drained. It formed in material that weathered from sedimentary rock. This soil is on ridges. Typically, the surface layer is grayish brown, medium acid silt loam about 7 inches thick. The subsoil is light olive brown, medium acid silt loam and extends to a depth of 20 inches. It is underlain by shale bedrock.

Permeability of the Millsholm soil is moderate. The available water capacity is 1.5 to 3.5 inches. The root zone is 10 to 20 inches deep. Runoff is very rapid, and the hazard of erosion is very high.

These soils are used mainly for recreation. The steep slopes limit the potential for recreation uses to a few paths and trails. To reduce the hazard of erosion, natural vegetation should be protected from fire, and paths and trails should be established across the slope.

Capability subclass VIIe(15), nonirrigated.

125—Marvin silt loam, saline-alkali. This is a very deep, somewhat poorly drained soil on low alluvial terraces. This soil is slightly affected by alkali. It formed in alluvium that derived mainly from sedimentary rock. Elevation ranges from 10 to 40 feet. Slopes are 0 to 2 percent. The average annual precipitation ranges from 16 to 18 inches, and the mean annual temperature is 57 degrees F. The average frost-free season is 300 to 320 days.

Typically, the surface layer is grayish brown, neutral silt loam about 4 inches thick. The subsoil extends to a depth of 36 inches. It is grayish brown, moderately alkaline heavy silty clay loam and clay. The substratum is mottled, light brownish gray and light yellowish brown heavy clay loam extending to a depth of 60 inches or more.

Included in mapping are small areas of Pescadero clay and Willows clay.

Permeability is slow. The available water capacity is 8.0 to 9.0 inches. The root zone for water-loving plants is 60 inches deep; for most of the commonly grown cultivated crops, the water table restricts the root zone to a depth of about 50 inches. Drainage has been improved by flood control structures. The water table is below a depth of 50 inches. Five percent of this map unit is not suited to most crops because of excess alkali.

This soil is used for urban development. A few small areas are used for vegetable crops.

Urban structures require special design because of the low strength and the high shrink-swell potential. Most of the plants used in landscaping should be tolerant of saline-alkali salts. Irrigation water should be applied slowly. Lawns respond to 1 pound of elemental nitrogen

per 1,000 square feet every 6 to 8 weeks, from April through October. Adding organic matter to the soil can improve the rate of water intake, aeration, and soil tilth.

Salt accumulation is a hazard on this slowly permeable soil if it is used for irrigated crops. Water should be applied slowly, and drainage is needed to remove excess surface and subsurface water and to maintain the water table below a depth of 50 inches. All crops respond to nitrogen and phosphate fertilizer.

Capability unit IVs-6(14), nonirrigated; IIIw-6(14), irrigated.

126—Maymen loam, 30 to 75 percent slopes. This is a shallow, somewhat excessively drained soil on uplands. It formed in material that weathered from sedimentary rock. Elevation ranges from 100 to 2,000 feet. The average annual precipitation is 22 inches, and the mean annual temperature is 56 degrees F. The average frost-free season ranges from 300 to 320 days.

Typically, the surface layer and subsoil are light brownish gray, strongly acid loam underlain by shale bedrock at a depth of 19 inches.

Included in mapping are small areas of Millsholm silt loam, Los Gatos loam, and a few areas of a very strongly acid, moderately deep, loamy soil.

Permeability is moderate. The available water capacity is 1 to 3 inches. The root zone is 10 to 20 inches deep. Runoff is rapid to very rapid, and the hazard of erosion is high to very high.

This soil is used for urban development, recreation, and watershed. If it is used for urban development, steep slopes and shallowness to bedrock are the main limitations. The steep banks that result from shaping this soil for use as building sites are highly erodible. They should be seeded to a fast-growing cover as soon as possible to reduce the hazard of erosion. Using straw mulch or jute netting helps to reduce the hazard of erosion during establishment of the grass cover. If runoff from higher areas is a problem, diversions may be needed at the head of these slopes. Tall trees used in landscaping are susceptible to windthrow because the soil is shallow. This soil is best suited to short trees. Lawn grasses grow best if about 1 pound of elemental nitrogen per 1,000 square feet is applied every 8 weeks, from April through October. Some ornamental plants respond to sulfur and to iron and aluminum chelates. Adding organic matter to the soil can improve the rate of water intake, aeration, and soil tilth.

The natural vegetation in recreation areas needs to be protected from fire and other destructive forces. To reduce the hazards of erosion and sedimentation, thick stands of eucalyptus trees should be thinned and regrowth controlled to reduce the fire hazard. The natural vegetation provides cover and food for deer, bush rabbits, quail, and songbirds.

Capability class VIIe(15), nonirrigated.

127—Maymen-Los Gatos complex, 30 to 75 percent slopes. This complex consists of steep and very steep soils on uplands at an elevation of 400 to 1,500 feet. Slopes range from 30 to 75 percent but are mainly 50 to 75 percent. The average annual precipitation is 21 inches, and the mean annual temperature is 56 degrees F. The average frost-free season ranges from 300 to 320 days.

This complex is about 50 percent Maymen soils and 35 percent Los Gatos soils. The components of this unit are so intricately intermingled that it was not practical to map them separately at the scale used. Included in mapping, and making up 15 percent of this complex, are small areas of Millsholm silt loam and some Rock outcrop.

The Maymen soil is shallow and somewhat excessively drained. This soil is on the upper part of slopes and on ridges. It formed in material that weathered from sedimentary rock. Typically, the surface layer and subsoil are light brownish gray, strongly acid loam. They are underlain by shale at a depth of 19 inches.

Permeability of the Maymen soil is moderate. The available water capacity is 1 to 3 inches. The root zone is 10 to 20 inches deep. Runoff is rapid to very rapid, and the hazard of erosion is high to very high.

The Los Gatos soil is moderately deep and well drained. It is on lower slopes and north-facing slopes. Typically, the surface layer is brown, neutral loam about 11 inches thick. The subsoil extends to a depth of 40 inches. It is brown and reddish brown, neutral and slightly acid loam and heavy loam and is underlain by sandstone.

Permeability of the Los Gatos soil is moderately slow. The available water capacity is 3.5 to 8.0 inches. The root zone is 24 to 40 inches deep. Runoff is rapid to very rapid, and the hazard of erosion is high to very high.

These soils are used for low density urban development, recreation, and watershed.

Urban development is limited by steep slopes and shallowness or moderate depth to bedrock. The steep banks that result from shaping these soils for use as building sites are highly erodible. They should be seeded to a fast-growing cover as soon as possible to reduce the hazard of erosion. Using straw mulch or jute netting helps to reduce the hazard of erosion during establishment of the grass cover. If runoff from higher areas is a problem, diversions may be needed at the head of these slopes.

The Maymen soil is best suited to short trees. Tall trees are susceptible to windthrow. Shrubs and trees can be drip irrigated to encourage deeper rooting. Lawn grasses grow best if about 1 pound of elemental nitrogen per 1,000 square feet is applied every 8 weeks, from April through October. Some ornamental plants respond to sulfur and to iron and aluminum chelates. Adding organic matter to the soil can improve the rate of water intake, aeration, and soil tilth.

The natural vegetation has esthetic value and supplies food and shelter for deer, rabbits, quail, and songbirds. It should be protected from fire. Thick stands of eucalyptus trees should be thinned to reduce the hazard of fire. Protecting the vegetation reduces the hazards of erosion and sedimentation.

Capability subclass VIIe(15), nonirrigated.

128—Millsholm silt loam, 30 to 50 percent slopes. This is a shallow, well drained soil on uplands. This soil formed in material that weathered from sedimentary rock. The elevation ranges from 300 to 1,500 feet. The average annual precipitation is 20 inches, the mean annual temperature is 57 degrees F, and the average frost-free season ranges from 300 to 320 days.

Typically, the surface layer is grayish brown, medium acid silt loam about 6 inches thick. The subsoil extends to a depth of 20 inches. It is a light olive brown, medium acid silt loam and it is underlain by shale bedrock.

Included in mapping are small areas of Maymen loam and Los Gatos loam and a shallow, brown silt loam soil that is underlain by soft bedrock.

Permeability is moderate. The available water capacity is 1.5 to 3.5 inches. The root zone is 10 to 20 inches deep. Runoff is rapid, and the hazard of erosion is high.

This soil is used as rangeland and watershed and for recreation and low density urban uses. Because this soil is shallow and steep, it is poorly suited to intensive urban development. Cuts should be protected from erosion by structural measures, mulching, and seeding with a fast-growing cover. Most of the plants that are used for landscaping respond to nitrogen fertilizer. Water should be applied frequently and slowly to reduce runoff. Natural vegetation should be protected from fire and other destructive forces to reduce soil loss and sedimentation.

Capability subclass VIIe(15), nonirrigated.

129—Millsholm silt loam, 50 to 75 percent slopes. This is a shallow, well drained soil that formed in material that weathered from sedimentary rock. This soil is on uplands at an elevation of 300 to 1,500 feet. The average annual precipitation is 20 inches, and the mean annual temperature is 57 degrees F. The average frost-free season is 300 to 320 days.

Typically, the surface layer is grayish brown, medium acid silt loam about 6 inches thick. The subsoil extends to a depth of 20 inches. It is light olive brown, medium acid silt loam and is underlain by shale bedrock.

Included in mapping are small areas of Maymen loam, Los Gatos loam, and Rock outcrop.

Permeability is moderate. The available water capacity is 1.5 to 3.5 inches. The root zone is 10 to 20 inches deep. Runoff is very rapid, and the hazard of erosion is very high.

This soil is used for recreation, watershed, and homesites. In most areas this soil is in natural vegetation that has a high esthetic value. The natural vegetation provides food and cover for deer, rabbits, quail, and songbirds. It should be protected from fire and other destructive forces to reduce the hazards of erosion and sedimentation.

Capability subclass VIIe(15), nonirrigated.

130—Montara-Rock outcrop complex, 30 to 75 percent slopes. This complex consists of steep and very steep soils on uplands at an elevation of about 200 to 1,500 feet. The average annual precipitation is 19 inches, and the mean annual temperature is 57 degrees F. The average frost-free season ranges from 300 to 320 days. Montara soils make up about 65 percent of the complex and Rock outcrop, 20 percent. Included in mapping, and making up about 15 percent of this complex are small areas of Millsholm silt loam and Los Gatos loam.

Montara soils are shallow and somewhat excessively drained. Typically, the surface layer is very dark grayish brown, mildly alkaline and moderately alkaline clay loam about 14 inches thick. It is underlain by ultrabasic rock.

Permeability is moderately slow. The available water capacity is 1.5 to 3.5 inches. The root zone is 10 to 20 inches deep. Runoff is rapid to very rapid, and the hazard of erosion is high to very high.

Rock outcrop consists of large areas of exposed ultrabasic rock. Runoff is very rapid, but the hazard of erosion is slight.

Most areas of Montara soils are used as parks; some areas are used as homesites. The natural vegetation needs to be protected from fire and other destructive forces to reduce the hazard of erosion.

Capability subclass VIIs(15), nonirrigated.

131—Omni silty clay loam, drained. This is a very deep, poorly drained soil on flood plains. It formed in alluvium that derived from mixed rock sources. Elevation ranges from 5 to 30 feet. The slopes are 0 to 2 percent. The average annual precipitation is 15 inches, and the mean annual air temperature is 57 degrees F. The average frost-free season ranges from 300 to 320 days.

Typically, the surface layer is grayish brown, moderately alkaline silty clay loam and silty clay about 15 inches thick. The subsoil extends to a depth of 52 inches. It is mottled, dark gray, mildly alkaline clay in the upper part and mottled light olive brown, moderately alkaline clay in the lower part. The substratum is mottled, light olive brown, moderately alkaline silty clay loam to a depth of 60 inches or more.

Included in mapping are small areas of Botella loam; Danville silty clay loam; and Clear Lake clay, drained.

Permeability is slow. The available water capacity is 7.5 to 10 inches. The root zone is 60 inches deep. Runoff is slow, and the hazard of erosion is slight. Drainage has been improved by flood control structures. The water table is below a depth of 5 feet.

This soil is used for urban development and for vegetable crops. The potential of this soil for urban use is limited by low strength and by the high shrink-swell potential.

The major crops are head lettuce and tomatoes, which are double-cropped with cauliflower. Head lettuce or tomatoes are grown and harvested in summer, and cauliflower is grown in winter. The yield of head lettuce is 550 crates; tomatoes, 25 tons; cauliflower, 460 crates. Crop residue should be returned to the soil to help maintain soil tilth and improve the water intake rate. Proper tillage practices minimize soil compaction. Water should be applied slowly and only in the amount needed for crop growth. Over-irrigation wastes water, leaches nutrients, and increases the risk of salt accumulation at the lower end of the run. Nitrogen fertilizer is needed for good crop growth.

Capability unit IIIs-3(14), nonirrigated; IIs-3(14), irrigated.

132—Omni silty clay loam, strongly saline. This is a very deep, poorly drained soil on flood plains. This soil formed in alluvium that derived from mixed rock sources. The slopes are less than 2 percent. Elevation ranges from 5 to 15 feet. The average annual precipitation is 16 inches, and the mean annual temperature is 57 degrees F. The average frost-free season ranges from 300 to 320 days.

Typically, the surface layer is grayish brown, moderately alkaline silty clay loam and silty clay about 15 inches thick. The subsoil extends to a depth of 52 inches. It is mottled, dark gray, mildly alkaline clay in the upper part and mottled, light olive brown, moderately alkaline clay in the lower part. The substratum is mottled, light olive brown silty clay loam to a depth of 60 inches or more.

Included in mapping are small areas of Willows clay, drained.

Permeability is slow. The available water capacity is 1.5 to 4.0 inches. The root zone for water-tolerant plants is 60 inches deep; but it is restricted to a depth of 48 inches for water-sensitive plants. Runoff is slow, and there is no hazard of erosion. The surface layer has excess saline salts.

Areas of this Omni soil were shaped for use as commercial salt ponds. Low levees were built around these areas. Most of these ponds have been abandoned and are now idle or are used as a source of sanitary landfill, though the high water table presents some problems for this use. Although the surface layer does have varying amounts of saline salts, this soil has fair potential for the development of habitat for wetland wildlife. Pickleweed, cordgrass, and saltgrass provide food and cover for wildlife.

Capability subclass VIw(14), nonirrigated.

133—Pescadero clay, drained. This is a very deep, poorly drained soil that formed on basin rims in alluvium that derived from sedimentary rock. Elevation ranges from 5 to 50 feet. The slopes are 0 to 2 percent. The average annual precipitation is 16 inches, and the mean annual temperature is 57 degrees F. The average frost-free season is 300 to 320 days.

Typically, the surface layer is a gray, slightly acid clay loam about 2 inches thick. The subsoil extends to a depth of 30 inches. It is mottled, dark gray and light gray, moderately alkaline clay. The substratum is gray, light olive gray, and light gray calcareous clay loam and extends to a depth of more than 60 inches.

Included in mapping are small areas of Willows clay, drained, and Omni silty clay loam, drained.

Permeability is very slow. The available water capacity is 3 to 7 inches. The water table has been lowered to a depth of 60 inches in most areas by flood control structures and natural stream cutting. The root zone for salt-tolerant plants is 60 inches deep. About 10 to 20 percent of this map unit is not suited to most vegetation. Runoff is very slow and some areas are ponded. Erosion is not a hazard.

This Pescadero soil is used mainly as dryland pasture and for open-type sanitary landfill. The main limitations to these uses are the clayey texture, excess salts, and ponding of water in winter. The clayey texture makes the soil material poorly suited to use as landfill cover material. This soil is difficult to work when wet or dry. Excess saline and alkali salts make revegetation difficult.

If used as dryland pasture, this soil should not be grazed when wet. Natural vegetation should be protected from over-grazing to help reduce invasion of undesirable weeds. Surface drainage is needed to reduce ponding in rainy periods.

Capability subclass VIs(14), nonirrigated.

134—Pescadero clay, ponded. This is a very deep, poorly drained soil that formed on basin rims in alluvium that derived from sedimentary rock. The slope is less than 2 percent. Elevation ranges from 5 to 15 feet. The average annual precipitation is 16 inches, and the mean annual temperature is 57 degrees F. The average frost-free season is 300 to 320 days.

Typically, the surface layer is gray, strongly alkaline clay loam about 2 inches thick. The subsoil extends to a depth of 30 inches. It is mottled, dark gray and light gray, strongly alkaline clay. The substratum is gray, light olive gray, and light gray, calcareous clay loam and extends to a depth of more than 60 inches.

Included in mapping are areas of Omni silty clay loam, strongly saline, and Reyes clay, ponded.

Permeability is very slow. The available water capacity is 2 to 6 inches. All rainfall is ponded unless levees or outlets are open. Most areas have no vegetation. The water table is usually at a depth of about 4 feet, but in winter it can rise up to 1 1/2 feet from the surface. Runoff is very slow, and erosion is not a hazard.

In most areas this soil has been shaped and ponded for use as commercial salt ponds. Areas that have been used as salt ponds have a high concentration of salt in the upper 30 inches of the soil material and are covered by water up to 3 feet deep.

If this soil is drained and if the excess salts are flushed out of the surface layer, salt-tolerant plants can provide some food and cover for wetland wildlife.

Capability subclass VIIIw(14), nonirrigated.

135—Pits, gravel. This miscellaneous area consists of large excavations that are the result of commercial sand and gravel extraction operations. Many of these gravel pits are now used to recharge the water table reservoir with imported water to prevent salt water intrusion of wells.

Capability classification not assigned.

136—Pleasanton gravelly loam, 0 to 5 percent slopes. This is a very deep, well drained soil on low terraces. This soil formed in alluvium that derived from sedimentary rock. Elevation ranges from 100 to 300 feet. The average annual precipitation is 16 inches, and the mean annual temperature is 57 degrees F. The average frost-free season ranges from 300 to 310 days.

Typically, the surface layer is grayish brown, slightly acid and neutral gravelly loam about 21 inches thick. The subsoil extends to a depth of 64 inches. It is brown, neutral gravelly sandy clay loam and gravelly loam about 43 inches thick. The substratum is yellowish brown, mildly alkaline gravelly fine sandy loam and extends to a depth of more than 60 inches.

Included in mapping are areas of Botella loam, Danville silty clay loam, and Rincon clay loam.

Permeability is moderately slow. The available water capacity is 5.5 to 8.0 inches. The root zone is more than 60 inches deep. Runoff is slow, and the hazard of erosion is slight.

This soil is used as dryland pasture and for low-density urban development. The natural vegetation should be protected from over-grazing to prevent infestation by weeds that are poisonous to livestock. There are few limitations for low-density urban uses. Septic tank filter fields should be enlarged or installed below a depth of about 5 feet because of the moderately slow permeabilty of the subsoil. Most of the plants used in landscaping respond to nitrogen and phosphate fertilizer. Lawn grasses grow best if 1 pound of elemental nitrogen per 1,000 square feet is applied every 8 weeks, from March to November.

Capability unit IIIe-3(14), nonirrigated; IIe-3(14), irrigated.

137—Reyes clay. This is a very deep, very poorly drained soil that formed in alluvium that derived from mixed sources. This soil is on tidal flats. The slope is less than 2 percent. The elevation ranges from sea level to 5 feet. The average annual rainfall is 15 inches, and the mean annual temperature is 57 degrees F. The average frost-free season ranges from 300 to 320 days.

Typically, the surface layer is olive gray, strongly alkaline clay about 6 inches thick. The underlying material, to a depth of 42 inches, is mottled dark greenish gray and black, strongly alkaline clay. Below that, to a depth of 72 inches, it is dark greenish gray, strongly alkaline silty clay. The underlying material contains polysulfides.

Included in mapping are small areas of a very poorly drained, strongly saline clay that does not contain polysulfides. Also included are small areas of Pescadero clay, drained.

Permeability is very slow. The available water capacity is 0.5 inch to 3.0 inches. The water table is between depths of 8 and 24 inches. Runoff is very slow, and most areas are subject to tidal inundation. There is no hazard of erosion. This soil is extremely acid when drained.

This soil is used for wildlife habitat. The natural vegetation is pickleweed, cordgrass, saltgrass, and other salt-tolerant plants that provide cover and food for waterfowl and other birds.

Capability subclass VIIIw(14), nonirrigated.

138—Reyes clay, ponded. This is a very deep, very poorly drained soil that formed in alluvium that derived from mixed sources. This soil is on tidal flats. The slope is less than 2 percent. The elevation ranges from sea level to 5 feet. The average annual precipitation is 15 inches, and the mean annual temperature is 57 degrees F. The average frost-free season ranges from 300 to 320 days.

Typically, the surface layer is olive gray, strongly alkaline clay about 6 inches thick. The underlying material, to a depth of 42 inches, is mottled dark greenish gray and black, strongly alkaline clay. Below that, to a depth of 72 inches, it is dark greenish gray, strongly alkaline silty clay. The underlying material contains polysulfides.

Included in mapping are small areas of a very poorly drained, strongly saline clay that does not contain polysulfides. Also included are small areas of Pescadero clay, ponded.

Permeability is very slow. This soil is ponded and is protected from tidal inundation by levees. Erosion is not a hazard. The areas are devoid of vegetation. This soil becomes extremely acid when drained.

This soil is used for commercial salt ponds and wildlife habitat.

Capability subclass VIIIw(14), nonirrigated.

139—Reyes clay, drained. This is a very deep, very poorly drained soil that formed in alluvium that derived from mixed sources. This soil is on tidal flats. The slope is less than 2 percent. This soil is at sea level and ranges to an elevation of 5 feet. The average annual precipitation is 16 inches, and the mean annual tempera-

ture is 57 degrees F. The average frost-free season ranges from 300 to 320 days.

Typically, the surface layer is olive gray, strongly acid clay about 6 inches thick. The underlying material to a depth of 42 inches is mottled dark greenish gray and black, extremely acid clay. Below that, to a depth of 72 inches, it is dark greenish gray, extremely acid silty clay. The underlying material contains polysulfides.

Included in mapping are small areas of a very poorly drained, strongly saline clay soil that does not contain polysulfides. Also included are small areas of Pescadero clay, drained.

Permeability is very slow. The available water capacity is 2.0 to 3.5 inches. The root zone for salt- and water-tolerant plants is 60 inches deep, and it is 2 to 4 feet deep for water-sensitive plants. The water table has been lowered to a depth of about 4 feet. Runoff is very slow, and there is no hazard of erosion.

This soil is used as dryland pasture and for barley. The natural vegetation is mainly mouse barley, saltgrass, pickleweed, and saltbush. The grazing capacity is about 1.5 AUM per acre. Pasture grasses should not be grazed when this soil is wet.

Capability unit IVw-9(14), nonirrigated.

140—Rincon clay loam, 0 to 2 percent slopes. This is a very deep, well drained soil that formed in alluvium that derived from sedimentary rock. It is on low terraces. Elevation ranges from 20 to 200 feet. The average annual precipitation is 16 inches, and the mean annual temperature is 57 degrees F. The average frost-free season ranges from 300 to 320 days.

Typically, the surface layer is grayish brown and dark grayish brown neutral clay loam about 16 inches thick. The subsoil extends to a depth of 52 inches. It is dark grayish brown, neutral heavy clay loam in the upper part, and brown, neutral and mildly alkaline clay in the lower part. The substratum is yellowish brown, calcareous clay loam and extends to a depth of 60 inches or more.

Included in mapping are small areas of Danville silty clay loam; Clear Lake clay, drained; and Yolo silt loam.

Permeability is slow. The available water capacity is 8 to 10 inches. The root zone is more than 60 inches deep. Runoff is slow, and the hazard of erosion is slight.

This soil is used mainly for urban development. In a few small areas it is used for row crops.

This soil has limitations for use as building sites. The shrink-swell potential is high; as a result, foundations can shift and crack. Building pads should be shaped so that water is drained away from the building site, thus keeping the soil beneath the foundation dry and reducing the hazards of differential settlement and shrink-swell. The high shrink-swell potential and low strength affect the construction of roads and streets. Suitable base material is needed. In sloping areas, intercepting drains should be provided to keep moisture from beneath the roads.

The water intake rate and permeability are slow; therefore, lawns should be watered slowly to reduce runoff. Shrubs and trees can be drip irrigated to encourage deep rooting. Lawn grasses grow best if 1 pound of elemental nitrogen per 1,000 square feet is applied every 8 weeks, from April through October. Some ornamental plants respond to sulfur and to iron and aluminum chelates. Adding organic matter to the soil can improve the rate of water intake, aeration, and soil tilth.

Capability unit IIIs-3(14), nonirrigated; IIs-3(14), irrigated.

141—Riverwash. This miscellaneous area consists of very gravelly, cobbly, or stony sediment on creek bottoms. Most areas are in the vicinity of the city of Niles. In some areas, Riverwash has been used as a source of construction material and fill.

Capability subclass VIIIw(14), nonirrigated.

142—Quarry. This miscellaneous area consists of large excavations, on uplands, from which rock is extracted for use as landfill.

Capability classification not assigned.

143—Sycamore silt loam, drained. This is a very deep, poorly drained soil that formed in alluvium that derived from sedimentary rock. It is on flood plains and has slopes of 0 to 2 percent. Elevation ranges from 10 to 50 feet. The average annual precipitation is 16 inches, and the mean annual temperature is 57 degrees F. The average frost-free season ranges from 300 to 320 days.

Typically, the surface layer is light brownish gray, moderately alkaline silt loam about 18 inches thick. The subsoil extends to a depth of 44 inches. It is mottled, grayish brown and light olive gray, moderately alkaline silt loam. The substratum is mottled, light olive gray, moderately alkaline heavy silt loam and extends to a depth of 60 inches or more.

Included in mapping are small areas of Laugenour loam, drained, and Omni silty clay loam, drained.

Permeability is moderate. The available water capacity is 8.0 to 10.5 inches. The root zone is more than 60 inches deep. In most places, natural stream cutting and flood control structures have lowered the water table to a depth of 72 inches. Runoff is slow, and the hazard of erosion is slight.

This soil is used mainly for row crops. Head lettuce, cauliflower, and tomatoes are the major crops. Head lettuce or tomatoes are grown and harvested in summer, cauliflower in winter. Returning crop residue to the soil helps to maintain tilth and improve the rate of water intake. Minimum tillage reduces soil compaction. Water should be applied only in the amount necessary for crop growth. Overirrigation wastes water and leaches nutrients. Nitrogen is needed for good crop growth. In a few areas this soil is used for urban development.

Capability unit IIIc-1(14), nonirrigated; class I(14), irrigated.

144—Sycamore silt loam, clay substratum. This is a very deep, poorly drained soil that formed in recent alluvium that derived from sedimentary rock. It is on flood plains and has slopes of 0 to 2 percent. Elevation ranges from 10 to 50 feet. The average annual precipitation is about 16 inches, and the mean annual temperature is about 57 degrees F. The average frost-free season ranges from 300 to 320 days.

Typically, the surface layer is light brownish gray, moderately alkaline silt loam about 18 inches thick. The subsoil extends to a depth of 44 inches. It is mottled, grayish brown and light olive gray, moderately alkaline silt loam. The substratum is very dark gray clay and extends to a depth of 60 inches or more.

Included in mapping are small areas of a light brownish gray silt loam that is underlain by clay at a depth of 24 to 40 inches.

Permeability is moderate in the surface layer and subsoil and slow in the clay substratum. The available water capacity is 7 to 9 inches. The root zone is 60 inches deep for most crops. In places, root development is restricted to structural faces or cracks in the substratum. Drainage has been improved by flood control structures that have lowered the water table to a depth of 6 feet or more in most areas. Runoff is slow, and the hazard of erosion is slight.

This soil is used mainly for urban development. It has few limitations for small structures or for local roads and streets. If irrigation for landscaping or gardening is in excess of the plant needs, a perched water table can form over the clay substratum. Most plants respond to nitrogen fertilizer. Some ornamental plants respond to sulfur and to aluminum chelates.

Capability unit IIIs-3(14), nonirrigated; IIs-3(14), irrigated.

145—Tierra loam, 0 to 5 percent slopes. This is a very deep, moderately well drained soil that formed in old alluvium on dissected terraces and terrace remnants. Elevation ranges from 100 to 250 feet. The average annual precipitation is 17 inches, and the mean annual temperature is 57 degrees F. The average frost-free season ranges from 300 to 320 days.

Typically, the surface layer is grayish brown, slightly acid loam about 11 inches thick. The subsurface layer is gray, slightly acid loam about one inch thick. The subsoil extends to a depth of 32 inches. It is very dark grayish brown, grayish brown, and brown, neutral clay. The substratum is variegated yellowish brown and brown, neutral sandy clay loam and extends to a depth of 60 inches or more.

Included in mapping are small areas of Azule clay loam and Danville silty clay loam.

Permeability is very slow. The available water capacity is 6 to 8 inches. The root zone is 60 or more inches deep, but roots may be restricted to the surface of peds in the clay subsoil. Runoff is slow, and the hazard of erosion is slight.

This Tierra soil is used mainly for low-density urban development. A few small areas are used as dryland pasture.

This soil has limitations for use as building sites. The shrink-swell potential is high; as a result, foundations can shift and crack. Building pads should be shaped so that water is drained away from the building site, thus keeping the soil beneath the foundation dry and reducing the hazards of differential settlement and shrink-swell. The high shrink-swell potential and low strength affect the construction of roads and streets. Suitable base material is needed.

The water intake rate and permeability are very slow; therefore, lawns should be watered slowly to reduce runoff. Shrubs and trees can be drip irrigated to encourage deeper rooting. Lawn grasses grow best if 1 pound of elemental nitrogen per 1,000 square feet is applied every 8 weeks, from April through October. Adding organic matter to the soil can improve the rate of water intake, aeration, and soil tilth.

If this soil is used for dryland pasture, the natural vegetation should not be grazed until the plants are 4 to 6 inches high. Enough residue should be left on the surface after the grazing period to prevent infiltration by weeds.

Capability unit IVe-3(15), nonirrigated.

146—Urban land. This miscellaneous area consists of land that is covered by buildings, roads, parking lots, and other urban structures. The soil material is mainly heterogeneous fill. Most areas are adjacent to San Francisco Bay.

Capability classification not assigned.

147—Urban land-Baywood complex. This complex consists of Urban land and Baywood loamy sand on mounds and ridges adjacent to the beaches at an elevation of 10 to 60 feet. Slope ranges from 0 to 8 percent, but the range is mainly 2 to 5 percent. The average annual precipitation is 17 inches, and the mean annual temperature is 57 degrees F. The average frost-free season ranges from 300 to 320 days.

This complex is about 60 percent Urban land, 35 percent Baywood loamy sand, and 5 percent other soils, including Laugenour loam, drained, and Omni silty clay loam, drained. Also included are small areas of a very deep, loamy sand that is weakly cemented below a depth of 30 inches.

Urban land consists of areas that are covered by buildings and other structures. The soil material has been altered or mixed, but it closely resembles the Baywood soil.

The Baywood soil is very deep and somewhat excessively drained. It formed in eolian sediment that derived from old beach deposits. Typically, the surface layer is grayish brown and brown, slightly acid loamy sand about 32 inches thick. The underlying material is pale brown and light yellowish brown, slightly acid loamy sand and extends to a depth of 60 inches or more.

Permeability is rapid. The available water capacity is 4.0 to 5.5 inches. The root zone is more than 60 inches deep. Runoff is slow to medium. Soil blowing is a serious hazard if this soil is left bare.

This soil has few limitations for urban development. Landscaped areas or gardens should be irrigated frequently and sparingly. Most plants respond to nitrogen and phosphate fertilizers, which are most effective if applied frequently and at low rates.

Capability classification not assigned.

148—Urban land-Clear Lake complex. This complex consists of Urban land and Clear Lake clay on basin rims. The slope ranges from 0 to 5 percent. The average annual precipitation is 17 inches, and the mean annual temperature is 57 degrees F. The average frost-free season ranges from 300 to 320 days.

This complex is about 55 percent Urban land and 35 percent Clear Lake clay. Included in mapping and making up about 10 percent of the acreage are a few small areas of Omni silty clay loam, drained, and Marvin silt loam, saline-alkali.

Urban land consists of areas that are covered by buildings and other related urban structures. The soil material has been altered or mixed during urban development.

The Clear Lake soil is very deep and poorly drained. It formed in alluvium that derived mainly from sedimentary rock. Typically, the surface layer is very dark gray, neutral and moderately alkaline clay about 37 inches thick. The underlying material is dark gray and grayish brown, calcareous clay and silty clay and extends to a depth of 60 inches or more.

Permeability is slow. The available water capacity is 7.0 to 9.5 inches. The root zone is 60 inches deep for water-tolerant plants and 48 inches deep for water-sensitive plants. Drainage has been improved by flood control structures, and the water table is below a depth of 48 to 60 inches. Runoff is slow, and there is no hazard of erosion.

The Clear Lake soil has certain limitations that should be overcome before construction is feasible. The shrink-swell potential is high; as a result, foundations can shift and crack. Building pads should be shaped so that water is drained away from the building site, thus keeping the soil beneath the foundation dry and reducing the hazards of differential settlement and shrink-swell. The high shrink-swell potential and low strength affect the construction of roads and streets. Suitable base material is needed.

The water intake rate and permeability are slow; therefore, lawns should be watered slowly to reduce runoff. Shrubs and trees can be drip irrigated to encourage deep rooting. Lawn grasses grow best if 1 pound of nitrogen per 1,000 square feet is applied every 8 weeks, from April through October. Some ornamental plants respond to sulfur and to iron and aluminum chelates. Adding organic matter to the soil can improve the rate of water intake, aeration, and soil tilth.

Capability classification not assigned.

149—Urban land-Danville complex. This complex is on low terraces and alluvial fans at an elevation of about 20 to 300 feet. The slopes are mainly nearly level; in a few areas, they are moderately sloping. The average annual precipitation is 17 inches, and the mean annual temperature is 57 degrees F. The average frost-free season ranges from 300 to 320 days.

This complex is about 60 percent Urban land and 30 percent Danville silty clay loam. Included in mapping and making up 10 percent of the complex are small areas of Botella loam; Clear Lake clay, drained; and Tierra loam.

Urban land consists of areas that are covered by buildings and related urban structures. The soil material has been altered or mixed during construction. Along freeways the soil material has been extensively altered.

The Danville soil is very deep and well drained. It formed in alluvium that derived mainly from sedimentary rock. Typically, the surface layer is grayish brown and dark gray, slightly acid silty clay loam about 21 inches thick. The subsoil extends to a depth of 61 inches. It is grayish brown, slightly acid and neutral silty clay, silty clay loam, and heavy silty clay loam. The substratum is grayish brown, neutral silty clay loam and extends to a depth of 80 inches or more.

Permeability is slow. The available water capacity is 8.5 to 10.5 inches. The root zone is more than 60 inches deep. Runoff is slow, and the hazard of erosion is slight.

This soil has certain limitations that should be overcome before construction is feasible. The shrink-swell potential is high; as a result, foundations can shift and crack. Building pads should be shaped so that water is drained away from the building site, thus keeping the soil beneath the foundation dry and reducing the hazards of differential settlement and shrink-swell. The high shrink-swell potential and low strength affect the construction of roads and streets. Suitable base material is needed.

The water intake rate and permeability are slow; therefore, lawns should be watered slowly to reduce runoff. Shrubs can be drip irrigated to encourage deep rooting. Lawn grasses grow best if 1 pound of elemental nitrogen per 1,000 square feet is applied every 8 weeks, from April through October. Some ornamental plants respond to sulfur and to iron and aluminum chelates. Adding organic matter to the soil can improve the rate of water intake, aeration, and soil tilth.

Capability classification not assigned.

150—Urban land-Tierra complex, 2 to 5 percent slopes. This complex consists of Urban land and Tierra loam on old dissected terraces at an elevation of 100 to 250 feet. The average annual precipitation is 17 inches, and the mean annual temperature is 57 degrees F. The average frost-free season ranges from 300 to 320 days.

This complex is about 50 percent Urban land and 42 percent Tierra loam. Included in mapping and making up about 8 percent of the complex are small areas of Azule clay loam and Danville silty clay loam.

Urban land consists of areas that are covered by buildings and other urban structures. The soil material has been altered or mixed during urban development.

The Tierra soil is very deep and moderately well drained. It formed in weakly consolidated old alluvium. Typically, the surface layer is grayish brown, slightly acid loam about 11 inches thick. The subsurface layer is gray, slightly acid loam about 1 inch thick. The subsoil extends to a depth of 32 inches. It is very dark grayish brown, grayish brown, and brown, neutral clay. The substratum is variegated yellowish brown and brown, neutral sandy clay loam and extends to a depth of 60 inches or more.

Permeability is very slow. The available water capacity is 6 to 8 inches. The root zone is 60 inches deep, but roots may be restricted to the surface of peds in the clay subsoil. Runoff is slow, and the hazard of erosion is slight.

In landscaping, Tierra soils are best suited to shallow-rooted plants. The very slowly permeable subsoil restricts root development and water penetration. If more irrigation water is used than plants need, it can accumulate above the subsoil. Most plants respond to nitrogen fertilizer.

The shrink-swell potential of the subsoil is high; therefore, patios and other slablike structures require a sand base to reduce the hazard of cracking.

Capability classification not assigned.

151—Urban land-Tierra complex, 5 to 15 percent slopes. This complex consists of Urban land and Tierra loam on old dissected terraces at an elevation of 100 to 250 feet. The average annual precipitation is 17 inches, and the mean annual temperature is 57 degrees F. The average frost-free season ranges from 300 to 320 days.

This complex is about 50 percent Urban land and 38 percent Tierra loam. Included in mapping and making up about 12 percent of the complex are small areas of Azule clay loam and Danville silty clay loam.

Urban land consists of areas that are covered by buildings and other urban structures. The soil material has been altered or mixed during urban development.

The Tierra soil is very deep and moderately well drained. It formed in weakly consolidated old alluvium. Typically, the surface layer is grayish brown, slightly acid loam about 11 inches thick. The subsurface layer is gray, slightly acid loam about 1 inch thick. The subsoil extends to a depth of 32 inches. It is very dark grayish brown, grayish brown, and brown, neutral clay. The substratum is variegated yellowish brown and brown, neutral sandy clay loam and extends to a depth of 60 inches or more.

Permeability is very slow. The available water capacity is 6 to 8 inches. The root zone is 60 inches deep, but roots may be restricted to the surface of peds in the clay subsoil. Runoff is medium, and the hazard of erosion is moderate.

In landscaping, Tierra soils are best suited to shallow-rooted plants. The subsoil restricts root development and water penetration. If irrigation water is applied in excess of plant needs, water can accumulate above the subsoil. Most plants respond to nitrogen fertilizer. Exposed banks should be planted to ground cover to reduce the hazard of erosion.

The shrink-swell potential of the subsoil is high; therefore, small structures need to be specially designed.

Capability classification not assigned.

152—Urban land-Tierra complex, 15 to 30 percent slopes. This complex consists of Urban land, Tierra loam, and Azule clay loam on old dissected terraces at an elevation of 100 to 250 feet. The average annual precipitation is 17 inches, and the mean annual temperature is 57 degrees F. The frost-free season ranges from 300 to 320 days.

This complex is about 50 percent Urban land, 25 percent Tierra loam, and 20 percent Azule clay loam. Included in mapping and making up about 5 percent of the complex are small areas of Los Osos silty clay loam.

Urban land consists of areas that are covered by houses and other urban structures. The soil material has been altered or mixed during urban development.

The Tierra soil is very deep and moderately well drained. It formed in weakly consolidated old alluvium. Typically, the surface layer is grayish brown, slightly acid loam about 11 inches thick. The subsurface layer is gray, slightly acid loam about 1 inch thick. The subsoil extends to a depth of 32 inches. It is very dark grayish brown, grayish brown, and brown, neutral clay. The substratum is variegated yellowish brown and brown, neutral sandy clay loam and extends to a depth of 60 inches or more.

Permeability is very slow. The root zone is 60 inches deep, but roots may be restricted to the surface of peds in the clay subsoil. The available water capacity is 6 to 8 inches. Runoff is rapid, and the hazard of erosion is moderate to high.

The Azule soil is moderately deep and well drained. It formed in material that weathered from consolidated alluvium. Typically, the surface layer is grayish brown, slightly acid clay loam about 6 inches thick. The subsoil extends to a depth of about 25 inches. It is grayish brown and dark grayish brown slightly acid clay in the upper part, and it grades to grayish brown and light yellowish brown, slightly acid clay in the lower part. Light yellowish brown, weakly cemented alluvial sediment is at a depth of about 25 inches.

Permeability is slow. The available water capacity is 3 to 6 inches. The root zone is 24 to 40 inches deep. Runoff is rapid, and the hazard of erosion is moderate to high.

In landscaping, the soils in this complex are best suited to shallow-rooted plants. Irrigation water should be applied slowly to reduce the loss of water and the hazard of erosion. Most plants respond to nitrogen and phosphate fertilizer. One pound of elemental nitrogen per 1,000 square feet should be applied to lawn grasses every 8 weeks, from April to November. If the subsoil is exposed, adding organic matter to the soil improves tilth and increases the rate of water intake and aeration.

Capability classification not assigned.

153—Vallecitos-Rock outcrop complex, 30 to 50 percent slopes. This complex of steep soils and Rock outcrop is in the Coyote Hills at an elevation of 5 to 290 feet. The average annual precipitation is 15 inches, and the mean annual temperature is 57 degrees F. The average frost-free season ranges from 300 to 320 days. This complex is about 65 percent Vallecitos gravelly loam and 20 percent Rock outcrop. Included in mapping and making up about 15 percent of the complex are small areas of Contra Costa clay loam.

The Vallecitos soil is shallow and well drained. It formed in residual material that weathered from metasedimentary rock. Typically, the surface layer is brown, neutral gravelly loam about 6 inches thick. The subsoil extends to a depth of 16 inches. It is reddish brown neutral heavy clay loam and brown, slightly acid heavy clay loam. It is underlain by sandstone bedrock.

Permeability is slow. The root zone is 10 to 20 inches deep. The available water capacity is 1 to 3 inches. Runoff is rapid, and the hazard of erosion is high.

Rock outcrop consists of exposed metamorphosed sandstone and large sandstone boulders.

Areas of this complex are used for recreation. The natural vegetation should be protected from fire and excessive foot traffic to maintain its esthetic value. If paths and trails are built, they should be established across the slope to reduce the hazard of erosion.

Capability subclass VIIe(15), nonirrigated.

154—Willows clay, drained. This is a very deep, poorly drained soil on basin rims. It formed in alluvium that derived mainly from sedimentary rock. The slope ranges between 0 and 2 percent. The elevation is 10 to 200 feet. The average annual precipitation is 16 inches, and the mean annual temperature is 57 degrees F. The average frost-free season ranges from 300 to 320 days.

Included in mapping are small areas of Clear Lake clay and Omni silty clay loam.

Typically, the surface layer is black, moderately alkaline clay about 19 inches thick. The next layer is mottled, dark gray, moderately alkaline clay about 10 inches thick. The underlying material consists of mottled, grayish brown, calcareous clay and extends to a depth of more than 60 inches.

Permeability is very slow. The available water capacity is 4.0 to 6.5 inches. The root zone is 60 inches deep. The water table has been lowered to a depth of 5 to 6 feet by flood control structures and natural downcutting of stream beds. Runoff is slow, and there is no hazard of erosion.

This soil is used mainly for industrial and commerical development. A few areas are used as dryland pasture.

This soil has limitations for use as building sites. The shrink-swell potential is high; as a result, foundations can shift and crack. Building pads should be shaped so that water is drained away from the building site, thus keeping the soil beneath the foundation dry and reducing the hazards of differential settlement and shrink-swell. The high shrink-swell potential and low strength affect the construction of roads and streets. Suitable base material is needed.

The water intake rate and permeability are slow; therefore lawns should be watered slowly to reduce runoff. Shrubs can be drip irrigated to encourage deep rooting. Lawn grasses grow best if 1 pound of elemental nitrogen per 1,000 square feet is applied every 8 weeks, from April through October. Some ornamental plants respond to sulfur and to iron and aluminum chelates. Adding organic matter to the soil can improve the rate of water intake, aeration, and soil tilth.

Capability unit IIIs-5(14), nonirrigated, and IIs-5(14), irrigated.

155—Xerorthents, clayey. This map unit consists of clayey material that is used as fill for building sites. The slopes are less than 2 percent. Elevation ranges from near sea level to 50 feet. The average annual precipitation is 16 inches, and the mean annual temperature is 57 degrees F. The average frost-free season ranges from 300 to 320 days.

Typically, these soils are dark brown, dark grayish brown, grayish brown, or brown. The texture is mainly heavy clay loam, but the range includes silty clay and clay. Reaction is mildly acid to moderately alkaine except where these soils are limed. Large pieces of asphalt, concrete, and sandstone and fragments of glass and other debris make up as much as 15 percent, by volume, of the profile.

Permeability is slow to very slow. The available water capacity is 6 to 7 inches. The root zone is 60 inches deep. Runoff is slow, and erosion is not a hazard.

Areas of this map unit are used mainly as sites for industrial development; however, certain limitations should be overcome before construction is feasible. The shrink-swell potential is high; as a result, foundations can shift and crack. Building pads should be shaped so that water is drained away from the building site, thus keeping the soil beneath the foundation dry and reducing the hazards of differential settlement and shrink-swell. The

high shrink-swell potential and low strength affect the construction of roads and streets. Suitable base material is needed.

The water intake rate and permeability are slow; therefore, lawns should be watered slowly to reduce runoff. Shrubs can be drip irrigated to encourage deep rooting. Lawn grasses grow best if 1 pound of elemental nitrogen per 1,000 square feet is applied every 8 weeks, from April through October. Some ornamental plants respond to sulfur and to iron and aluminum chelates. Adding organic matter to the soil can improve the rate of water intake, aeration, and tilth.

Capability classification not assigned.

156—Xeropsamments, fill. This unit consists of sandy material that was dredged from old beach areas. Slopes are less than 2 percent. Elevation ranges from near sea level to 10 feet. The average annual precipitation is 17 inches, and the mean annual temperature is 57 degrees F. The average frost-free season ranges from 300 to 320 days.

Included in mapping, and making up about 10 percent of the map unit, are a few areas that are underlain by strongly alkaline clay at a depth of 36 to 48 inches. Also included, and making up about 5 percent of the map unit, are concave areas that have a water table within a depth of 36 inches and can be ponded in winter.

Typically, Xeropsamments are moderately alkaline sands that extend to a depth of 60 inches. In a few areas they are as much as 5 percent, by volume, shells that are less than one inch in diameter.

These soils are rapidly permeable. The root zone for water-tolerant plants is 60 inches deep; the water table restricts the root zone for water-sensitive plants to a depth of 40 to 60 inches. The available water capacity is 3 to 4 inches. Runoff is slow, and the hazard of erosion is slight. Soil blowing is a serious hazard.

These soils are used mainly for urban and industrial development and as airfields. A few areas are used for small grain. Levees prevent erosion of this fill material.

Frequent and light applications of irrigation water and fertilizer are needed to establish a vegetative cover. Most plants respond to nitrogen and phosphate fertilizer. Iron and aluminum chelates are needed for some ornamental plants.

Capability classification not assigned.

157—Xerorthents-Altamont complex, 30 to 50 percent slopes. This complex consists of soils on foothills adjacent to the bay. The elevation ranges from 200 to 1,500 feet. The average annual precipitation is 16 inches, and the mean annual temperature is 57 degrees F. The average frost-free season ranges from 300 to 320 days. Xerorthents, clayey, make up about 75 percent of this complex; Altamont clay, 20 percent.

Xerorthents consist of soil material that resulted from cutting or filling for urban development; therefore, the soil characteristics are variable. Fill areas consist of heavy clay loam, silty clay, and clay and are as much as 20 percent angular fragments of shale and sandstone. Colors are variable. Reaction is mildly alkaline or moderately alkaline, and these soils are calcareous throughout the profile. Cut areas consist of interbedded shale and fine-grained sandstone. The bedrock dips between 50 and 80 degrees.

Permeability is slow or very slow, depending on the soil texture and on the amount of compaction that takes place during construction.

The Altamont soil is deep and well drained. It formed in the material that weathered from soft, interbedded sedimentary rock and makes up most of the undisturbed areas of this complex. Typically, the surface layer is dark brown, slightly acid to mildly alkaline clay about 28 inches thick. The next layer is finely mixed dark brown and dark yellowish brown, calcareous clay about 9 inches thick. The underlying material extends to a depth of 50 inches. It is yellowish brown, calcareous clay. Below that is highly fractured and weathered fine-grained sandstone and shale.

Permeability is slow. The available water capacity is 5.0 to 9.5 inches. The root zone is 40 to 60 inches deep. Runoff is rapid, and the hazard of erosion is high.

Areas of this complex are used mainly for residential developments that have a density of two to four single family dwellings per acre. Approximately 25 percent of the area is covered by buildings or other urban related structures.

Certain limitations should be overcome before construction is feasible. The shrink-swell potential is high; as a result, foundations can shift and crack. Building pads should be shaped so that water is drained away from the building site, thus keeping the soil beneath the foundation dry and reducing the hazards of differential settlement and shrink-swell. The high shrink-swell potential and low strength affect the construction of roads and streets. Suitable base material is needed. In sloping areas, intercepting drains should be provided to keep moisture from beneath the roads.

Steep banks that result from reshaping these soils for use as building sites are highly erodible. These soils should be seeded to a fast-growing cover as soon as possible to reduce the hazard of erosion. Using straw mulch or jute netting helps to reduce the hazard of erosion during establishment of the grass cover. If runoff from higher areas is a problem, diversions may be needed at the head of these slopes.

The water intake rate and permeability are slow; therefore, lawns should be watered slowly to reduce runoff. Shrubs and trees can be drip irrigated to encourage deep rooting. Lawn grasses grow best if 1 pound of nitrogen per 1,000 square feet is applied every 8 weeks, from April through October. Some ornamental plants respond to sulfur and to iron and aluminum chelates.

Adding organic matter to the soil can improve the rate of water intake, aeration, and soil tilth.

Capability classification not assigned.

158—Xerorthents-Los Osos complex, 30 to 50 percent slopes. This complex consists of soils on hills at an elevation of 200 to 1,500 feet. The average annual precipitation is 20 inches, and the mean annual temperature is 57 degrees F. The average frost-free season is 300 to 320 days.

Xerorthents, loamy, make up about 70 percent of this complex; Los Osos silty clay loam, 20 percent. Included in mapping and making up about 10 percent of the complex are small areas of Altamont clay, Climara clay, and Millsholm silt loam.

Xerorthents consist of soil material that resulted from cutting or filling for urban development, therefore; the soil characteristics are quite variable. Fill areas consist of clay loam, heavy loam, and silty clay loam and are as much as 20 percent angular fragments of shale and sandstone. Colors are variable. Reaction is slightly acid to mildly alkaline. In a few areas these soils are calcareous.

Permeability is slow. The rooting zone is more than 10 inches deep. Runoff is rapid, and the hazard of erosion is high.

The Los Osos soil is moderately deep and well drained. It formed in material that weathered from sedimentary rock and makes up most of the undisturbed areas in this complex. Typically, the surface layer is grayish brown, medium acid silty clay loam about 8 inches thick. The subsoil extends to a depth of 30 inches. It is dark grayish brown, slightly acid silty clay loam and heavy silt clay loam and is underlain by weathered shale.

Permeability is slow. The available water capacity is 3.5 to 6.5 inches. The root zone is 24 to 40 inches deep. Runoff is rapid, and the hazard of erosion is high.

Areas of this complex are used mainly for residential developments that have a density of two to four single family dwellings per acre. Approximately 25 percent of the area is covered by streets, shopping areas, and other related urban structures. Exposed banks should have a vegetative or structural protective cover. Only the minimum amount of irrigation water needed for maintaining plant growth should be used. Water should be applied slowly to reduce the hazard of erosion. Surface drainage should be provided to remove excess water, and the outlets of drains and downspouts should be protected against gullying.

Most plants respond to nitrogen fertilizer. Lawn grasses grow best if 1 pound of elemental nitrogen per 1,000 square feet is applied every 8 weeks, from April through October.

To reduce cracking in paths and sidewalks, the soil material should be compacted and covered by a blanket of sand.

Capability classification not assigned.

159—Xerorthents-Millsholm complex, 30 to 50 percent slopes. The soils in this complex are on hills at an elevation of 200 to 1,500 feet. The average annual precipitation is 20 inches, and the mean annual temperature is 57 degrees F. The average frost-free season ranges from 300 to 320 days.

This complex is about 70 percent loamy Xerorthents and 20 percent Millsholm loam. Included in mapping, and making up about 10 percent of the complex, are small areas of Maymen loam and Los Gatos loam.

The Xerorthents in this complex are well drained to somewhat excessively drained. They consist of soil material that has been altered by cutting or filling for urban development; as a result, they have variable soil characteristics. Fill areas consist of loam and silt loam and are as much as 25 percent angular fragments of shale and sandstone. The color varies. Reaction is medium acid to mildly alkaline. In a few areas these soils are calcareous. Cut areas consist of interbedded shale and fine-grained sandstone. Bedrock has a dip of 30 to 80 degrees.

Permeability is moderate. The root zone is more than 20 inches deep. Runoff is rapid, and the hazard of erosion is high.

The Millsholm soil is shallow and well drained. It formed in material that weathered from shale or fine-grained sandstone. This soil makes up most of the undisturbed areas in this complex. Typically, the surface layer is grayish brown, medium acid silt loam about 7 inches thick. The subsoil is light olive brown, medium acid silt loam and extends to a depth of 20 inches; it is underlain by shale bedrock.

Permeability of the Millsholm soil is moderate. The available water capacity is 1.5 to 3.5 inches. The root zone is 10 to 20 inches deep. Runoff is rapid, and the hazard of erosion is high.

Areas of this complex are used primarily as sites for residential developments that consist of two to four single family dwellings per acre. Approximately 25 percent of the area is covered by roads, parking lots, and small shopping centers.

These soils require careful water management to reduce erosion and prevent the saturation of fill areas. A permanent vegetative cover should be maintained. Only the minimum amount of irrigation water should be applied to prevent mud flow. Surface drains can remove excess water from buildings.

Most of the plants in areas of this complex respond to nitrogen fertilizer. Lawn grasses grow best if 1 pound of elemental nitrogen per 1,000 square feet is applied about every 8 weeks, from April through October.

Capability classification not assigned.

160—Xerorthents-Millsholm complex, 50 to 75 percent slopes. This complex consists of soils on hills at an elevation of 200 to 1,500 feet. The average annual

precipitation is 20 inches, and the mean annual temperature is 57 degrees F. The average frost-free season ranges from 300 to 330 days. Xerorthents, loamy, makes up about 60 percent of this complex; Millsholm loam, 20 percent. Included in mapping and making up about 20 percent of the complex are small areas of Maymen loam, Los Gatos loam, and Los Osos silty clay loam.

Xerorthents consist of well drained and somewhat excessively drained soils. These soils have resulted from cutting or filling for urban development; therefore, the soil characteristics are variable. Fill areas consist of loam, silt loam, and light silty clay loam and are as much as 50 percent angular fragments of shale and sandstone. Colors are variable. Reaction is medium acid to mildly alkaline. In a few areas, these soils are calcareous. Cut areas consist of interbedded shale and fine-grained sandstone. Bedrock has a dip of 30 to 80 degrees.

Permeability is moderate. The root zone is more than 20 inches deep. Runoff is rapid to very rapid, and the hazard of erosion is high to very high.

The Millsholm soil is shallow and well drained. It formed in the residuum of weathered shale or fine-grained sandstone. This soil makes up most of the undisturbed areas in this complex. Typically, the surface layer is grayish brown, medium acid silt loam about 7 inches thick. The subsoil extends to a depth of 20 inches; it is light olive brown, medium acid silt loam and is underlain by shale bedrock.

Permeability is moderate. The available water capacity is 1.5 to 3.5 inches. The root zone is 10 to 20 inches deep. Runoff is rapid, and the hazard of erosion is high.

The soils of this map unit are used mainly for homesites. The density is less than one single family dwelling per acre. Approximately 15 percent of the area is covered by roads and other urban works and structures.

Plants selected for landscaping and stabilizing banks should be drought resistant. Irrigation water should not be applied in excess of plant needs. Terracing can be used to reduce erosion. Surface drains should be provided to remove excess water from building sites, and the outlets of drains and downspouts should be protected against gullying.

Most plants respond to nitrogen fertilizers. Lawn grasses grow best if 1 pound of elemental nitrogen per 1,000 square feet is applied every 8 weeks, from April through October. Vegetative cover other than lawns may be desirable to reduce the hazard of soil saturation by over-irrigating. Sloping areas that are not landscaped should be mulched, fertilized, and seeded with annual grasses and legumes.

Capability classification not assigned.

161—Yolo silt loam, 0 to 2 percent slopes. This is a very deep, well drained soil that formed in alluvium that derived from sedimentary rock. It is on flood plains and alluvial fans. Elevation ranges from 20 to 200 feet. The average annual precipitation is 16 inches, and the mean annual temperature is 57 degrees F. The average frost-free season ranges from 300 to 320 days.

Included in mapping are small areas of Sycamore silt loam, drained, and Botella loam.

Typically, the surface layer is grayish brown, neutral silt loam about 8 inches thick. The underlying material is brown, mildly and moderately alkaline silt loam and extends to a depth of more than 60 inches.

Permeability is moderate. The root zone is more than 60 inches deep. The available water capacity is 9.5 to 11.0 inches. Runoff is slow, and there is no erosion hazard.

Areas of this Yolo soil are used mainly for urban development. A few areas are used for vegetable crops.

This soil has few limitations for urban development. Because of low strength and a moderate shrink-swell potential, special design is needed for urban buildings and roads and streets.

Most of the plants used for landscaping respond to nitrogen fertilizer. The addition of organic matter will increase the rate of water intake. Some ornamental plants respond to sulfur and to iron and aluminum chelates.

Capability unit IIIc-1(14), nonirrigated; class I(14), irrigated.

Use and management of the soils

The soil survey is a detailed inventory and evaluation of the most basic resource of the survey area—the soil. It is useful in adjusting land use, including urbanization, to the limitations and potentials of natural resources and the environment. Also, it can help avoid soil-related failures in uses of the land.

While a soil survey is in progress, soil scientists, conservationists, engineers, and others keep extensive notes about the nature of the soils and about unique aspects of behavior of the soils. These notes include data on erosion, drought damage to specific crops, flooding, the functioning of septic tank disposal systems, and other factors affecting the productivity, potential, and limitations of the soils under various uses and management. In this way, field experience and measured data on soil properties and performance are used as a basis for predicting soil behavior.

Information in this section is useful in planning use and management of soils for crops and pasture, as sites for buildings, highways and other transportation systems, sanitary facilities, and parks and other recreation facilities, and for wildlife habitat. From the data presented, the potential of each soil for specified land uses can be determined, soil limitations to these land uses can be identified, and costly failures in houses and other structures, caused by unfavorable soil properties, can be avoided. A site where soil properties are favorable can

be selected, or practices that will overcome the soil limitations can be planned.

Planners and others using the soil survey can evaluate the impact of specific land uses on the overall productivity of the survey area or other broad planning area and on the environment. Productivity and the environment are closely related to the nature of the soil. Plans should maintain or create a land-use pattern in harmony with the natural soil.

Contractors can find information that indicates the presence of bedrock, wetness, or very firm soil horizons that cause difficulty in excavation.

Health officials, highway officials, engineers, and many other specialists also can find useful information in this soil survey. The safe disposal of wastes, for example, is closely related to properties of the soil. Pavements, sidewalks, picnic areas, playgrounds, lawns, and trees and shrubs are influenced by the nature of the soil.

Capability classification

Capability classification shows, in a general way, the suitability of soils for most kinds of field crops. The soils are classed according to their limitations when they are used for field crops, the risk of damage when they are used, and the way they respond to treatment. The grouping does not take into account major and generally expensive landforming that would change slope, depth, or other characteristics of the soils; does not take into consideration possible but unlikely major reclamation projects; and does not apply to rice, cranberries, horticultural crops, or other crops that require special management. Capability classification is not a substitute for interpretations designed to show suitability and limitations of groups of soils for rangeland, for forest trees, or for engineering purposes.

In the capability system, soils can be grouped at three levels: capability class, subclass, and unit. These levels are defined in the following paragraphs. A survey area may not have soils of all classes.

Capability classes, the broadest groups, are designated by Roman numerals I through VIII. The numerals indicate progressively greater limitations and narrower choices for practical use. The classes are defined as follows:

Class I soils have few limitations that restrict their use.

Class II soils have moderate limitations that reduce the choice of plants or that require moderate conservation practices.

Class III soils have severe limitations that reduce the choice of plants, or that require special conservation practices, or both.

Class IV soils have very severe limitations that reduce the choice of plants, or that require very careful management, or both.

Class V soils are not likely to erode but have other limitations, impractical to remove, that limit their use.

Class VI soils have severe limitations that make them generally unsuitable for cultivation.

Class VII soils have very severe limitations that make them unsuitable for cultivation.

Class VIII soils and landforms have limitations that nearly preclude their use for commercial crop production.

Capability subclasses are soil groups within one class; they are designated by adding a small letter, *e, w, s,* or *c,* to the class numeral, for example, IIe. The letter *e* shows that the main limitation is risk of erosion unless close-growing plant cover is maintained; *w* shows that water in or on the soil interferes with plant growth or cultivation (in some soils the wetness can be partly corrected by artificial drainage); *s* shows that the soil is limited mainly because it is shallow, droughty, or stony; and *c*, used in only some parts of the United States, shows that the chief limitation is climate that is too cold or too dry.

In class I there are no subclasses because the soils of this class have few limitations. Class V contains only the subclasses indicated by *w, s,* or *c* because the soils in class V are subject to little or no erosion, though they have other limitations that restrict their use to pasture, rangeland, woodland, wildlife habitat, or recreation.

Capability units are soil groups within the subclasses. The soils in one capability unit are enough alike to be suited to the same crops and pasture plants, to require similar management, and to have similar productivity. Thus, the capability unit is a convenient grouping for making many statements about management of soils for cropland. Capability units are generally designated by adding an Arabic numeral to the subclass symbol, for example, IIe-4 or IIIe-6. The capability units for this survey area are defined as follows:

0.—Indicates that a problem or limitation is caused by stony, cobbly, or gravelly material in the substratum.

1.—Indicates that a problem or limitation is caused by slope or by actual or potential erosion hazard.

2.—Indicates that a problem or limitation of wetness is caused by poor drainage or flooding.

3.—Indicates that a problem or limitation of slow or very slow permeability of the subsoil or substratum is caused by a clayey subsoil or a substratum that is semiconsolidated.

4.—Indicates that a problem or limitation is caused by sandy or gravelly soils that have a low available water capacity.

5.—Indicates that a problem or limitation is caused by a fine textured or very fine textured surface layer.

6.—Indicates that a problem or limitation is caused by salt or alkali.

7.—Indicates that a problem or limitation is caused by rocks, stones, or cobblestones.

8.—Indicates that a problem or limitation exists in the root zone, which generally is less than 40 inches over massive bedrock and lacks moisture for plants.

9.—Indicates that a problem or limitation is caused by low or very low fertility, acidity, or toxicity that cannot be corrected by adding normal amounts of fertilizer, lime, or other amendments.

No unit designations are shown for class I soils since soil characteristics are similar for all soils in this class. Unit designations are also deleted from classes V through VIII soils since these soils are normally not intensively managed for cropland.

The capability classification is identified in the description of each soil map unit in the section "Soil maps for detailed planning."

Land resource areas

In this survey, capability classification is further refined by designating land resource areas. A land resource area is a distinct combination of climate, soils, vegetation, management needs, and kinds of crops. The 48 conterminous states in the nation have been divided into 156 land resource areas. Parts of two of these areas are in this survey area. These areas and their numbers are Central California Coastal Valleys (14), and Central California Coast Range (15). The number of the resource area is added in parenthesis to the class, subclass, and unit designation at the end of the map unit description.

Land resource area (14) consists of the flood plains, alluvial fans, and low terraces adjacent to the Bay Area. Elevation ranges from sea level to about 300 feet. This area receives sea breezes from San Francisco Bay during much of the year. Morning and evening fog is common. Precipitation ranges from 14 to 20 inches and the frost-free season is 300 to 330 days.

Major agricultural problems are poor drainage, excessive amounts of salts that are toxic to plant growth, lack of precipitation during the growing season, and poor quality water for irrigation.

Most of the land in this resource area is being used for urban development. A large area adjacent to the bay is used for salt ponds. The land remaining in agriculture is used mainly for irrigated row crops. A few areas are used as dryland pasture or are idle because of poor soil conditions.

Land resource area (15) consists of high terraces and uplands. Except for a few small areas adjacent to the San Francisco Bay, this area is along the eastern edge of the survey area. It is at sea level near the Coyote Hills, and ranges to an elevation of about 2,000 feet along ridges and peaks east of the city of Oakland. This area receives sea breezes during much of the year. Morning and evening fog is common. Precipitation ranges from 14 to 25 inches, and the frost-free season is 300 to 330 days.

Major agricultural problems are steep slopes, shallowness to bedrock, lack of precipitation during the growing season, and lack of water for irrigation.

Most of the land in this resource area is used for urban development. The little remaining acreage is used for parks, range, and dryland grains.

Engineering

This section provides information about the use of soils for building sites, sanitary facilities, construction material, and water management. Among those who can benefit from this information are engineers, landowners, community planners, town and city managers, land developers, builders, contractors, and farmers and ranchers.

The ratings in the engineering tables are based on test data and estimated data in the "Soil properties" section. The ratings were determined jointly by soil scientists and engineers of the Soil Conservation Service using known relationships between the soil properties and the behavior of soils in various engineering uses.

Among the soil properties and site conditions identified by a soil survey and used in determining the ratings in this section were grain-size distribution, liquid limit, plasticity index, soil reaction, depth to bedrock, hardness of bedrock that is within 5 or 6 feet of the surface, soil wetness, depth to a seasonal high water table, slope, likelihood of flooding, natural soil structure or aggregation, in-place soil density, and geologic origin of the soil material. Where pertinent, data about kinds of clay minerals, mineralogy of the sand and silt fractions, and the kind of absorbed cations were also considered.

On the basis of information assembled about soil properties, ranges of values can be estimated for erodibility, permeability, shrink-swell potential, available water capacity, shear strength, compressibility, slope stability, and other factors of expected soil behavior in engineering uses. As appropriate, these values can be applied to each major horizon of each soil or to the entire profile.

These factors of soil behavior affect construction and maintenance of roads, airport runways, pipelines, foundations for small buildings, ponds and small dams, irrigation projects, drainage systems, sewage and refuse disposal systems, and other engineering works. The ranges of values can be used to (1) select potential residential, commercial, industrial, and recreational areas; (2) make preliminary estimates pertinent to construction in a particular area; (3) evaluate alternative routes for roads, streets, highways, pipelines, and underground cables; (4) evaluate alternative sites for location of sanitary landfills, onsite sewage disposal systems, and other waste disposal facilities; (5) plan detailed onsite investigations of soils and geology; (6) plan farm drainage systems, irrigation systems, ponds, and other structures for soil and water conservation; (7) relate performance of structures already built to the properties of the kinds of soil on which they are built so that performance of similar structures on the same or a similar soil in other locations can be predicted; and (8) predict the trafficability of soils for

cross-country movement of vehicles and construction equipment.

Data presented in this section are useful for land-use planning and for choosing alternative practices or general designs that will overcome unfavorable soil properties and minimize soil-related failures. Limitations to the use of these data, however, should be well understood. First, the data are generally not presented for soil material below a depth of 5 or 6 feet. Also, because of the scale of the detailed map in this soil survey, small areas of soils that differ from the dominant soil may be included in mapping. Thus, these data do not eliminate the need for onsite investigations, testing, and analysis by personnel having expertise in the specific use contemplated.

The information is presented mainly in tables. Table 4 shows, for each kind of soil, the degree and kind of limitations for building site development; table 5, for sanitary facilities; and table 6, for water management.

The information in the tables, along with the soil map, the soil descriptions, and other data provided in this survey, can be used to make additional interpretations and to construct interpretive maps for specific uses of land.

Some of the terms used in this soil survey have a special meaning in soil science. Many of these terms are defined in the Glossary.

Building site development

The degree and kind of soil limitations that affect shallow excavations, dwellings with and without basements, small commercial buildings, and local roads and streets are indicated in table 4. A *slight* limitation indicates that soil properties generally are favorable for the specified use and that limitations are minor and easily overcome. A *moderate* limitation indicates that soil properties and site features are unfavorable for the specified use, but the limitations can be overcome or minimized by special planning and design. A *severe* limitation indicates that one or more soil properties or site features are so unfavorable or difficult to overcome that a major increase in construction effort, special design, or intensive maintenance is required. For some soils rated severe, such costly measures may not be feasible.

Shallow excavations are made for pipelines, sewerlines, communications and power transmission lines, open ditches, and cemeteries. Such digging or trenching is influenced by soil wetness caused by a seasonal high water table; the texture and consistence of soils; the tendency of soils to cave in or slough; and the presence of very firm, dense soil layers, bedrock, or large stones. In addition, excavations are affected by slope of the soil and the probability of flooding. Ratings do not apply to soil horizons below a depth of 6 feet unless otherwise noted.

In the soil series descriptions, the consistence of each soil horizon is given, and the presence of very firm or extremely firm horizons, usually difficult to excavate, is indicated.

Dwellings and *small commercial buildings* referred to in table 4 are built on undisturbed soil and have foundation loads of a dwelling no more than three stories high. Separate ratings are made for small commercial buildings without basements and for dwellings with and without basements. For such structures, soils should be sufficiently stable that cracking or subsidence of the structure from settling or shear failure of the foundation does not occur. These ratings were determined from estimates of the shear strength, compressibility, and shrink-swell potential of the soil. Soil texture, plasticity and in-place density, soil wetness, and depth to a seasonal high water table were also considered. Soil wetness and depth to a seasonal high water table indicate potential difficulty in providing adequate drainage for basements, lawns, and gardens. Depth to bedrock, slope, and large stones in or on the soil are also important considerations in the choice of sites for these structures and were considered in determining the ratings. Susceptibility to flooding is a serious hazard.

Local roads and streets referred to in table 4 have an all-weather surface that can carry light to medium traffic all year. They consist of a subgrade of the underlying soil material; a base of gravel, crushed rock fragments, or soil material stabilized with lime or cement; and a flexible or rigid surface, commonly asphalt or concrete. The roads are graded with soil material at hand, and most cuts and fills are less than 6 feet deep.

The load supporting capacity and the stability of the soil as well as the quantity and workability of fill material available are important in design and construction of roads and streets. The classifications of the soil and the soil texture, density, and shrink-swell potential are indicators of the traffic supporting capacity used in making the ratings. Soil wetness, flooding, slope, depth to hard rock or very compact layers, and content of large stones affect stability and ease of excavation.

Sanitary facilities

Favorable soil properties and site features are needed for proper functioning of septic tank absorption fields, sewage lagoons, and sanitary landfills. The nature of the soil is important in selecting sites for these facilities and in identifying limiting soil properties and site features to be considered in design and installation. Also, those soil properties that affect ease of excavation or installation of these facilities will be of interest to contractors and local officials. Table 5 shows the degree and kind of limitations of each soil for such uses and for use of the soil as daily cover for landfills. It is important to observe local ordinances and regulations.

If the degree of soil limitation is expressed as *slight*, soils are generally favorable for the specified use and limitations are minor and easily overcome; if *moderate*,

soil properties or site features are unfavorable for the specified use, but limitations can be overcome by special planning and design; and if *severe*, soil properties or site features are so unfavorable or difficult to overcome that major soil reclamation, special designs, or intensive maintenance is required. Soil suitability is rated by the terms *good*, *fair*, and *poor*, which mean about the same as *slight*, *moderate*, and *severe*.

Septic tank absorption fields are subsurface systems of tile or perforated pipe that distribute effluent from a septic tank into the natural soil. Only the soil horizons between depths of 18 and 72 inches are evaluated for this use. The soil properties and site features considered are those that affect the absorption of the effluent and those that affect the construction of the system.

Properties and features that affect absorption of the effluent are permeability, depth to seasonal high water table, depth to bedrock, and susceptibility to flooding. Stones, boulders, and shallowness to bedrock interfere with installation. Excessive slope can cause lateral seepage and surfacing of the effluent. Also, soil erosion and soil slippage are hazards if absorption fields are installed on sloping soils.

In some soils, loose sand and gravel or fractured bedrock is less than 4 feet below the tile lines. In these soils the absorption field does not adequately filter the effluent, and ground water in the area may be contaminated.

On many of the soils that have moderate or severe limitations for use as septic tank absorption fields, a system to lower the seasonal water table can be installed or the size of the absorption field can be increased so that performance is satisfactory.

Sewage lagoons are shallow ponds constructed to hold sewage while aerobic bacteria decompose the solid and liquid wastes. Lagoons have a nearly level floor and cut slopes or embankments of compacted soil material. Aerobic lagoons generally are designed to hold sewage within a depth of 2 to 5 feet. Nearly impervious soil material for the lagoon floor and sides is required to minimize seepage and contamination of ground water. Soils that are very high in content of organic matter and those that have cobbles, stones, or boulders are not suitable. Unless the soil has very slow permeability, contamination of ground water is a hazard if the seasonal high water table is above the level of the lagoon floor. If the water table is seasonally high, seepage of ground water into the lagoon can seriously reduce the lagoon's capacity for liquid waste. Slope, depth to bedrock, and susceptibility to flooding also affect the suitability of sites for sewage lagoons or the cost of construction. Shear strength and permeability of compacted soil material affect the performance of embankments.

Sanitary landfill is a method of disposing of solid waste by placing refuse in successive layers either in excavated trenches or on the surface of the soil. The waste is spread, compacted, and covered daily with a thin layer of soil material. Landfill areas are subject to heavy vehicular traffic. Risk of polluting ground water and trafficability affect the suitability of a soil for this use. The best soils have a loamy or silty texture, have moderate to slow permeability, are deep to a seasonal water table, and are not subject to flooding. Clayey soils are likely to be sticky and difficult to spread. Sandy or gravelly soils generally have rapid permeability, which might allow noxious liquids to contaminate ground water. Soil wetness can be a limitation because operating heavy equipment on a wet soil is difficult. Seepage into the refuse increases the risk of pollution of ground water.

Ease of excavation affects the suitability of a soil for the trench type of landfill. A suitable soil is deep to bedrock and free of large stones and boulders. If the seasonal water table is high, water will seep into trenches.

Unless otherwise stated, the limitations in table 5 apply only to the soil material within a depth of about 6 feet. If the trench is deeper, a limitation of slight or moderate may not be valid. Site investigation is needed before a site is selected.

Daily cover for landfill should be soil that is easy to excavate and spread over the compacted fill in wet and dry periods. Soils that are loamy or silty and free of stones or boulders are better than other soils. Clayey soils may be sticky and difficult to spread; sandy soils may be subject to soil blowing.

The soils selected for final cover of landfills should be suitable for growing plants. Of all the horizons, the A horizon in most soils has the best workability, more organic matter, and the best potential for growing plants. Thus, for either the area- or trench-type landfill, stockpiling material from the A horizon for use as the surface layer of the final cover is desirable.

If it is necessary to bring in soil material for daily or final cover, thickness of suitable soil material available and depth to a seasonal high water table in soils surrounding the site should be evaluated. Other factors to be evaluated are those that affect reclamation of the borrow areas. These factors include slope, erodibility, and potential for plant growth.

Water management

Many soil properties and site features that affect water management practices have been identified in this soil survey. In table 6, soil and site features that affect use are indicated for each kind of soil. This information is significant in planning, installing, and maintaining water control structures.

Pond reservoir areas hold water behind a dam or embankment. Soils best suited to this use have a low seepage potential, which is determined by permeability and the depth to fractured or permeable bedrock or other permeable material.

Embankments, dikes, and levees require soil material that is resistant to seepage, erosion, and piping and has

favorable stability, shrink-swell potential, shear strength, and compaction characteristics. Large stones and organic matter in a soil downgrade the suitability of the soil for use in embankments, dikes, and levees.

Drainage of soil is affected by such soil properties as permeability; texture; depth to bedrock, hardpan, or other layers that affect the rate of water movement; depth to the water table; slope; stability of ditchbanks; susceptibility to flooding; salinity and alkalinity; and availability of outlets for drainage.

Irrigation is affected by such features as slope, susceptibility to flooding, hazards of water erosion and soil blowing, texture, presence of salts and alkali, depth of root zone, rate of water intake at the surface, permeability of the soil below the surface layer, available water capacity, need for drainage, and depth to the water table.

Grassed waterways are constructed to channel runoff to outlets at a nonerosive velocity. Features that affect the use of soils for waterways are slope, permeability, erodibility, wetness, and suitability for permanent vegetation.

Recreation

The soils of the survey area are rated in table 7 according to limitations that affect their suitability for recreation uses. The ratings are based on such restrictive soil features as flooding, wetness, slope, and texture of the surface layer. Not considered in these ratings, but important in evaluating a site, are location and accessibility of the area, size and shape of the area and its scenic quality, the ability of the soil to support vegetation, access to water, potential water impoundment sites available, and either access to public sewerlines or capacity of the soil to absorb septic tank effluent. Soils subject to flooding are limited, in varying degree, for recreation use by the duration and intensity of flooding and the season when flooding occurs. Onsite assessment of height, duration, intensity, and frequency of flooding is essential in planning recreation facilities.

The degree of the limitation of the soils is expressed as slight, moderate, or severe. *Slight* means that the soil properties are generally favorable and that the limitations are minor and easily overcome. *Moderate* means that the limitations can be overcome or alleviated by planning, design, or special maintenance. *Severe* means that soil properties are unfavorable and that limitations can be offset only by costly soil reclamation, special design, intensive maintenance, limited use, or by a combination of these measures.

The information in table 7 can be supplemented by information in other parts of this survey. Especially helpful are interpretations for septic tank absorption fields, given in table 5, and interpretations for dwellings without basements and for local roads and streets, given in table 4.

Camp areas require such site preparation as shaping and leveling for tent and parking areas, stabilizing roads and intensively used areas, and installing sanitary facilities and utility lines. Camp areas are subject to heavy foot traffic and some vehicular traffic. The best soils for this use have mild slopes and are not wet or subject to flooding during the period of use. The surface has few or no stones or boulders, absorbs rainfall readily but remains firm, and is not dusty when dry. Strong slopes and stones or boulders can greatly increase the cost of constructing camping sites.

Picnic areas are subject to heavy foot traffic. Most vehicular traffic is confined to access roads and parking areas. The best soils for use as picnic areas are firm when wet, are not dusty when dry, are not subject to flooding during the period of use, and do not have slopes or stones or boulders that will increase the cost of shaping sites or of building access roads and parking areas.

Playgrounds require soils that can withstand intensive foot traffic. The best soils are almost level and are not wet or subject to flooding during the season of use. The surface is free of stones or boulders, is firm after rains, and is not dusty when dry. If shaping is required to obtain a uniform grade, the depth of the soil over bedrock or hardpan should be enough to allow necessary grading.

Paths and trails for walking, horseback riding, bicycling, and other uses should require little or no cutting and filling. The best soils for this use are those that are not wet, are firm after rains, are not dusty when dry, and are not subject to flooding more than once during the annual period of use. They should have moderate slopes and have few or no stones or boulders on the surface.

Wildlife habitat

Soils affect the kind and amount of vegetation that is available to wildlife as food and cover, and they affect the construction of water impoundments. The kind and abundance of wildlife that populate an area depend largely on the amount and distribution of food, cover, and water. If any one of these elements is missing, is inadequate, or is inaccessible, wildlife either are scarce or do not inhabit the area.

If the soils have the potential, wildlife habitat can be created or improved by planting appropriate vegetation, by maintaining the existing plant cover, or by helping the natural establishment of desirable plants.

In table 8, the soils in the survey area are rated according to their potential to support the main kinds of wildlife habitat in the area. This information can be used in planning for parks, wildlife refuges, nature study areas, and other developments for wildlife; selecting areas that are suitable for wildlife; selecting soils that are suitable for creating, improving, or maintaining specific elements

of wildlife habitat; and determining the intensity of management needed for each element of the habitat.

The potential of the soil is rated good, fair, poor, or very poor. A rating of *good* means that the element of wildlife habitat or the kind of habitat is easily created, improved, or maintained. Few or no limitations affect management, and satisfactory results can be expected if the soil is used for the designated purpose. A rating of *fair* means that the element of wildlife habitat or kind of habitat can be created, improved, or maintained in most places. Moderately intensive management is required for satisfactory results. A rating of *poor* means that limitations are severe for the designated element or kind of wildlife habitat. Habitat can be created, improved, or maintained in most places, but management is difficult and must be intensive. A rating of *very poor* means that restrictions for the element of wildlife habitat or kind of habitat are very severe and that unsatisfactory results can be expected. Wildlife habitat is impractical or even impossible to create, improve, or maintain on soils having such a rating.

The elements of wildlife habitat are briefly described in the following paragraphs.

Grain and seed crops are seed-producing annuals used by wildlife. The major soil properties that affect the growth of grain and seed crops are depth of the root zone, texture of the surface layer, available water capacity, wetness, slope, surface stoniness, and flood hazard. Soil temperature and soil moisture are also considerations. Examples of grain and seed crops are corn, wheat, oats, and barley.

Grasses and legumes are domestic perennial grasses and herbaceous legumes that are planted for wildlife food and cover. Major soil properties that affect the growth of grasses and legumes are depth of the root zone, texture of the surface layer, available water capacity, wetness, surface stoniness, flood hazard, and slope. Soil temperature and soil moisture are also considerations. Examples of grasses and legumes are fescue, hardinggrass, bromegrass, vetch, clover, and alfalfa.

Wild herbaceous plants are native or naturally established grasses and forbs, including weeds, that provide food and cover for wildlife. Major soil properties that affect the growth of these plants are depth of the root zone, texture of the surface layer, available water capacity, wetness, surface stoniness, and flood hazard. Soil temperature and soil moisture are also considerations. Examples of wild herbaceous plants are milkthistle, dove weed, tarweed, filaree, soft chess, needlegrass, and wild oats.

Shrubs are bushy woody plants that produce fruit, buds, twigs, bark, or foliage used by wildlife or that provide cover and shade for some species of wildlife. Major soil properties that affect the growth of shrubs are depth of the root zone, available water capacity, salinity, and moisture. Examples of shrubs are coyotebush, toyon, manzanita, snowberry, and California sagebrush.

Wetland plants are annual and perennial wild herbaceous plants that grow on moist or wet sites, exclusive of submerged or floating aquatics. They produce food or cover for wildlife that use wetland as habitat. Major soil properties affecting wetland plants are texture of the surface layer, wetness, reaction, salinity, slope, and surface stoniness. Examples of wetland plants are smartweed, wild millet, pickleweed, saltgrass, and cordgrass and rushes, sedges, and reeds.

Shallow water areas are bodies of water that have an average depth of less than 5 feet and that are useful to wildlife. They can be naturally wet areas, or they can be created by dams or levees or by water-control structures in marshes or streams. Major soil properties affecting shallow water areas are depth to bedrock, wetness, surface stoniness, slope, and permeability. The availability of a dependable water supply is important if water areas are to be developed. Examples of shallow water areas are marshes, waterfowl feeding areas, and ponds.

The kinds of wildlife habitat are briefly described in the following paragraphs.

Openland habitat consists of cropland, pasture, meadows, and areas that are overgrown with grasses, herbs, shrubs, and vines. These areas produce grain and seed crops, grasses and legumes, and wild herbaceous plants. The kinds of wildlife attracted to these areas include California quail, pheasant, meadowlark, field sparrow, cottontail rabbit, and skunk.

Wetland habitat consists of open, marshy or swampy, shallow water areas where water-tolerant plants grow. Some of the wildlife attracted to such areas are ducks, geese, herons, shore birds, muskrat, mink, and beaver.

Rangeland habitat consists of areas of wild herbaceous plants and shrubs. Wildlife attracted to rangeland include antelope, black-tailed deer, California mule deer, mourning dove, meadowlark, and horned lark.

Soil properties

Extensive data about soil properties are summarized on the following pages. The two main sources of these data are the many thousands of soil borings made during the course of the survey and the laboratory analyses of selected soil samples from typical profiles.

In making soil borings during field mapping, soil scientists can identify several important soil properties. They note the seasonal soil moisture condition or the presence of free water and its depth. For each horizon in the profile, they note the thickness and color of the soil material; the texture, or amount of clay, silt, sand, and gravel or other coarse fragments; the structure, or the natural pattern of cracks and pores in the undisturbed soil; and the consistence of the soil material in place under the existing soil moisture conditions. They record the depth of plant roots, determine the pH or reaction of the soil, and identify any free carbonates.

Samples of soil material are analyzed in the laboratory to verify the field estimates of soil properties and to determine all major properties of key soils, especially properties that cannot be estimated accurately by field observation. Laboratory analyses are not conducted for all soil series in the survey area, but laboratory data for many soil series not tested are available from nearby survey areas.

The available field and laboratory data are summarized in tables. The tables give the estimated range of engineering properties, the engineering classifications, and the physical and chemical properties of each major horizon of each soil in the survey area. They also present data about pertinent soil and water features.

Engineering properties

Table 9 gives estimates of engineering properties and classifications for the major horizons of each soil in the survey area.

Most soils have, within the upper 5 or 6 feet, horizons of contrasting properties. Table 9 gives information for each of these contrasting horizons in a typical profile. *Depth* to the upper and lower boundaries of each horizon is indicated. More information about the range in depth and about other properties in each horizon is given for each soil series in the section "Soil series and morphology."

Texture is described in table 9 in the standard terms used by the U.S. Department of Agriculture. These terms are defined according to percentages of sand, silt, and clay in soil material that is less than 2 millimeters in diameter. "Loam," for example, is soil material that is 7 to 27 percent clay, 28 to 50 percent silt, and less than 52 percent sand. If a soil contains gravel or other particles coarser than sand, an appropriate modifier is added, for example, "gravelly loam." Other texture terms are defined in the Glossary.

The two systems commonly used in classifying soils for engineering use are the Unified Soil Classification System (*2*) and the system adopted by the American Association of State Highway and Transportation Officials (AASHTO) (*1*).

The *Unified* system classifies soils according to properties that affect their use as construction material. Soils are classified according to grain-size distribution of the fraction less than 3 inches in diameter, plasticity index, liquid limit, and organic-matter content. Soils are grouped into 15 classes—eight classes of coarse-grained soils, identified as GW, GP, GM, GC, SW, SP, SM, and SC; six classes of fine-grained soils, identified as ML, CL, OL, MH, CH, and OH; and one class of highly organic soils, identified as Pt. Soils on the borderline between two classes have a dual classification symbol, for example, CL-ML.

The *AASHTO* system classifies soils according to those properties that affect their use in highway construction and maintenance. In this system a mineral soil is classified in one of seven basic groups ranging from A-1 through A-7 on the basis of grain-size distribution, liquid limit, and plasticity index. Soils in group A-1 are coarse grained and low in content of fines. At the other extreme, in group A-7, are fine-grained soils. Highly organic soils are classified in group A-8 on the basis of visual inspection.

When laboratory data are available, the A-1, A-2, and A-7 groups are further classified as follows: A-1-a, A-1-b, A-2-4, A-2-5, A-2-6, A-2-7, A-7-5, and A-7-6. As an additional refinement, the desirability of soils as subgrade material can be indicated by a group index number. These numbers range from 0 for the best subgrade material to 20 or higher for the poorest. The estimated classification, without group index numbers, is given in table 9. Also in table 9 the percentage, by weight, of rock fragments more than 3 inches in diameter is estimated for each major horizon. These estimates are determined mainly by observing volume percentage in the field and then converting that, by formula, to weight percentage.

Percentage of the soil material less than 3 inches in diameter that passes each of four sieves (U.S. standard) is estimated for each major horizon. The estimates are based on tests of soils that were sampled in the survey area and in nearby areas and on field estimates from many borings made during the survey.

Liquid limit and *plasticity index* indicate the effect of water on the strength and consistence of soil. These indexes are used in both the Unified and AASHTO soil classification systems. They are also used as indicators in making general predictions of soil behavior. Range in liquid limit and plasticity index are estimated on the basis of test data from the survey area or from nearby areas and on observations of the many soil borings made during the survey.

The estimates are rounded to the nearest 5 percent. Thus, if the ranges of gradation and Atterberg limits extend a marginal amount across classification boundaries (1 or 2 percent), the classification in the marginal zone is omitted.

Physical and chemical properties

Table 10 shows estimated values for several soil characteristics and features that affect behavior of soils in engineering uses. These estimates are given for each major horizon, at the depths indicated, in the typical pedon of each soil. The estimates are based on field observations and on test data for these and similar soils.

Permeability is estimated on the basis of known relationships among the soil characteristics observed in the field—particularly soil structure, porosity, and gradation or texture—that influence the downward movement of water in the soil. The estimates are for vertical water movement when the soil is saturated. Not considered in

the estimates is lateral seepage or such transient soil features as plowpans and surface crusts. Permeability of the soil is an important factor to be considered in planning and designing drainage systems, in evaluating the potential of soils for septic tank systems and other waste disposal systems, and in many other aspects of land use and management.

Available water capacity is rated on the basis of soil characteristics that influence the ability of the soil to hold water and make it available to plants. Important characteristics are content of organic matter, soil texture, and soil structure. Shallow-rooted plants are not likely to use the available water from the deeper soil horizons. Available water capacity is an important factor in the choice of plants or crops to be grown and in the design of irrigation systems.

Soil reaction is expressed as a range in pH values. The range in pH of each major horizon is based on many field checks. For many soils, the values have been verified by laboratory analyses. Soil reaction is important in selecting the crops, ornamental plants, or other plants to be grown; in evaluating soil amendments for fertility and stabilization; and in evaluating the corrosivity of soils.

Salinity is expressed as the electrical conductivity of the saturation extract, in millimhos per centimeter at 25 degrees C. Estimates are based on field and laboratory measurements at representative sites of the nonirrigated soils. The salinity of individual irrigated fields is affected by the quality of the irrigation water and by the frequency of water application. Hence, the salinity of individual fields can differ greatly from the value given in table 10. Salinity affects the suitability of a soil for crop production, its stability when used as a construction material, and its potential to corrode metal and concrete.

Shrink-swell potential depends mainly on the amount and kind of clay in the soil. Laboratory measurements of the swelling of undisturbed clods were made for many soils. For others the swelling was estimated on the basis of the kind and amount of clay in the soil and on measurements of similar soils. The size of the load and the magnitude of the change in soil moisture content also influence the swelling of soils. Shrinking and swelling of some soils can cause damage to building foundations, basement walls, roads, and other structures unless special designs are used. A high shrink-swell potential indicates that special design and added expense may be required if the planned use of the soil will not tolerate large volume changes.

Erosion factors are used to predict the erodibility of a soil and its tolerance to erosion in relation to specific kinds of land use and treatment. The soil erodibility factor (K) is a measure of the susceptibility of the soil to erosion by water. Soils having the highest K values are the most erodible. K values range from 0.10 to 0.64. To estimate annual soil loss per acre, the K value of a soil is modified by factors representing plant cover, grade and length of slope, management practices, and climate. The soil-loss tolerance factor (T) is the maximum rate of soil erosion, whether from rainfall or soil blowing, that can occur without reducing crop production or environmental quality. The rate is expressed in tons of soil loss per acre per year.

Soil and water features

Table 11 contains information helpful in planning land uses and engineering projects that are likely to be affected by soil and water features.

Hydrologic soil groups are used to estimate runoff from precipitation. Soils not protected by vegetation are placed in one of four groups on the basis of the intake of water after the soils have been wetted and have received precipitation from long-duration storms.

The four hydrologic soil groups are:

Group A. Soils having a high infiltration rate (low runoff potential) when thoroughly wet. These consist chiefly of deep, well drained to excessively drained sands or gravels. These soils have a high rate of water transmission.

Group B. Soils having a moderate infiltration rate when thoroughly wet. These consist chiefly of moderately deep or deep, moderately well drained or well drained soils that have moderately fine texture to moderately coarse texture. These soils have a moderate rate of water transmission.

Group C. Soils having a slow infiltration rate when thoroughly wet. These consist chiefly of soils that have a layer that impedes the downward movement of water or soils that have moderately fine texture or fine texture. These soils have a slow rate of water transmission.

Group D. Soils having a very slow infiltration rate (high runoff potential) when thoroughly wet. These consist chiefly of clay soils that have a high shrink-swell potential, soils that have a permanent high water table, soils that have a claypan or clay layer at or near the surface, and soils that are shallow over nearly impervious material. These soils have a very slow rate of water transmission.

Flooding is the temporary covering of soil with water from overflowing streams, with runoff from adjacent slopes, and by tides. Water standing for short periods after rains or after snow melts is not considered flooding, nor is water in swamps and marshes. Flooding is rated in general terms that describe the frequency and duration of flooding and the time of year when flooding is most likely. The ratings are based on evidence in the soil profile of the effects of flooding, namely thin strata of gravel, sand, silt, or, in places, clay deposited by floodwater; irregular decrease in organic-matter content with increasing depth; and absence of distinctive soil horizons that form in soils of the area that are not subject to flooding. The ratings are also based on local information about floodwater levels in the area and the extent of flooding and on information that relates the position of each soil on the landscape to historic floods.

The generalized description of flood hazards is of value in land-use planning and provides a valid basis for land-use restrictions. The soil data are less specific, however, than those provided by detailed engineering surveys that delineate flood-prone areas at specific flood frequency levels.

High water table is the highest level of a saturated zone more than 6 inches thick for a continuous period of more than 2 weeks during most years. The depth to a seasonal high water table applies to undrained soils. Estimates are based mainly on the relationship between grayish colors or mottles in the soil and the depth to free water observed in many borings made during the course of the soil survey. Indicated in table 11 are the depth to the seasonal high water table; the kind of water table, that is, perched, artesian, or apparent; and the months that the water table commonly is high. Only saturated zones above a depth of 5 or 6 feet are indicated.

Information about the seasonal high water table helps in assessing the need for specially designed foundations, the need for specific kinds of drainage systems, and the need for footing drains to insure dry basements. Such information is also needed to decide whether or not construction of basements is feasible and to determine how septic tank absorption fields and other underground installations will function. Also, a seasonal high water table affects ease of excavation.

Depth to bedrock is shown for all soils that are underlain by bedrock at a depth of 5 to 6 feet or less. For many soils, the limited depth to bedrock is a part of the definition of the soil series. The depths shown are based on measurements made in many soil borings and on other observations during the mapping of the soils. The kind of bedrock and its hardness as related to ease of excavation is also shown. Rippable bedrock can be excavated with a single-tooth ripping attachment on a 200-horsepower tractor, but hard bedrock requires blasting.

Classification of the soils

The system of soil classification used has six categories (*5*). Beginning with the broadest, these categories are the order, suborder, great group, subgroup, family, and series. In this system the classification is based on the different soil properties that can be observed in the field or those that can be inferred either from other properties that are observable in the field or from the combined data of soil science and other disciplines. The properties selected for the higher categories are the result of soil genesis or of factors that affect soil genesis. In table 12, the soils of the survey area are classified according to the system. Categories of the system are discussed in the following paragraphs.

ORDER. Ten soil orders are recognized as classes in the system. The properties used to differentiate among orders are those that reflect the kind and degree of dominant soil-forming processes that have taken place. Each order is identified by a word ending in *sol*. An example is Mollisol.

SUBORDER. Each order is divided into suborders based primarily on properties that influence soil genesis and are important to plant growth or that are selected to reflect the most important variables within the orders. The last syllable in the name of a suborder indicates the order. An example is Xeroll (*Xer*, meaning dry, plus *oll*, from Mollisol).

GREAT GROUP. Each suborder is divided into great groups on the basis of close similarities in kind, arrangement, and degree of expression of pedogenic horizons; soil moisture and temperature regimes; and base status. Each great group is identified by the name of a suborder and a prefix that suggests something about the properties of the soil. An example is Argixerolls (*Argi*, meaning argillic horizon, plus *xeroll*, the suborder of Mollisols that have a xeric moisture regime).

SUBGROUP. Each great group may be divided into three subgroups: the central (typic) concept of the great groups, which is not necessarily the most extensive subgroup; the intergrades, or transitional forms to other orders, suborders, or great groups; and the extragrades, which have some properties that are representative of the great groups but do not indicate transitions to any other known kind of soil. Each subgroup is identified by one or more adjectives preceding the name of the great group. The adjective *Typic* identifies the subgroup that is thought to typify the great group. An example is Typic Argixerolls.

FAMILY. Families are established within a subgroup on the basis of similar physical and chemical properties that affect management. Among the properties considered in horizons of major biological activity below plow depth are particle-size distribution, mineral content, temperature regime, thickness of the soil penetrable by roots, consistence, moisture equivalent, soil slope, and permanent cracks. A family name consists of the name of a subgroup and a series of adjectives. The adjectives are the class names for the soil properties used as family differentiae. An example is fine, montmorillonitic, thermic, Typic Argixerolls.

SERIES. The series consists of soils that formed in a particular kind of material and have horizons that, except for texture of the surface soil or of the underlying substratum, are similar in differentiating characteristics and in arrangement in the soil profile. Among these characteristics are color, texture, structure, reaction, consistence, and mineral and chemical composition.

Soil series and morphology

In this section, each soil series recognized in the survey area is described in detail. The descriptions are arranged in alphabetic order by series name.

Characteristics of the soil and the material in which it formed are discussed for each series. The soil is then compared to similar soils and to nearby soils of other series. Then a pedon, a small three-dimensional area of soil that is typical of the soil series in the survey area, is described. The detailed descriptions of each soil horizon follow standards in the Soil Survey Manual (*3*). Unless otherwise noted, colors described are for dry soil.

Following the pedon description is the range of important characteristics of the soil series in this survey area. Phases, or map units, of each soil series are described in the section "Soil maps for detailed planning."

Some of the pedons described are outside the survey area. They are typical pedons in the area mapped for the "Soil Survey of Alameda Area, California," which was published in 1966 (*4*).

Altamont series

The Altamont series consists of deep, well drained soils that formed in residuum of soft interbedded sedimentary rock. Altamont soils are on foothills. Slope ranges from 5 to 50 percent. The average annual precipitation ranges from 14 to 20 inches, and the mean annual temperature is 57 degrees F.

Altamont soils are similar to the Clear Lake, Diablo, and Climara soils. The Clear Lake soils have slopes of 0 to 9 percent and do not have a paralithic or lithic contact. The Diablo and Climara soils when moist have chroma of less than 1.5 in the upper part of the solum.

Typical pedon of Altamont clay, 30 to 50 percent slopes, 750 feet east and 2,250 feet south of the northeast corner of sec. 19, T. 2 S., R. 3 E. (outside the survey area):

A11—0 to 7 inches; dark brown (10YR 4/3) clay, dark brown (10YR 3/3) moist; grayish brown (10YR 5/2) in the very thin surface crust; strong coarse prismatic structure parting to strong coarse and medium blocky, with very dark brown to black carbonaceous films and mats on some ped faces; very hard, very firm, sticky and very plastic; many fine flattened, exped roots; few very fine tubular pores; slightly acid; clear smooth boundary.

A12—7 to 19 inches; dark brown (10YR 4/3) clay, dark brown (10YR 3/3) moist; moderate coarse prismatic structure parting to moderate coarse blocky; very hard, very firm, sticky and very plastic; few fine exped roots; few very fine tubular pores; many slickensides; matrix is noneffervescent but has few whitish lime coats on faces of peds in lower part; neutral; clear smooth boundary.

A13—19 to 28 inches; dark brown (10YR 4/3) clay, dark brown (10YR 3/3) moist; moderate coarse prismatic structure parting to moderate coarse and medium blocky; very hard, very firm, sticky and very plastic; few fine exped roots; few very fine tubular pores; many slickensides; slightly effervescent with few fine whitish soft coatings on faces of peds; mildly alkaline; clear smooth boundary.

ACca—28 to 37 inches; finely mixed dark brown (10YR 4/3) and dark yellowish brown (10YR 4/4) clay, dark brown (10YR 3/3) and dark yellowish brown (10YR 3/4) moist; weak coarse prismatic structure parting to moderate medium blocky; very hard, very firm, sticky and very plastic; few fine exped roots; few very fine tubular pores; few soft, fine, yellowish brown (10YR 5/6, 5/8) segregations of iron oxide; few small embedded fragments of shale; many slickensides; strongly effervescent; carbonates mostly disseminated with few fine whitish soft to slightly hard segregations and films of lime; mildly alkaline; clear smooth boundary.

C1ca—37 to 50 inches; yellowish brown (10YR 5/4) clay, dark yellowish brown (10YR 4/4) moist; weak medium blocky structure; very hard, very firm, sticky and plastic; few fine roots mostly along structural faces; few very fine tubular pores; few small fragments of shale; few slickensides; strongly effervescent; many whitish, soft to slightly hard segregations and nodules of lime; moderately alkaline; clear smooth boundary.

C2r—50 inches; olive (5Y 5/3) highly fractured and weathered fine grained sandstone and shale, dark olive (5YR 3/3) moist.

Depth to sedimentary rock ranges from 40 to 60 inches. The A horizon is dark brown, brown, dark grayish brown, or very dark grayish brown (10YR 4/3, 5/3, 4/2, or 3/2). Reaction is slightly acid to mildly alkaline. Thickness of the A horizon ranges from 20 to 28 inches. After a long dry period, cracks 1/4 inch to 2 inches wide extend from the surface through the A horizon and into the upper part of the C horizon. Coarse and very coarse prismatic structure is formed as a result of the cracking. Depth to free lime ranges from 15 to 36 inches.

The C1ca horizon ranges from 6 to 14 inches in thickness. This horizon is clay or silty clay and is as much as 10 percent gravel in areas where the soil formed in soft conglomerate.

Azule series

The Azule series consists of moderately deep, well drained soils that formed in residuum of consolidated alluvial sediment, soft shale, or fine grained sandstone. Azule soils are on uplands and have slopes ranging from 9 to 50 percent. The average annual precipitation ranges

from 14 to 24 inches, and the mean annual temperature is 57 degrees F.

Azule soils are similar to Contra Costa, Los Osos, and Rincon soils and are near Altamont, Diablo, Los Osos, Tierra, and Rincon soils. Contra Costa soils have hue of 7.5YR or 5YR in the Bt horizon and have hard bedrock at a depth of 20 to 40 inches. Los Osos soils have a mollic epipedon. Rincon soils are very deep. Altamont and Diablo soils are more than 35 percent clay throughout. Tierra soils are very deep and have an abrupt boundary between the A and B horizons.

Typical pedon of Azule clay loam, about 10 miles southeast of Pleasanton, in the SE1/4SE1/4NW1/4 of sec. 24, T. 4 S., R. 1 E. (projected in the Valle de San Jose Land Grant). This site is outside the survey area:

A1—0 to 6 inches; grayish brown (10YR 5/2) clay loam, very dark grayish brown (2.5Y 3/2) moist; massive; hard, firm, sticky and plastic; many fine and very fine roots; many very fine, common fine, and few medium tubular pores; slightly acid; clear smooth boundary.

B21t—6 to 12 inches; grayish brown (10YR 5/2) clay, very dark grayish brown (2.5Y 3/2) moist; moderate coarse prismatic structure parting to strong medium angular blocky; very hard, very firm, sticky and plastic; many fine and common very fine roots; many very fine and fine tubular pores; common thin clay films on faces of peds and in pores; slightly acid; diffuse smooth boundary.

B22t—12 to 21 inches; dark grayish brown (2.5Y 4/2) clay, very dark grayish brown (2.5Y 3/2) moist; moderate coarse prismatic structure parting to moderate medium angular blocky; very hard, very firm, sticky and very plastic; many fine and very fine roots; many very fine and fine and few medium pores; common moderately thick clay films on faces of peds and in pores; slightly acid; gradual irregular boundary.

B3—21 to 25 inches; grayish brown (2.5Y 5/2) and light yellowish brown (2.5Y 6/4) clay that has a mottled appearance, very dark grayish brown (2.5Y 3/2) and light olive brown (2.5Y 5/4) moist; moderate coarse subangular blocky structure; very hard, very firm, sticky and very plastic; few very fine roots; many very fine and fine tubular pores; common thin clay films on faces of peds and in pores; slightly acid; clear smooth boundary.

Cr—25 inches; light yellowish brown (2.5Y 6/4) consolidated alluvial sediment, light olive brown (2.5Y 5/4) moist.

The solum is 24 to 40 inches thick. The content of coarse fragments in the solum is 0 to 15 percent. Reaction ranges from medium acid through neutral.

The A1 horizon is grayish brown or dark grayish brown (10YR 5/2, 4/2). It is clay loam or silty clay loam. The B2t horizon is grayish brown, dark grayish brown, or brown (10YR 5/2, 4/2, 5/3). It ranges from clay to sandy clay. The Cr horizon is light yellowish brown or yellowish brown (2.5Y 6/4; 10YR 5/6). Depth to the Cr horizon is 24 to 40 inches.

Baywood series

The Baywood series consists of very deep, somewhat excessively drained soils that formed in sandy eolian deposits that derived from old beach deposits. These soils are on mounds and ridges. The slopes range from 0 to 9 percent. The average annual precipitation ranges from 16 to 18 inches, and the mean annual temperature is about 57 degrees F.

Baywood soils are associated with and are similar to the sandy Xerorthents, which do not have a mollic epipedon. They are associated with the Tierra and Reyes soils. Tierra soils have an argillic horizon and a fine control section. Reyes soils are very poorly drained and clayey.

Typical pedon of Baywood loamy sand, in an area of Urban land-Baywood complex, in the city of Alameda, at the intersection of Eighth Street and Santa Clara Avenue:

A11—0 to 16 inches; grayish brown (10YR 5/2) loamy sand, very dark grayish brown (10YR 3/2) moist; weak medium and fine granular structure; soft, very friable, nonsticky and nonplastic; many very fine roots; many fine interstitial pores; slightly acid; clear smooth boundary.

A12—16 to 32 inches; brown (10YR 5/3) loamy sand, dark brown (10YR 3/3) moist; massive; soft, very friable, nonsticky and nonplastic; few very fine roots; many fine interstitial pores; slightly acid; diffuse wavy boundary.

C1—32 to 44 inches; pale brown (10YR 6/3) loamy sand, light brownish gray (10YR 6/2) moist; massive; soft, very friable, nonsticky and nonplastic; few fine roots; many fine interstitial pores; slightly acid; diffuse wavy boundary.

C2—44 to 60 inches; light yellowish brown (10YR 6/4) loamy sand, dark brown (7.5YR) moist; thin discontinuous wavy sandy loam lamellae, reddish brown (5YR 4/4) moist; massive; slightly hard, friable, slightly sticky and slightly plastic; no roots; few very fine tubular pores in the lamellae; slightly acid.

Reaction is neutral to strongly acid. In many pedons, the soil material is more acid as depth increases. It is sand or loamy sand throughout. The profile is not stratified.

The A horizon is grayish brown, brown, dark brown, or very dark gray (10YR 5/2, 5/3, 3/3, 3/1). The C horizon is light yellowish brown or pale brown (10YR 6/4, 6/3). Lamellae are dark brown, strong brown, reddish brown, or reddish yellow (7.5YR 3/3, 5/6; 5YR 5/4, 6/6). In

some pedons there are a few dark reddish brown (5YR 3/3) concretions ranging from 2 to 5 mm in diameter.

Baywood Variant

The Baywood Variant soils are very deep and somewhat poorly drained. They formed in sandy sediment on old coastal plains. The slopes are 0 to 2 percent. The average annual precipitation ranges from 15 to 18 inches, and the mean annual temperature is 57 degrees F.

Baywood Variant soils are similar to Xeropsamments, which are fill soils that consist of beach sand that was dredged from the peripheral areas of Alameda Naval Air Station and Oakland Airport.

Typical pedon of Baywood Variant, sand, on Bay Farm Island, 200 feet north of center of sec. 25, T. 2 S., R. 4 W.

Ap—0 to 14 inches; dark grayish brown (10YR 4/2) sand, very dark brown (10YR 2/2) moist; weak fine granular structure; soft, very friable, nonsticky and nonplastic; common fine and very fine roots; few very fine tubular and interstitial pores; slightly effervescent; mildly alkaline; gradual smooth boundary.

A12—14 to 21 inches; very dark grayish brown (10YR 3/2) sand, very dark brown (10YR 2/2) moist; common medium distinct strong brown mottles (7.5YR 5/6, 5/8); weak fine granular structure; soft, very friable, nonsticky and nonplastic; common very fine and fine roots; very few very fine tubular and interstitial pores; slightly effervescent; mildly alkaline; gradual smooth boundary.

C1—21 to 32 inches; brown (10YR 5/3) sand, dark brown (7.5YR 4/4) moist; common fine distinct strong brown (7.5YR 5/6, 5/8) mottles; single grained; loose; neutral; gradual smooth boundary.

C2—32 to 60 inches; yellowish brown (10YR 5/4) sand, dark yellowish brown (10YR 4/4) moist; single grained; loose; neutral.

The water table generally is at a depth of 40 to 50 inches; in a few areas it is at a depth of 18 inches in winter.

The A horizon is gray, dark gray, grayish brown, dark grayish brown, and very dark grayish brown (10YR 5/1, 4/1, 5/2, 4/2, 3/2). In some places it is noncalcareous, and in other places it is calcareous and may contain small shells. The A horizon is 20 to 24 inches thick. Reaction is neutral to moderately alkaline. The C horizon is brown, yellowish brown, light yellowish brown, or light olive brown (10YR 5/3, 5/4, 6/4; 2.5Y 5/4).

Botella series

The Botella series consists of very deep, well drained soils that formed in alluvium that derived mainly from sedimentary rock sources. Botella soils are on low terraces and alluvial fans and have slopes ranging from 0 to 2 percent. The average annual precipitation ranges from 14 to 20 inches. The mean annual temperature is 57 degrees F.

Botella soils are similar to Danville soils and are associated with Rincon and Yolo soils. Danville soils have an argillic horizon and a fine control section. Rincon soils have an ochric epipedon. Yolo soils have an ochric epipedon and do not have an argillic horizon.

Typical pedon of Botella loam, in the town of Fremont, 1,800 feet northwest and 600 feet south of the intersection of Fremont Boulevard and Mowry Avenue:

Ap—0 to 9 inches; grayish brown (10YR 5/2) loam, very dark grayish brown (10YR 3/2) moist; moderate medium subangular blocky structure; hard, friable, slightly sticky and slightly plastic; many very fine, fine, and medium roots; many fine and medium and common coarse tubular pores; neutral; clear smooth boundary.

B2t—9 to 22 inches; dark grayish brown (10YR 4/2) light clay loam, very dark grayish brown (10YR 3/2) moist; weak medium prismatic structure parting to moderate medium angular blocky; very hard, firm, sticky and slightly plastic; common very fine and fine roots; common very fine and fine and few medium tubular and interstitial pores; common moderately thick clay films lining pores and on faces of peds; neutral; gradual smooth boundary.

B3t—22 to 33 inches; dark brown (10YR 4/3) light clay loam, dark brown (10YR 3/3) moist; moderate medium angular blocky structure; hard, friable, sticky and slightly plastic; few moderately thick clay films lining pores and on faces of peds; neutral; gradual smooth boundary.

C1—33 to 42 inches; brown (10YR 5/3) clay loam, dark brown (10YR 4/3) moist; weak moderate and fine angular blocky structure; hard, friable, sticky and slightly plastic; mildly alkaline; diffuse smooth boundary.

C2—42 to 60 inches; yellowish brown (10YR 5/4) when moist; silt loam; weak coarse angular blocky structure; hard, friable, sticky and slightly plastic; slightly effervescent; moderately alkaline.

The A horizon is grayish brown or dark grayish brown (10YR 5/2, 4/2). It is granular or subangular blocky in structure. It is neutral or mildly alkaline. The B2t horizon is dark brown, dark grayish brown, or very dark grayish brown (10YR 4/3, 4/2, 3/2). It ranges from heavy loam to clay loam. The B2t horizon is neutral or mildly alkaline. The C horizon is dark grayish brown, grayish brown, brown, or yellowish brown (10YR 4/2, 5/2, 4/3, 5/3, 5/4). It is sandy loam, silt loam, loam, or clay loam. The C horizon is mildly alkaline or moderately alkaline. Botella soils in this survey area are browner and have higher pH values than is defined in the range for the series. This

difference, however, does not significantly affect their use and management.

Clear Lake series

The Clear Lake series consists of very deep, poorly drained soils that formed in alluvium that derived mainly from sedimentary rock sources. These soils are in basins or in areas of the coastal valley. The slopes are concave and range from 0 to 9 percent. The average annual precipitation ranges from 14 to 20 inches. The mean annual temperature is 57 degrees F.

Clear Lake soils are similar to Altamont, Diablo, and Climara soils. They are associated with Omni and Pescadero soils. Altamont, Diablo, and Climara soils have a lithic or paralithic contact within a depth of 60 inches and in some horizons have moist chroma of 1.5 or more above a depth of 40 inches. Omni soils do not have intersecting slickensides, and the content of organic matter decreases irregularly with depth. The Pescadero soils have a natric horizon.

Typical pedon of Clear Lake clay, drained, near Russell City, 2,000 feet east and 1,650 feet north of the sewage disposal plant on Depot Road:

Ap—0 to 9 inches; very dark gray (N 3/0) clay, black (N 2/0) moist; strong coarse prismatic structure parting to coarse angular blocky; extremely hard, very firm, very sticky and very plastic; many fine tubular pores; neutral; gradual smooth boundary.

A12—9 to 26 inches; very dark gray (N 3/0) clay, black (N 2/0) moist; strong coarse prismatic structure parting to coarse angular blocky; extremely hard, very firm, very sticky and very plastic; many very fine roots; very few very fine tubular pores; many slickensides; moderately alkaline; gradual wavy boundary.

ACca—26 to 37 inches; very dark gray (N 3/0) clay, black (10YR 2/1) moist; strong coarse prismatic structure parting to coarse angular blocky; extremely hard, firm, very sticky and very plastic; common very fine roots; very few very fine tubular pores; many intersecting slickensides; lime occurring in seams; moderately alkaline; gradual smooth boundary.

C1ca—37 to 48 inches; dark gray (5Y 4/1) clay, very dark gray (5Y 3/1) moist; many fine distinct yellowish brown (10YR 5/4) mottles; weak fine angular blocky structure; slightly hard, friable, sticky and plastic; few very fine roots; few very fine pores; many intersecting slickensides; lime occurring as fine soft masses; moderately alkaline; gradual smooth boundary.

C2ca—48 to 60 inches; grayish brown (2.5Y 5/2) silty clay, dark grayish brown (2.5Y 4/2) moist; many fine distinct yellowish brown (10YR 5/6) mottles; weak fine angular blocky structure; hard, friable, sticky and plastic; no roots; many very fine tubular pores; lime occurring throughout the soil matrix; moderately alkaline.

In summer, cracks that are 1/2 inch to 2 inches wide extend from the surface to the C horizon and form very coarse and coarse prismatic structure.

The A horizon is dark gray, very dark gray, or black (N 4/0, 3/0, 2/0). It is slightly acid to moderately alkaline. In some pedons, a few fine concretions of lime are in the Ap or A12 horizon. The C horizon is olive, light olive brown, grayish brown, dark gray, or dark grayish brown (5Y 5/3; 2.5Y 5/4, 5/2, 4/1, 4/2) clay loam, silty clay loam, silty clay, or clay.

Climara series

The Climara series consists of moderately deep, well drained soils that formed in residuum of ultrabasic rock. Climara soils are on uplands and have slopes ranging from 30 to 50 percent. The average annual precipitation ranges from 18 to 22 inches, and the mean annual temperature is 57 degrees F.

Climara soils are similar to Altamont, Diablo, and Clear Lake soils and are near Los Osos and Altamont soils. Altamont and Diablo soils have a paralithic contact at a depth greater than 40 inches. Clear Lake soils have chroma of less than 1.5 at a depth of 40 inches or more and do not have a paralithic or lithic contact. Los Osos soils have a mollic epipedon and an argillic horizon.

Typical pedon of Climara clay, on a moderately steep west-facing grassy slope, in the hills east of San Leandro, 400 feet north of the county dog pound, in the NW1/4SW1/4NW1/4 of sec. 32, T. 2 W., R. 2 S. (projected):

A11—0 to 9 inches; black (10YR 2/1) clay, dry and moist; strong coarse prismatic structure; very hard, firm, sticky and very plastic; common fine roots; common fine tubular pores; neutral; diffuse wavy boundary.

A12—9 to 22 inches; black (10YR 2/1) clay, dry and moist; strong coarse prismatic structure; very hard, firm, sticky and very plastic; common fine roots; common fine tubular pores; few intersecting slickensides; neutral; clear wavy boundary.

A13—22 to 27 inches; black (10YR 2/1) clay, dry and moist; some splotches of variegated very dark grayish brown (2.5Y 3/2) and olive (5Y 4/4, 5/6) moist; strong coarse prismatic structure; very hard, firm, sticky and very plastic; common fine roots; common fine tubular pores; numerous slickensides; mildly alkaline; clear wavy boundary.

C1ca—27 to 33 inches; variegated very dark brown (10YR 2/2), olive brown (2.5Y 4/4), and olive (2.5Y 4/4) clay, dry and moist; moderate medium subangular blocky structure; very hard, firm, sticky and plastic; few fine roots; common fine tubular pores;

strongly effervescent; moderately alkaline; abrupt wavy boundary.
C2r—33 to 40 inches; soft weathered ultrabasic rock that has yellowish brown and dark brown (10YR 5/6, 3/3) coatings along fracture planes.
R—40 inches; hard ultrabasic rock.

These soils have cracks more than one inch wide that extend to a depth of 20 inches or more. Depth to bedrock is 20 to 40 inches. The A horizon ranges from 16 to 31 inches in thickness. In places, the lower part of this horizon is calcareous. The A horizon is black, very dark gray, or dark gray (10YR 2/1, 3/1, 4/1). The C horizon is as much as 35 percent pebbles. Some pedons do not have a C2r horizon.

Contra Costa series

The Contra Costa series consists of moderately deep, well drained soils that formed in residuum of metabasic and metasedimentary rock. These soils are on uplands. The slopes range from 30 to 50 percent. The average annual precipitation ranges from 14 to 18 inches. The mean annual temperature is 57 degrees F.

Contra Costa soils are similar to Azule soils and are associated with Vallecitos soils. Azule soils have a paralithic contact between 24 and 40 inches. Vallecitos soils have a lithic contact at a depth between 10 and 20 inches.

Typical pedon of Contra Costa clay loam, in a roadcut overlooking salt ponds, in Coyote Hills Regional Park, 700 feet west and 700 feet north of water tower:

A11—0 to 7 inches; brown (7.5YR 5/2) clay loam, dark brown (7.5YR 3/2) moist; massive; hard, friable, sticky and plastic; many very fine, fine, and medium roots; common fine and very fine tubular pores; 5 percent small angular gravel; neutral; diffuse smooth boundary.
A12—7 to 24 inches; brown (7.5YR 5/2) clay loam, dark brown (7.5YR 3/2) moist; massive; hard, friable, sticky and plastic; common medium and very fine roots; few medium and fine tubular pores; 5 percent small angular gravel; neutral; gradual smooth boundary.
B21t—24 to 30 inches; reddish brown (5YR 4/4) heavy clay loam, dark reddish brown (5YR 3/3) moist; massive; very hard, friable, sticky and plastic; common very fine roots; few medium tubular pores; few very thin clay films; neutral; clear smooth boundary.
B22t—30 to 35 inches; yellowish red (5YR 4/6) gravelly clay, dry and moist; massive; hard, firm, sticky and very plastic; few very fine roots; few very thin clay films; 15 percent gravel; neutral; abrupt wavy boundary.
R—35 inches; fractured, partly weathered, metasedimentary bedrock.

The A horizon is dark reddish brown, brown, or dark brown (5YR 3/2, 3/3; 7.5YR 5/2, 4/2, 3/2). Gravel content ranges from 5 to 15 percent. The A horizon is slightly acid or neutral. The B2t horizon is dark brown, reddish brown, or yellowish red (7.5YR 3/2, 4/4; 5YR 4/4, 4/6). It is heavy clay loam or light clay and is as much as 25 percent cobbles, the largest percentage making up the lower part of the horizon. The B2t horizon is medium acid to neutral. Depth to bedrock ranges from 20 to 40 inches.

Danville series

The Danville series consists of very deep, well drained soils that formed in alluvium that derived mainly from sedimentary rock sources. These soils are on low terraces and alluvial fans and have slopes ranging from 0 to 9 percent. The average annual precipitation ranges from 14 to 20 inches, and the mean annual temperature is 57 degrees F.

Danville soils are similar to and are near Botella and Rincon soils. Botella soils have a fine-loamy control section. Rincon soils have an ochric epipedon.

Typical pedon of Danville silty clay loam, 2.5 miles north of intersection of Crow Canyon Road and Cull Canyon Road, in a roadcut on the east side of Cull Canyon Road (outside of the survey area):

A11—0 to 10 inches; grayish brown (10YR 5/2) silty clay loam, very dark gray (10YR 3/1) moist; weak fine granular structure; slightly hard, friable, sticky and plastic; many very fine roots; many very fine, common fine and medium, and few coarse pores; slightly acid; gradual smooth boundary.
A12—10 to 21 inches; dark gray (10YR 4/1) silty clay loam, very dark gray (10YR 3/1) moist; weak fine granular structure; hard, friable, sticky and plastic; many very fine roots; many very fine, common fine, and few medium pores; slightly acid; gradual smooth boundary.
B21t—21 to 39 inches; grayish brown (10YR 5/2) silty clay, very dark grayish brown (10YR 3/2) moist; weak medium prismatic structure parting to strong medium blocky; very hard, firm, very sticky and plastic; common very fine roots; many very fine tubular pores; common thick continuous clay films on faces of peds and in pores; slightly acid; gradual smooth boundary.
B22t—39 to 53 inches; grayish brown (10YR 5/2) heavy silty clay loam, dark grayish brown (10YR 4/2) moist; strong coarse blocky structure; very hard, firm, very sticky and plastic; few very fine roots; many very fine pores; common thick continuous clay films on faces of peds and in tubular pores; slightly acid; gradual smooth boundary.
B3t—53 to 61 inches; grayish brown (10YR 5/2) silty clay loam, dark grayish brown (10YR 4/2) moist;

moderate coarse blocky structure; hard, friable, sticky and plastic; few very fine roots; common very fine pores; thick continuous clay films in tubular pores; few thick continuous clay films on faces of peds; neutral; gradual smooth boundary.

C—61 to 80 inches; grayish brown (10YR 5/2) silty clay loam, dark brown (10YR 4/3) moist; massive; hard, friable, sticky and plastic; few very fine roots; few very fine pores; thin discontinuous clay films in some pores; neutral.

The A1 horizon is dark gray, very dark gray, grayish brown, or dark grayish brown (10YR 4/1, 3/1, 5/2, 4/2). Structure is granular or subangular blocky. The B2t horizon is grayish brown or dark grayish brown (10YR 5/2, 4/2) heavy silty clay loam, silty clay, or clay. It is slightly acid or neutral. The C horizon is grayish brown, brown, or dark yellowish brown (10YR 5/2, 5/3, 4/4). It is neutral to moderately alkaline. In some pedons, the C horizon is calcareous.

Diablo series

The Diablo series consists of deep, well drained soils that formed in residuum of calcareous, soft fine-grained sandstone or shale. These soils are on foothills near Mission San Jose. The slopes range from 9 to 50 percent. The average annual precipitation ranges from 14 to 20 inches, and the mean annual temperature is 57 degrees F.

Diablo soils are similar to and are geographically associated with Altamont, Clear Lake, and Climara soils. Altamont soils have chroma of 2 or more throughout the profile. Clear Lake soils are very deep, nearly level to moderately sloping soils that do not have a paralithic contact within a depth of 80 inches. Climara soils have a lithic contact between depths of 20 and 40 inches.

Typical pedon of Diablo clay, 1,325 feet east and 275 feet north of the southwest corner of sec. 25, T. 2 S., R. 1 E. (outside the survey area):

Ap—0 to 6 inches; dark gray (5Y 4/1) clay, the immediate surface crust being light gray (5Y 7/1), very dark gray (5Y 3/1) moist; strong medium granular structure in the upper 3 inches and strong coarse and medium blocky in the lower 3 inches; very hard, very firm, sticky and very plastic; common fine roots; few fine and very fine tubular pores; neutral; clear wavy boundary.

A12—6 to 15 inches; dark gray (5Y 4/1) silty clay, very dark gray (5Y 3/1) moist; moderate coarse prismatic structure parting to moderate coarse blocky; very hard, very firm, very sticky and very plastic; few fine exped roots; few fine and very fine tubular pores; few slickensides; matrix is noneffervescent except for occasional fine hard whitish lime nodules; mildly alkaline; clear smooth boundary.

A13ca—15 to 26 inches; variegated gray (5Y 5/1) and olive gray (5Y 5/2) silty clay, dark gray (5Y 4/1) and olive gray (5Y 4/2) moist; moderate coarse prismatic structure parting to moderate medium blocky; very hard, very firm, sticky and very plastic; few fine exped roots; few fine and very fine tubular pores; many intersecting slickensides; slightly effervescent with few fine hard whitish lime nodules; mildly alkaline; clear wavy boundary.

A14ca—26 to 32 inches; variegated gray (5Y 5/1) and olive gray (5Y 5/2) silty clay, dark gray (5Y 4/1) and olive gray (5Y 4/2) moist; weak coarse prismatic structure that parts to weak medium blocky; very hard, very firm, sticky and very plastic; few fine exped roots; few fine and very fine tubular pores; numerous intersecting slickensides; slightly effervescent with few fine exped roots; few fine and very fine tubular pores; numerous intersecting slickensides; slightly effervescent with few fine hard whitish lime nodules; mildly alkaline; diffuse smooth boundary.

ACca—32 to 42 inches; light olive gray (5Y 6/2) silty clay, olive gray (5Y 5/2) moist; weak medium subangular blocky structure; very hard, very firm, slightly sticky and plastic; few fine roots; few fine and very fine tubular pores; strongly effervescent with many fine whitish soft lime segregations; mildly alkaline; clear wavy boundary.

C1—42 to 50 inches; variegated olive gray (5Y 5/2) and light olive gray (5Y 6/2) silty clay loam that has many soft shale fragments, olive gray (5Y 5/2 and 4/2) moist; weak fine and medium subangular blocky structure; very hard, very firm, slightly sticky and plastic; few fine roots; few fine and very fine tubular pores; strongly effervescent with many fine and medium whitish lime films and soft to hard lime nodules; moderately alkaline; clear smooth boundary.

C2r—50 inches; light olive gray (5Y 6/2) thinly bedded shale; whitish lime coatings along bedding planes.

Depth to bedrock ranges from 40 to 60 inches. The A horizon is dark gray, gray, or very dark gray (5Y 4/1, 5/1, 3/1) but may be mixed with olive gray (5Y 4/2) in the lower part. After a long dry period, cracks that are as much as 4 inches wide at the surface extend into the C horizon. The A horizon is slightly acid to mildly alkaline in the upper part and mildly alkaline or moderately alkaline in the lower part. In the upper part of the A horizon the soil material typically is noncalcareous, but in some pedons there are a few fine lime nodules.

Gaviota series

The Gaviota series consists of shallow, well drained soils that formed in residuum of sandstone. These soils are on uplands and have slopes ranging from 15 to 50

percent. The average annual precipitation ranges from 15 to 25 inches, and the mean annual air temperature is 57 degrees F.

Gaviota soils are similar to and are near the Maymen and Millsholm soils. The Maymen soils have a base saturation of less than 60 percent. The Millsholm soils have a cambic horizon.

Typical pedon of Gaviota sandy loam, in the NW1/4NE1/4 of sec. 30, T. 3 S., R. 2 W. (outside the survey area):

A11—0 to 1 inch; brown (10YR 5/3) sandy loam, dark brown (10YR 4/3) moist; weak very fine granular structure; soft, friable, nonsticky and nonplastic; many very fine roots; many very fine pores; slightly acid; clear wavy boundary.

A12—1 inch to 11 inches; brown (10YR 5/3) sandy loam, dark brown (10YR 4/3) moist; massive; slightly hard, friable, nonsticky and nonplastic; medium acid; abrupt irregular boundary.

R—11 inches; yellowish brown (10YR 5/6) hard sandstone.

The A1 horizon is brown or grayish brown (10YR 4/3, 5/3). It is medium acid to neutral. It is as much as 15 percent pebbles. Depth to bedrock ranges from 10 to 20 inches.

Laugenour series

The Laugenour series consists of very deep, poorly drained soils that formed in recent alluvium from mixed sources. These soils are on alluvial plains adjacent to streams. They have slopes ranging from 0 to 2 percent. The average annual precipitation ranges from 15 to 18 inches. The mean annual temperature is 57 degrees F.

The Laugenour soils are associated with and are similar to Sycamore soils. Sycamore soils are more than 18 percent clay in the control section.

Typical pedon of Laugenour loam, drained, in Fremont, .15 mile northwest of San Lorenzo Creek, 100 feet northeast of railroad track, .15 mile south-southwest of intersection of Lewelling and Wick Boulevard, at the end of the trailer park:

Ap—0 to 8 inches; grayish brown (2.5Y 5/2) loam, mixed very dark grayish brown and dark grayish brown (2.5Y 3/2, 4/2) moist; massive; hard, friable, sticky and plastic; many very fine and few fine roots; common fine tubular pores; moderately alkaline; clear smooth boundary.

A12—8 to 19 inches; grayish brown (2.5Y 5/2) fine sandy loam, dark grayish brown (2.5Y 4/2) moist; common fine distinct dark yellowish brown (10YR 4/4) mottles; massive; slightly hard, friable, slightly sticky and slightly plastic; many very fine and fine roots; many very fine and fine tubular pores; slightly effervescent; moderately alkaline; abrupt wavy boundary.

A13—19 to 23 inches; grayish brown (2.5Y 5/2) fine sandy loam, very dark grayish brown (2.5Y 3/2) moist; many fine prominent dark yellowish brown (10YR 4/4) mottles; massive; slightly hard, friable, slightly sticky and nonplastic; common very fine roots; many very fine and fine tubular pores; slightly effervescent; moderately alkaline; abrupt smooth boundary.

C1—23 to 40 inches; olive gray (5Y 5/2) loam, dark olive gray (5Y 3/2) moist; many medium prominent light brownish gray (2.5Y 6/2) and light gray (2.5Y 7/2) mottles; massive; slightly hard, friable, sticky and slightly plastic; few very fine roots; common very fine tubular pores; slightly effervescent; moderately alkaline; abrupt smooth boundary.

IIC2—40 to 60 inches; grayish brown (2.5Y 5/2) and yellow (2.5Y 7/6) silty clay loam, olive gray (5Y 4/2) and olive (5Y 4/4) moist; massive; slightly hard, friable, sticky and plastic; no roots; few very fine pores; slightly effervescent with lime disseminated and in small soft masses; moderately alkaline.

The A horizon is grayish brown or light grayish brown (2.5Y 5/2, 6/2). The soils are calcareous below a depth of 8 to 20 inches. The control section is stratified with thin lenses of silt loam.

Los Gatos series

The Los Gatos series consists of moderately deep, well drained soils that formed in residuum of interbedded sedimentary rock. These soils are on north-facing slopes or on toe slopes on uplands. The slopes range from 30 to 75 percent. The average annual precipitation ranges from 15 to 25 inches. The mean annual temperature is 56 degrees F.

Los Gatos soils are associated with and are similar to Los Osos, Maymen, and Millsholm soils. Los Osos soils have a fine control section. Maymen and Millsholm soils have a lithic contact within a depth of 20 inches.

Typical pedon of Los Gatos loam, in a roadcut in the SE1/4SE1/4SW1/4SW1/4 of sec. 3, T. 4 S., R. 2 E. (projected). This site is outside the survey area:

A11—0 to 5 inches; brown (10YR 4/3) loam, dark brown (10YR 3/3) moist; moderate fine granular structure; slightly hard, friable, slightly sticky and slightly plastic; many very fine roots; few fine and very fine interstitial pores; neutral; clear smooth boundary.

A12—5 to 11 inches; brown (10YR 4/3) loam, dark brown (7.5YR 3/2) moist; moderate medium granular structure; hard, friable, slightly sticky and slightly plastic; many very fine roots; few medium and fine tubular pores, many very fine tubular pores, and many very fine interstitial pores; neutral; gradual smooth boundary.

B1—11 to 19 inches; brown (10YR 4/3) loam, dark brown (7.5YR 3/2) moist; massive; hard, friable, slightly sticky and slightly plastic; many very fine and few fine and medium roots; few medium and fine tubular pores, many very fine tubular pores, and many very fine interstitial pores; many discontinuous clay films in pores; neutral; gradual smooth boundary.

B2t—19 to 32 inches; reddish brown (5YR 5/4) heavy loam, dark reddish brown (5YR 3/4) moist; massive; slightly hard, friable, slightly sticky and slightly plastic; many very fine and few fine and medium roots; few medium and fine and many very fine tubular pores and many very fine interstitial pores; continuous clay films in pores; neutral; gradual smooth boundary.

B3t—32 to 40 inches; brown (7.5YR 5/4) loam, dark brown (7.5YR 4/4) moist; massive; slightly hard, friable, slightly sticky and slightly plastic; few very fine, fine, and medium roots; many very fine tubular and interstitial pores; slightly acid; gradual irregular boundary.

R—40 inches; very pale brown (10YR 7/4) shattered sandstone.

The A11 horizon is loam or silt loam. It is brown or dark brown (10YR 4/3, 3/3). Structure is moderate fine or moderate medium granular or subangular blocky. Reaction ranges from medium acid to neutral. The B2t horizon is heavy loam or clay loam that is as much as 15 percent pebbles. It is brown or reddish brown (7.5YR 5/4, 5YR 4/4). Depth to bedrock is 24 to 40 inches.

Los Osos series

The Los Osos series consists of moderately deep, well drained soils that formed in residuum of interbedded sedimentary rock. The slopes range from 9 to 75 percent. The average annual precipitation ranges from 15 to 25 inches, and the mean annual temperature is 57 degrees F.

Los Osos soils are similar to Los Gatos soils and are associated with Los Gatos, Maymen, and Millsholm soils. Los Gatos soils have a fine-loamy control section. Maymen and Millsholm soils have a lithic contact within a depth of 20 inches.

Typical pedon of Los Osos silty clay loam, 40 feet east and 120 feet south of the northwest corner of sec. 19, T. 2 S., R. 1 W. (projected). This site is outside the survey area:

A1—0 to 8 inches; grayish brown (10YR 5/2) silty clay loam, very dark grayish brown (2.5Y 3/2) moist; moderate medium granular structure; hard, friable, sticky and plastic; few medium and many fine and very fine roots; few medium and common very fine pores; few worm casts; medium acid; gradual wavy boundary.

B21t—8 to 24 inches; dark grayish brown (10YR 4/2) heavy silty clay loam, very dark grayish brown (10YR 3/2) moist; moderate medium subangular blocky structure; hard, friable, sticky and plastic; few fine and many very fine roots; few medium and common very fine pores; many moderately thick clay films on faces of peds; slightly acid; gradual wavy boundary.

B22t—24 to 30 inches; dark grayish brown (10YR 4/2) silty clay loam, dark brown (10YR 3/3) moist; moderate medium subangular blocky structure; hard, friable, sticky and plastic; few fine and many very fine roots; few medium and fine and common very fine pores; common thin clay films in pores and on faces of peds; slightly acid; clear irregular boundary.

Cr—30 inches; pale olive (5Y 6/3) weathered shale.

The A1 horizon is grayish brown or dark grayish brown (10YR 5/2, 4/2). It is medium acid or slightly acid. Structure is weak to moderate medium granular or fine subangular blocky. The B2t horizon is dark grayish brown or grayish brown (10YR 4/2, 5/2). Interbedded sedimentary rock is at a depth of 24 to 40 inches.

Marvin series

The Marvin series consists of very deep, somewhat poorly drained soils on low alluvial terraces. These soils formed in mixed alluvium that derived mainly from sedimentary rock sources. The slopes range from 0 to 2 percent. The average annual precipitation ranges from 15 to 18 inches. The mean annual temperature is 57 degrees F.

Marvin soils are similar to Rincon soils and are associated with Danville and Pescadero soils. Rincon soils are well drained. Danville soils have a mollic epipedon. Pescadero soils have a natric horizon.

Typical pedon of Marvin silt loam, saline-alkali, in the city of Newark, about 1,200 feet northwest of the intersection of Central and Filbert Streets, 1,300 feet southwest of Filbert Street, SE1/4SW1/4SW1/4 of sec. 1, T. 5 S., R. 2 W.

Ap—0 to 4 inches; grayish brown (10YR 5/2) silt loam, very dark grayish brown (10YR 3/2) moist; massive; hard, friable, slightly sticky and slightly plastic; many very fine and fine roots; many very fine and few fine tubular pores; neutral; clear smooth boundary.

B1t—4 to 11 inches; grayish brown (10YR 5/2) heavy silty clay loam, very dark gray (10YR 3/1) moist; dark grayish brown (2.5Y 4/2) stains, very dark grayish brown (2.5Y 3/2) moist; moderate coarse angular blocky structure; very hard, firm, sticky and plastic; many very fine roots; many very fine tubular pores; moderately alkaline; gradual smooth boundary.

B21t—11 to 23 inches; grayish brown (2.5Y 5/2) clay, very dark grayish brown (2.5Y 3/2) moist; few fine distinct light yellowish brown (2.5Y 6/4) mottles,

olive brown (2.5Y 4/4) moist; moderate coarse angular blocky structure; hard, firm, sticky and plastic; common very fine roots; common very fine tubular pores; continuous moderately thick clay films on faces of peds; very slightly effervescent; moderately alkaline; diffuse smooth boundary.

B22t—23 to 36 inches; grayish brown (2.5Y 5/2) clay, dark grayish brown (2.5Y 4/2) moist; common medium and coarse distinct gray (10YR 5/1) mottles, very dark gray (10YR 3/1) moist; moderate coarse angular blocky structure; hard, firm, sticky and plastic; few very fine roots; common very fine tubular pores; common moderately thick clay films on faces of peds; strongly effervescent, soft masses of lime; moderately alkaline; clear smooth boundary.

C—36 to 60 inches; light brownish gray (2.5Y 6/2) and light yellowish brown (2.5Y 6/3) heavy clay loam, dark grayish brown (2.5Y 4/2) and olive brown (2.5Y 4/4) moist; few fine and medium distinct olive gray (5Y 5/2) mottles, dry and moist; weak coarse angular blocky structure; hard, friable, sticky and slightly plastic; many very fine tubular pores; few thin clay films on faces of peds and lining pores; violently effervescent, soft masses of lime; moderately alkaline.

The A horizon is 3 to 12 inches thick. It ranges from grayish brown to dark grayish brown (10YR 5/2, 4/2). The A horizon is neutral to mildly alkaline. The B2t horizon is 20 to 25 inches thick. It is grayish brown or dark grayish brown (2.5Y 5/2, 4/2) heavy clay loam, heavy silty clay loam, silty clay, or clay. The C horizon is dark grayish brown, light brownish gray, or light olive brown (2.5Y 4/2, 6/2, 5/6). It ranges from loam to heavy clay loam. In places, small concretions and soft masses of lime are in the upper part of the C horizon.

Maymen series

The Maymen series consists of shallow, somewhat excessively drained soils that formed in residuum of sedimentary rock. The slopes range from 30 to 75 percent. The average annual precipitation ranges from 18 to 26 inches. The mean annual temperature is 56 degrees F.

Maymen soils are similar to and are associated with Gaviota and Millsholm soils. Gaviota and Millsholm soils have a base saturation of more than 60 percent.

Typical pedon of Maymen loam, in the city of Oakland, on a southwest-facing slope at the intersection of Skyline Boulevard and Manzanita Drive, opposite Snake Road:

A1—0 to 9 inches; light brownish gray (10YR 6/2) loam, dark grayish brown (10YR 4/2) moist; weak fine granular structure; slightly hard, friable, sticky and slightly plastic; many fine, medium, and coarse roots; many fine interstitial and tubular pores; strongly acid; diffuse wavy boundary.

B2—9 to 19 inches; light brownish gray (10YR 6/2) loam, dark grayish brown (10YR 4/2) moist; weak medium and fine subangular blocky structure; slightly hard, friable, sticky and slightly plastic; many fine, medium, and coarse roots; many fine interstitial and tubular pores; strongly acid; clear wavy boundary.

R—19 inches; light yellowish brown (10YR 6/4) shale that has dark yellowish brown (10YR 4/4) coatings.

The A horizon is light brownish gray or pale brown (10YR 6/2, 6/3). The B2 horizon is loam, silt loam, and light clay loam. Depth to bedrock ranges from 10 to 20 inches.

Millsholm series

The Millsholm series consists of shallow, well drained soils that formed in residuum of shale and fine grained sandstone. The slopes range from 9 to 75 percent. The average annual precipitation ranges from 15 to 25 inches. The mean annual temperature is 57 degrees F.

Millsholm soils are similar to Gaviota and Maymen soils. Gaviota soils are less than 18 percent clay and do not have a cambic horizon. Maymen soils have a base saturation of less than 60 percent.

Typical pedon of Millsholm silt loam, near the junction of Palomares and Stonybrook Roads, in the SE1/4SE1/4NE1/4 sec. 28, T. 3 S., R. 1 W.

A1—0 to 7 inches; grayish brown (2.5Y 5/2) silt loam, olive brown (2.5Y 4/3) moist; massive; hard, friable, slightly sticky and slightly plastic; many very fine roots; many very fine pores; few worm casts; medium acid; clear smooth boundary.

B21—7 to 14 inches; light olive brown (2.5Y 5/3) silt loam, olive brown (2.5Y 3/3) moist; massive; hard, friable, slightly sticky and slightly plastic; many very fine roots; many very fine pores; few thin discontinuous clay films in pores; medium acid; clear smooth boundary.

B22—14 to 20 inches; light olive brown (2.5Y 5/4) silt loam, olive brown (2.5Y 4/4) moist; massive; very hard, firm, sticky and plastic; many fine roots; many very fine pores; few thin continuous clay films in pores; medium acid; clear irregular boundary.

R—20 inches; grayish brown (2.5Y 5/2) shale, dark grayish brown (2.5Y 4/2) moist.

The A1 horizon is light olive brown (2.5Y 5/4) or grayish brown (2.5Y 5/2) loam or silt loam. It is medium acid or slightly acid. The B2 horizon is massive or has weak fine to medium subangular blocky structure. The bedrock is at a depth of 10 to 20 inches.

Montara series

The Montara series consists of shallow, well drained soils that formed in residuum of ultrabasic rock. The slopes range from 30 to 75 percent. The average annual precipitation ranges from 18 to 20 inches. The mean annual temperature is 58 degrees F.

Montara soils are similar to Climara, Maymen, and Millsholm soils. Climara soils are fine textured and have slickensides. Millsholm and Maymen soils have an ochric epipedon.

Typical pedon of Montara clay loam, in the Oakland Hills, on an east-facing slope, in Joaquin Miller Park, in the SW1/4NW1/4, sec. 34, T. 1 S., R. 3 W. (projected):

A11—0 to 6 inches; very dark grayish brown (10YR 3/2) clay loam, very dark brown (10YR 2/2) moist; moderate fine granular structure; slightly hard, friable, sticky and plastic; many fine, medium, and coarse roots; many fine interstitial pores; mildly alkaline; diffuse smooth boundary.

A12—6 to 14 inches; very dark grayish brown (10YR 3/2) clay loam, very dark brown (10YR 2/2) moist; moderate very fine granular structure; slightly hard, friable, sticky and plastic; many fine, medium, and coarse roots; many very fine interstitial pores; moderately alkaline; abrupt wavy boundary.

R—14 inches; ultrabasic rock.

The A1 horizon is very dark grayish brown, dark grayish brown, dark gray, or very dark gray (10YR 3/2, 4/2, 4/1, 3/1). In places, the lower part of the A12 horizon is calcareous. Depth to bedrock is 10 to 20 inches.

Omni series

The Omni series consists of very deep, poorly drained soils that formed in alluvium that derived from mixed rock sources. These soils are on the lower flood plains. The slopes are 0 to 2 percent. The average annual precipitation ranges from 15 to 18 inches. The mean annual temperature is 57 degrees F.

Omni soils are associated with Botella, Clear Lake, and Marvin soils. Botella soils are well drained and have a fine-loamy control section. Clear Lake soils have intersecting slickensides. Marvin soils are somewhat poorly drained and have a fine control section.

Typical pedon of Omni silty clay loam, drained, in the NW1/4NW1/4NE1/4 of sec. 27, T. 4 S., R. 2 W. (projected):

Ap—0 to 6 inches; grayish brown (10YR 5/2) silty clay loam, very dark brown (10YR 2/2) moist; weak fine granular structure; hard, friable, slightly sticky and plastic; many very fine and fine and few medium roots; many fine tubular and interstitial pores; moderately alkaline; clear wavy boundary.

A12—6 to 15 inches; grayish brown (10YR 5/2) silty clay that has common fine distinct mottles; very dark gray (5Y 3/1) moist; weak fine subangular blocky structure; hard, friable, sticky and plastic; common fine roots; many very fine tubular pores; slightly effervescent; moderately alkaline; diffuse wavy boundary.

B21g—15 to 25 inches; dark gray (5Y 4/1) clay with common medium prominent light yellowish brown (2.5Y 6/4) mottles, dark olive gray (5Y 3/2) moist; weak medium subangular blocky structure; hard, friable, sticky and plastic; common fine roots; many very fine tubular pores; slightly effervescent; mildly alkaline; clear smooth boundary.

B22cag—25 to 35 inches; light olive brown (2.5Y 5/4) clay that has common medium prominent gray (2.5Y 6/1) and yellowish brown (10YR 5/6) mottles, very dark gray (N 3/0) moist; weak medium subangular blocky structure; hard, friable, sticky and plastic; few fine roots; many very fine tubular pores; strongly effervescent, soft masses of lime; moderately alkaline; gradual wavy boundary.

B23cag—35 to 52 inches; light olive brown (2.5Y 5/4) clay that has many coarse distinct gray (2.5Y 6/1) and light yellowish brown (2.5Y 6/4) mottles, dark gray (N 4/0) moist; weak medium and fine subangular blocky structure; hard, friable, sticky and plastic; very few fine roots; many fine tubular pores; strongly effervescent, soft masses of lime; moderately alkaline; gradual smooth boundary.

Cca—52 to 60 inches; light olive brown (2.5Y 5/4) silty clay loam that has few fine faint light olive brown (2.5Y 5/6) mottles, olive brown (2.5Y 4/4) moist; weak fine subangular blocky structure; hard, friable, slightly sticky and plastic; no roots; few fine tubular pores; strongly effervescent; moderately alkaline.

The A horizon is grayish brown, dark grayish brown, very dark grayish brown, gray, or dark gray (10YR 5/2, 4/2, 3/2, 5/1, 4/1). The B2 horizon is dark gray, grayish brown, and light olive brown (10YR 4/1, 5/2; 2.5Y 5/4). It is heavy silty clay loam, silty clay, or clay. The C horizon is light olive brown, olive brown, or olive yellow (2.5Y 5/4, 4/4, 6/6). It is silty clay loam or clay loam. In places, this horizon has thin strata of very fine sand.

Pescadero series

The Pescadero series consists of very deep, poorly drained soils that formed in alluvium that derived from sedimentary rock sources. These soils are on the basin rims. They have slopes of less than 2 percent. The average annual precipitation ranges from 14 to 18 inches. The mean annual temperature is 57 degrees F.

Pescadero soils are similar to Clear Lake and Marvin soils, which do not have a natric horizon.

Typical pedon of Pescadero clay, drained, north of the city of Livermore, 150 feet south of Hartford Avenue and 0.7 mile east of the junction of North Livermore and Hartford Avenues (outside the survey area):

A2—0 to 2 inches; gray (10YR 5/1) clay loam, dark gray (10YR 4/1) moist; weak thin platy structure; hard, friable, sticky and plastic; common very fine roots; few fine tubular pores; slightly acid; clear wavy boundary.

B21t—2 to 12 inches; dark gray (N 4/0) clay, very dark gray (N 3/0) moist; few fine prominent olive (5Y 4/3) mottles; moderate medium prismatic structure; very hard, firm, slightly sticky and plastic; common very fine roots; many very fine tubular pores; few thin clay films on faces of peds; moderately alkaline; gradual wavy boundary.

B22t—12 to 20 inches; dark gray (10YR 4/1) clay, black (10YR 2/1) moist; common fine prominent very dark gray (5Y 3/1) mottles; moderate medium prismatic structure; very hard, firm, slightly sticky and plastic; few very fine roots; many very fine tubular pores; common moderately thick clay films on faces of peds; slightly effervescent; moderately alkaline; gradual wavy boundary.

B23tca—20 to 30 inches; light gray (5Y 7/1) clay, gray (5Y 5/1) moist; moderate medium prismatic structure; hard, firm, sticky and plastic; few very fine and fine roots; many very fine tubular pores; common moderately thick clay films on faces of peds; strongly effervescent; moderately alkaline; gradual wavy boundary.

C1ca—30 to 40 inches; gray (5Y 6/1) clay loam, gray (5Y 5/1) moist; massive; very hard, firm, slightly sticky and plastic; no roots; many very fine tubular pores; violently effervescent, soft masses of lime; moderately alkaline; gradual wavy boundary.

C2ca—40 to 58 inches; light olive gray (5Y 6/2) clay loam, olive gray (5Y 5/2) moist; massive; very hard, firm, slightly sticky and plastic; common very fine tubular pores; violently effervescent, soft masses of lime; moderately alkaline; gradual wavy boundary.

C3ca—58 to 72 inches; light gray (5Y 7/2) clay loam, olive gray (5Y 5/2) moist; massive; hard, firm, slightly sticky and plastic; few very fine tubular pores; violently effervescent, many soft masses of lime; moderately alkaline.

Drainage of the Pescadero soils has been improved by the use of deep drainage ditches and natural stream cutting. The water table is below a depth of 4 feet in most years. In winter, these soils are subject to ponding where surface drainage is not provided.

The A2 horizon is gray, light gray, or light brownish gray (10YR 5/1, 7/1, 6/2) loam or clay loam. It is dominantly slightly acid or moderately alkaline but is strongly alkaline in ponded areas. If present, the A1 horizon is dark gray or dark grayish brown (10YR 4/1, 4/2) clay loam or silty clay loam. The B2t horizon is moderately alkaline or strongly alkaline. Structure is columnar or prismatic. Content of saline and alkali salts increases with depth. In some pedons, gypsum is at a depth of 36 to 48 inches.

Pleasanton series

The Pleasanton series consists of very deep, well drained soils that formed on low terraces in alluvium that derived from sedimentary rock sources. The slopes range from 0 to 5 percent. The average annual precipitation is 16 inches. The mean annual temperature is 57 degrees F.

Pleasanton soils are similar to Rincon soils, which are more than 35 percent clay in the argillic horizon.

Typical pedon of Pleasanton gravelly loam, in the SE1/4NE1/4NE1/4 of sec. 24, T. 3 S., R. 2 E. (outside the survey area):

Ap—0 to 9 inches; grayish brown (10YR 5/2) gravelly loam, very dark grayish brown (10YR 3/2) moist; massive; hard, friable, slightly sticky and slightly plastic; many very fine and common fine and medium roots; common very fine and fine interstitial pores; 20 percent gravel; slightly acid; abrupt smooth boundary.

A12—9 to 21 inches; grayish brown (10YR 5/2) gravelly loam, very dark grayish brown (10YR 3/2) moist; massive; hard, friable, slightly sticky and slightly plastic; many very fine and common fine and medium roots; common very fine and fine interstitial pores; 20 percent gravel; neutral; clear smooth boundary.

B2t—21 to 48 inches; brown (10YR 4/3) gravelly sandy clay loam, dark brown (10YR 3/3) moist; moderate medium subangular blocky structure; very hard, friable, sticky and plastic; common very fine and fine roots; many very fine and fine and few medium tubular pores; common moderately thick clay films on faces of peds and lining pores; 20 percent gravel; neutral; gradual wavy boundary.

B3t—48 to 64 inches; brown (10YR 4/3) gravelly loam, dark brown (10YR 3/3) moist; weak medium subangular blocky structure; very hard, friable, sticky and plastic; few very fine roots; many very fine and common fine pores; few thick and few thin clay films on faces of peds and lining pores; 20 percent gravel; neutral; gradual wavy boundary.

C—64 to 72 inches; yellowish brown (10YR 5/4) gravelly fine sandy loam, dark yellowish brown (10YR 4/4) moist; massive; hard, friable, sticky and slightly plastic; many very fine, common fine, and few medium pores; few thin clay films in pores; 25 percent gravel; mildly alkaline.

The A horizon is grayish brown, brown, or pale brown (10YR 5/2, 5/3, 6/3). The B2t horizon is dark brown or brown (10YR 4/3, 5/3). Reaction is neutral or mildly alkaline. The C horizon is gravelly silt loam, gravelly loam, or gravelly fine sandy loam. Gravel content ranges from 15 to 35 percent throughout. In some pedons, the C horizon is calcareous.

Reyes series

The Reyes series consists of very deep, very poorly drained soils on tidal flats. These soils formed in alluvium that derived from mixed sources. The average annual precipitation ranges from 14 to 18 inches. The mean annual temperature is 57 degrees F.

Reyes soils are near Laugenour, Pescadero, and Willows soils. Laugenour soils are stratified sandy loam, fine sandy loam, and loam. Pescadero soils have a natric horizon. Willows soils have intersecting slickensides.

Typical pedon of Reyes clay, in the city of Hayward, 500 feet northeast of the end of the flood control road adjacent to the flood control channel, T. 4 S., R. 3 W. (This pedon is covered by water at high tide.)

A1—0 to 6 inches; olive gray (5Y 4/2) clay, dark olive gray (5Y 3/2) moist; massive; hard, friable, sticky and plastic; many fine, medium, and coarse roots; estimated 5 percent fibers; strongly alkaline; clear smooth boundary.

C1—6 to 18 inches; mottled dark greenish gray (5GY 4/1) and black (N 2/0) clay; massive; hard, friable, sticky and plastic; many fine, medium, and coarse roots; strong odor of hydrogen sulfide when treated with hydrochloric acid; strongly alkaline; clear smooth boundary.

C2—18 to 23 inches; mottled dark greenish gray (5GY 4/1) and black (N 2/0, 10YR 2/1) clay; massive; hard, friable, sticky and plastic; many fine roots; strong odor of hydrogen sulfide when treated with hydrochloric acid; strongly alkaline; clear smooth boundary.

C3—23 to 42 inches; mottled dark greenish gray (5GY 4/1) and black (N 2/0) clay; massive; hard, friable, sticky and plastic; no roots; strong odor of hydrogen sulfide when treated with hydrochloric acid; strongly alkaline; gradual smooth boundary.

C4—42 to 72 inches; dark greenish gray (5GY 4/1) silty clay; massive; hard, friable, sticky and plastic; strong odor of hydrogen sulfide when treated with hydrochloric acid; strongly alkaline.

Reyes soils are very poorly drained unless the drainage has been altered. This soil is covered with water at high tides. The A1 horizon is olive gray, dark gray, or dark grayish brown (5Y 5/2, 4/1, 2.5Y 4/2). The upper part of the C horizon has black (N 2/0), reddish brown, and yellowish brown (5YR 5/4, 10YR 5/6) mottles. The C horizon is strongly alkaline except where the water table has been lowered. Some pedons have jarosite in the C horizon, but most sulfides occur as black (N 2/0) mottling that becomes dark gray when exposed to air or when treated with dilute hydrochloric acid.

Rincon series

The Rincon series consists of very deep, well drained soils that formed in alluvium that derived from sedimentary rock sources. These soils are on low terraces. The slopes range from 0 to 2 percent. The average annual precipitation ranges from 14 to 20 inches. The mean annual temperature is 57 degrees F.

Rincon soils are associated with and are similar to Danville, Marvin, and Pleasanton soils. Danville soils have a mollic epipedon. Marvin soils are somewhat poorly drained. Pleasanton soils are less than 35 percent clay in the argillic horizon.

Typical pedon of Rincon clay loam, 150 feet west of Mountain House Road, between Mountain House School and an east-west dirt road in the SE1/4SE1/4SE1/4NW1/4 of sec. 6, T. 2 S., R. 4 E. (outside the survey area):

Ap—0 to 8 inches; grayish brown (10YR 5/2) clay loam, dark brown (10YR 3/3) moist; massive; very hard, friable, sticky and plastic; many fine and few medium and very fine roots; common fine and few very fine and medium tubular pores; neutral; abrupt smooth boundary.

A12—8 to 16 inches; dark grayish brown (10YR 4/2) clay loam, dark brown (10YR 3/3) moist; massive; very hard, friable, sticky and plastic; many fine and very fine roots; common fine and very fine tubular pores; neutral; abrupt smooth boundary.

B21t—16 to 28 inches; dark grayish brown (10YR 4/2) heavy clay loam, dark brown (10YR 3/3) moist; weak coarse blocky structure; very hard, friable, sticky and plastic; many fine and very fine roots; many fine and very fine tubular pores; few thin clay films on faces of peds and lining pores; neutral; gradual wavy boundary.

B22t—28 to 38 inches; brown (10YR 5/3) and grayish brown (10YR 5/2) clay, dark brown (10YR 4/3) and dark grayish brown (10YR 4/2) moist; moderate coarse blocky structure; extremely hard, firm, sticky and very plastic; few fine and many very fine roots; common fine and very fine tubular pores; common thin clay films on faces of peds and lining pores; neutral; gradual wavy boundary.

B3t—38 to 52 inches; brown (10YR 5/3) clay, dark brown (10YR 4/3) moist; moderate medium blocky structure; extremely hard, very firm, sticky and very plastic; few fine and very fine roots; common fine and very fine tubular pores; common thin and few moderately thick clay films on faces of peds and lining pores; mildly alkaline; gradual wavy boundary.

Cca—52 to 60 inches; yellowish brown (10YR 5/4) clay loam, dark yellowish brown (10YR 4/4) moist; massive; extremely hard, very firm, slightly sticky and very plastic; few very fine roots; common fine and very fine pores; moderately thick clay films lining pores; strongly effervescent, seams of lime; moderately alkaline.

The A horizon is grayish brown, dark grayish brown, or brown (10YR 5/2, 4/2, 4/3). It is slightly acid or neutral. The B2t horizon is dark grayish brown, brown, or dark yellowish brown (10YR 4/2, 5/3, 4/6). It is neutral to moderately alkaline. In a few pedons, the B2t horizon is slightly effervescent. The C horizon is yellowish brown or light yellowish brown (10YR 5/6, 6/4) loam, clay loam, or silty clay loam.

Sycamore series

The Sycamore series consists of very deep, poorly drained soils that formed in alluvium that derived from sedimentary rock sources. These soils are on flood plains. The slopes range from 0 to 2 percent. The average annual precipitation ranges from 14 to 18 inches. The mean annual temperature is 57 degrees F.

Sycamore soils are associated with Laugenour and Yolo soils. Laugenour soils are less than 18 percent clay between depths of 10 and 40 inches. Yolo soils are well drained.

Typical pedon of Sycamore silt loam, 1,250 feet east of Hopyard Road, 50 feet north of Black Avenue, and 1/4 mile north of Pleasanton (outside the survey area):

Ap—0 to 7 inches; light brownish gray (2.5Y 6/2) silt loam, dark grayish brown (2.5Y 4/2) moist; weak medium granular structure; slightly hard, friable, sticky and slightly plastic; many fine roots; few fine tubular pores and common medium interstitial pores; moderately alkaline; gradual smooth boundary.

A12—7 to 18 inches; light brownish gray (2.5Y 6/2) silt loam, dark grayish brown (2.5Y 4/2) moist; massive; slightly hard, friable, sticky and slightly plastic; many fine roots; few fine tubular pores; moderately alkaline; gradual smooth boundary.

B21—18 to 30 inches; grayish brown (2.5Y 5/2) silt loam, dark grayish brown (2.5Y 4/2) moist; few fine prominent yellowish brown (10YR 5/6) mottles; massive; slightly hard, friable, sticky and slightly plastic; few fine roots; few fine tubular pores and few medium interstitial pores; slightly effervescent; moderately alkaline; gradual smooth boundary.

B22—30 to 44 inches; light olive gray (5Y 6/2) silt loam, olive gray (5Y 5/2) moist; common fine distinct dark yellowish brown (10YR 4/4) mottles; massive; slightly hard, friable, slightly sticky and slightly plastic; few fine roots; few and very few fine tubular pores; strongly effervescent, small soft whitish concretions and seams of lime; moderately alkaline; abrupt smooth boundary.

C—44 to 60 inches; light olive gray (5Y 6/2) heavy silt loam, olive gray (5Y 4/2) moist; common fine and medium distinct yellowish brown (10YR 5/6) mottles; massive; slightly hard, friable, sticky and plastic; few fine roots; very few fine tubular pores; strongly effervescent; small soft whitish nodules and seams of lime; moderately alkaline.

The A horizon is light brownish gray or grayish brown (2.5Y 6/2, 10YR 5/2). It is neutral to moderately alkaline. The B horizon is grayish brown, light brownish gray, or light olive gray (2.5Y 5/2, 6/2, 5Y 6/2). The C horizon is light olive gray or light olive brown (5Y 6/2, 2.5Y 5/4) heavy silt loam or clay.

Tierra series

The Tierra series consists of very deep, moderately well drained soils on dissected terraces and terrace remnants. These soils formed in weakly consolidated, stratified old alluvium interspersed with beds of sandstone. The slopes range from 0 to 30 percent. The average annual precipitation ranges from 15 to 20 inches. The mean annual temperature is 57 degrees F.

Tierra soils are associated with Azule soils and they are near Diablo and Danville soils. Azule soils do not have an abrupt boundary between the A and B horizons; they have a paralithic contact between depths of 20 and 40 inches. Diablo soils are more than 35 percent clay throughout the solum and have intersecting slickensides. Danville soils have a mollic epipedon.

Typical pedon of Tierra loam, 100 feet northeast of Paseo Padre Parkway, 1/8 mile northwest of the intersection of Washington Boulevard and Paseo Padre Parkway, and 1/8 mile southeast of Paseo Padre and Interstate 680 overpass, in the NE1/4NE1/4 of sec. 2, T. 5 S., R. 1 W. (projected):

Ap—0 to 6 inches; grayish brown (10YR 5/2) loam, very dark grayish brown (10YR 3/2) moist; massive; hard, friable, slightly sticky and slightly plastic; many very fine and fine roots; many very fine and fine tubular pores; slightly acid; clear smooth boundary.

A12—6 to 11 inches; grayish brown (10YR 5/2) loam, very dark grayish brown (10YR 3/2) moist; massive; hard, friable, sticky and slightly plastic; slightly acid; clear smooth boundary.

A2—11 to 12 inches; gray (10YR 6/1) loam, dark gray (10YR 4/1) moist; weak thin platy structure; soft, friable, slightly sticky and slightly plastic; common very fine and fine horizontal roots; common very fine and fine tubular and interstitial pores; slightly acid; abrupt smooth boundary.

B21t—12 to 17 inches; very dark grayish brown (10YR 3/2) clay, dry or moist; strong coarse prismatic structure; very hard, firm, sticky and very plastic; few

very fine and fine exped roots; common very fine and fine tubular pores; many thick clay films on faces of peds; neutral; clear wavy boundary.

B22t—17 to 24 inches; grayish brown (10YR 5/2) clay that has gray (10YR 5/1) stains on peds, dark grayish brown (10YR 4/2) moist; strong coarse prismatic structure; very hard, firm, sticky and very plastic; few very fine and fine exped roots; few very fine and fine tubular pores; many thick clay films on faces of peds; neutral; clear wavy boundary.

B3t—24 to 32 inches; brown (10YR 5/3) clay, dark brown (10YR 3/3) moist; moderate coarse angular blocky structure; very hard, firm, sticky and plastic; very few very fine interstitial and tubular pores; common thin clay films on faces of peds; neutral; clear wavy boundary.

C—32 to 60 inches; variegated yellowish brown (10YR 5/4) and brown (10YR 5/3) sandy clay loam, dark yellowish brown (10YR 4/4) moist; many medium distinct very pale brown (10YR 7/4) mottles; massive; very hard, firm, sticky and plastic; neutral.

The A1 horizon is dark grayish brown, grayish brown, or dark gray (10YR 4/2, 5/2, 4/1). Reaction is medium acid or slightly acid. The A2 horizon is also medium acid or slightly acid. It is sandy loam or loam. The B2t horizon is very dark brown, grayish brown, dark grayish brown, or very dark grayish brown (10YR 2/2, 4/2, 5/2, 3/2). The C horizon is sandy clay loam or clay loam.

Vallecitos series

The Vallecitos series consists of shallow, well drained soils that formed in residuum of metasedimentary rock. The slopes range from 30 to 50 percent. The average annual precipitation ranges from 14 to 18 inches. The mean annual temperature is 57 degrees F.

Vallecitos soils are similar to Contra Costa soils, which have a lithic contact between depths of 20 to 40 inches.

Typical pedon of Vallecitos gravelly loam, in the SW1/4SW1/4 of sec. 9, T. 5 S., R. 4 E. (outside the survey area):

A11—0 to 1 1/2 inches; brown (10YR 5/3) gravelly loam, dark brown (10YR 3/3) moist; moderate medium granular structure; soft, friable, slightly sticky and plastic; many very fine roots; many very fine pores; 20 percent gravel; neutral; clear smooth boundary.

A12—1 1/2 to 6 inches; brown (10YR 5/3) gravelly loam, dark brown (10YR 3/3) moist; massive; hard, friable, slightly sticky and plastic; many very fine roots; many very fine pores; 20 percent gravel; neutral; abrupt wavy boundary.

B21t—6 to 12 inches; reddish brown (5YR 4/3) heavy clay loam, dark reddish brown (5YR 3/3) moist; weak medium angular blocky structure; very hard, firm, slightly sticky and very plastic; many very fine roots; many very fine pores; thin continuous clay films lining pores and as bridges; 10 percent gravel; neutral; clear smooth boundary.

B22t—12 to 16 inches; brown (10YR 5/3) heavy clay loam, dark brown (10YR 4/3) moist; massive; very hard, firm, slightly sticky and very plastic; few very fine roots; common very fine pores; thin continuous clay films lining pores; slightly acid; abrupt irregular boundary.

R—16 inches; bluish gray (5B 5/1) fine-grained, metamorphosed sandstone that has calcite seams; clay films along cleavage planes.

The A1 horizon is brown or pale brown (10YR 5/3, 6/3). The B2t horizon is reddish brown or brown (5YR 4/3; 7.5YR 5/4; 10YR 5/3). Some pedons do not have a B2t horizon. Depth to bedrock ranges from 10 to 20 inches.

Willows series

The Willows series consists of very deep, poorly drained soils that formed in mixed alluvium that derived mainly from sedimentary rock sources. These soils are on the upper edge of the basin rim and have slopes ranging from 0 to 2 percent. The average annual precipitation ranges from 14 to 18 inches, and the mean annual temperature is 57 degrees F.

Willows soils are similar to Clear Lake soils and are near Danville and Omni soils. Clear Lake soils do not have excess salts. Danville and Omni soils have a mollic epipedon.

Typical pedon of Willows clay, in the city of Hayward, 200 feet southeast of Corporate Avenue, near the Eden Industrial Park, in the SE1/4SW1/4 of sec. 32, T. 3 S., R. 2 W. (projected):

A11—0 to 9 inches; black (N 2/0) clay, moist and dry; moderate very coarse prismatic structure; very hard, firm, sticky and very plastic; few medium and many very fine roots; common very fine tubular pores; moderately alkaline; clear smooth boundary.

A12—9 to 19 inches; black (5Y 2/1) clay, moist and dry; moderate very coarse prismatic structure that parts to moderate medium angular blocky; very hard, firm, sticky and very plastic; common very fine roots; many very fine tubular pores; many intersecting slickensides; moderately effervescent; moderately alkaline; gradual smooth boundary.

ACcs—19 to 29 inches; dark gray (5Y 4/1) clay, very dark gray (5Y 3/1) moist; many medium distinct dark grayish brown (10YR 4/2) mottles; many medium prominent yellowish brown (10YR 5/4) mottles; moderate very coarse prismatic structure that parts to moderate medium angular blocky; very hard, firm, sticky and plastic; few very fine roots; many very fine tubular pores; many large intersecting slickensides; many seams of gypsum; strongly effervescent; moderately alkaline; clear smooth boundary.

C1ca—29 to 48 inches; grayish brown (2.5Y 5/2) clay; dark grayish brown (2.5Y 4/2) moist; many medium faint grayish brown (10YR 5/2) and many medium prominent yellowish brown (10YR 5/4) mottles; weak coarse angular blocky structure; very hard, firm, sticky and plastic; few very fine roots; common very fine tubular pores; many slickensides; strongly effervescent; moderately alkaline; abrupt smooth boundary.

C2ca—48 to 72 inches; grayish brown (2.5Y 5/2) clay; dark grayish brown (2.5Y 4/2) moist; many fine distinct dark greenish gray (5GY 4/1) mottles; massive; very hard, firm, sticky and plastic; few very fine roots; few very fine tubular pores; many irregularly shaped hard lime concretions about 1/8 to 1/4 inch in diameter; violently effervescent; moderately alkaline.

These soils have cracks that are 1 to 2 inches wide at the surface (unless plowed) and extend to a depth of 30 to 40 inches. The A1 horizon is black (N 2/0) or very dark gray (N 3/0; 5Y 3/1, 2/1). Moist value is 2 or 3. Structure is granular, angular blocky, or prismatic. Reaction ranges from mildly alkaline to strongly alkaline. Secondary calcium carbonate occurs in most places at a depth of 14 to 40 inches. Soft masses of secondary calcium carbonate are common in the lower part of the AC horizon and in the C horizon. The C horizon has mottled colors with a matrix of grayish brown, light olive brown, or yellowish brown (2.5Y 5/2, 5/4; 10YR 5/4).

Yolo series

The Yolo series consists of very deep, well drained soils that formed in alluvium that derived from sedimentary rock sources. These soils are on alluvial fans and flood plains of the larger streams. The slopes are less than 2 percent. The average annual precipitation ranges from 14 to 18 inches. The mean annual temperature is 57 degrees F.

Yolo soils are associated with Sycamore soils, which are poorly drained and have distinct mottling in the B2 horizon.

Typical pedon of Yolo silt loam, in the city of Fremont, 500 feet northwest of Mowry Avenue and 100 feet northeast of Parkside Drive, in the SE1/4NW1/4, sec. 28, T. 4 S., R. 1 W. (projected):

Ap—0 to 8 inches; grayish brown (10YR 5/2) silt loam, very dark grayish brown (10YR 3/2) moist; massive; hard, friable, sticky and plastic; many medium, fine, and very fine roots; few very fine and fine tubular pores; neutral; clear smooth boundary.

C1—8 to 18 inches; brown (10YR 5/3) silt loam, dark brown (10YR 4/3) moist; massive; hard, friable, sticky and plastic; common coarse, fine, and very fine roots; very few very fine and fine tubular pores; mildly alkaline; gradual smooth boundary.

C2—18 to 34 inches; brown (10YR 5/3) silt loam, dark brown (10YR 4/3) moist; massive; hard, friable, sticky and plastic; common fine and very fine roots; very few tubular pores; moderately alkaline; diffuse smooth boundary.

C3—34 to 60 inches; brown (10YR 5/3) silt loam, dry and moist; massive; hard, friable, sticky and plastic; common fine and very fine roots; many very fine tubular pores; moderately alkaline.

The A horizon is grayish brown or brown (10YR 5/2, 5/3). The C horizon is silt loam or silty clay loam and has thin strata of very fine sandy loam. It is brown, grayish brown, or pale brown (10YR 5/3, 5/2, or 6/3).

Formation of the soils

In this section, the factors that affect the formation of soils in the survey area are discussed and important processes in morphology are described.

Soil is a natural formation on the surface of the earth in which plants grow. It is composed of mineral and organic material. Soils differ in their appearance, composition, productivity, and management requirements in different localities and even within short distances. Five soil-forming factors cause soils to differ. They are parent material, relief, climate, plants and animals, and time. The relative effect of each of these factors varies from one soil to another.

The process of soil formation is quite complex. The influence of each soil-forming factor and the relationships among these factors are more easily described by relating soils within areas of a similar landform or geomorphic unit. In the paragraphs that follow, the landscape and climate are discussed. Then the soil-forming factors are considered in relation to the soils in each geomorphic unit.

Landscape

The survey area is bordered on the west by San Francisco Bay and on the east by ridges of the Coast Range.

The upland area of the Coast Range is hilly to very steep. Folding and faulting have formed a topography made up of nearly parallel, northwest-trending ridges that consist mainly of steeply dipping sedimentary rock. These ridges are at an elevation of about 500 to 2,000 feet. A few major streams in the area dissect the hills at approximately right angles to the ridges. The drainage pattern of most of the smaller streams has been altered by horizontal fault displacement at the foot slopes.

Terraces border the foothills in the northern half of the survey area and extend almost to the tidal areas. The bay plain extends from the foothills or terraces to the tidal flats of the bay. A few small but prominent hills are adjacent to the tidal areas and consist primarily of steep-

ly dipping sedimentary rock and some basic intrusive rock.

Alameda County, Western Part, can be divided into three geomorphic units based on differences in landforms. The interaction of soil forming factors differs for each unit and the relationship among the soils in each unit is significantly different. These geomorphic units are (1) Hilly to very steep uplands of the coast ranges; (2) Flood plains, fans, and terraces of the bay plain; and (3) Tidal flats of the bay.

Climate

The climate is mild. It varies locally, but the overall differences in temperature and rainfall are not extreme. Winters are cool and moist. Summers are dry and, as a result of frequent sea breezes and early morning fog, they are cool.

The annual rainfall is about 14 inches near Newark and increases with elevation to about 25 inches near Hayward. Precipitation effectiveness is greater on north-facing slopes.

The soils are moist from late fall to early spring and dry the remainder of the time. There is about 2 to 11 inches of moisture in excess of evapotranspiration requirements of the natural vegetation. This surplus is not sufficient for active leaching in most areas. Very little leaching occurs in the deeper soils. The redistribution of carbonates and translocation of clays is slow. Most soils have a good supply of bases, and many do not have a prominent argillic horizon. There are a few small areas where the parent rock contains seams of jarosite or pyrite in extremely acid soils.

This warm climate promotes rapid decomposition of organic matter and retards the accumulation of organic material, especially when the soils are moist. The soils are rarely, if ever, frozen so that surface horizons are not broken up by frost action and are not well granulated. Many soils have a massive and hard surface layer and are relatively low in content of organic matter. Soils that have darker and softer surface horizons are commonly associated with the moister sites. Many of the soils are dry below a depth of 20 inches in summer and fall unless they are irrigated. During this dry period many biological and chemical processes are retarded. The alternate wet and dry cycle causes the soils high in montmorillonitic clays to shrink and swell. Large cracks develop in Altamont and Climara soils. Soil material from the surface layer sloughs into these cracks and mixes with the soil material in the lower horizons.

Geomorphic units

Hilly to very steep uplands of the coast ranges

The uplands of this area of the Coast Ranges consist mainly of sedimentary rock; there is some metamorphic and basic igneous rock. Many ridges are composed of interbedded shale, siltstone, sandstone, claystone, and conglomerate that have been folded and faulted. Some of these strata have volcanic material that was deposited in a marine environment. The shale, siltstone, mudstone, and argillaceous sandstone parent rock weather to silty or clayey material. The clays are mainly montmorillonitic. Most rock material is enriched with lime. Some has many seams of lime. These rocks are relatively soft and fractured, making them susceptible to rapid weathering.

Very steep slopes affect soil stability. Clayey material creeps and slides if slopes are excessive. As a result of landslides, slips, and slumps, soil erosion has kept pace with soil formation in many areas. Millsholm soils and other shallow soils are examples.

Altamont, Diablo, and Los Osos soils are moderately deep or deep soils. These soils formed in soft parent material that is more easily weathered. The Altamont and Diablo soils are expansive clay soils and are characterized by little horizon differentiation. The Los Osos soils are not so expansive as the Altamont, Climara, and Diablo soils and have a distinct argillic horizon. The Los Osos soils have a more permeable surface layer and are therefore less stable than the Altamont and Diablo soils. Some parent rock is less easily weathered, and the soils that formed in material derived from this kind of rock are shallow. The Montara soils, which formed in material that weathered from ultrabasic rock, are an example. These soils are also susceptible to erosion, which accounts in part for their shallowness.

The vegetation in much of this area of the Coast Ranges consists of annual grasses and scattered oak. Shrubs, dense stands of oak, bay leaf, and madrone are on moister sites. A few areas of coastal redwood, madrone, and ferns are in cooler, moister sites on steep, north-facing slopes.

The grasses furnish organic matter that darkens the A horizon to a depth of about 10 inches. Most of the soils that are associated with the grass cover are more than 1 percent organic matter. This percentage is highest on moister and cooler sites.

Livestock has grazed the hills of this area of the Coast Ranges since the establishment of the Spanish missions in the early 1800's. At times, the number of animals was so great that the grasslands were overgrazed and erosion was accelerated. Nearly contour trails or terracettes are on most steep, grassy slopes. Gulleys are prevalent in deeper soils along ravines and concave slopes. Man is altering the landscape near urban centers. Large areas of soils are cut and filled for urban structures. Machines are used to excavate the marine sediment and reshape the landscape. Erosion is often severe on cut and fill slopes. The hazards of landslide, slippage, and slumping are increased by manipulation of the soil material.

Flood plains, fans, and terraces of the bay plain

The bay plain lies between the tidal flats and the uplands of the Coast Range as part of the fault block of San Francisco Bay. The streams draining the surrounding hills are not large and stream gradients are slight upon reaching the valley. The valley fill material is medium to fine grained sediment eroded from the adjacent uplands. Soils are poorly drained in parts of the flood plains and basins and well drained on the fans and low terraces at slightly higher elevations.

Some valley flood plains have depressions or basins, which are ponded in wet periods. The Clear Lake soils formed in basinlike positions under poor drainage conditions. These soils have a thick, dark surface horizon and mottled, calcareous lower horizons. Stream entrenchment and diversion structures lower the water table so that the montmorillonitic clays shrink during dry periods. Shrinking and swelling in the surface horizon and lower horizons produce slickensides.

The Pescadero soils formed on basin rims where sodium was concentrated near the surface by capillary rise from the water table and lateral movement of ground water from higher areas. The exchangeable sodium dispersed clay particles, and columnar and prismatic structure formed in the subsurface horizons.

In areas cut by larger streams, deposition consists of medium-textured material. Much of this material has been deposited since settlement by man; erosion was accelerated by cultivation of the steeper areas of the watershed. The Sycamore soils formed under these conditions.

Nearly level to gently sloping soils of the bay plain are drained by small intermittent streams, and deposition is minimal. These soils have an argillic horizon. The Danville and Rincon soils are examples.

Old terraces are mainly in the central part of the survey area and extend from the uplands to the bay plain. They represent an older landscape which remained fairly stable during the formation of valleys and uplands. Thus, the soils that formed on terraces have had a longer time to form and to develop prominent morphological features associated mainly with translocation and accumulation of silicate clays. Tierra soils are the main soils on these terraces; they are characterized by a thin loamy A1 horizon, a light A2 horizon, and an abrupt boundary to a clay Bt horizon, which has a strong prismatic structure.

Near downtown Oakland and Alameda, the terrain is wind-blown. Prevailing winds reworked sandy beach deposits and moved the sandy sediment inland. The Baywood soils are an example. The accumulation of organic matter in the surface layer is the prominent pedogenic process.

Agricultural land is being converted to Urban land. The original soils are altered, mainly in the surface horizon, to meet the needs of urban works and structures. Soils on nearly level or gentle slopes are subject to less cutting and filling. In general, the degree of alteration is less in areas that were converted before heavy earth-moving equipment was available.

Tidal flats of the bay

Marshy tidal flats border San Francisco Bay. These tidal flats consist of unconsolidated sediment, mostly clay and silt from mixed sources, that is deposited in the shallow water around the perimeter of the bay by tidal action, currents, and waves. Cordgrass and pickleweed are salt-tolerant plants that grow on the flats and help trap additional sediment and prevent erosion. The bay mud is impregnated with salt from the brackish bay water and contains reduced sulfur compounds.

The Reyes soils formed on tidal flats. They consist of dark-colored, gleyed clays and are about 5 to 10 percent organic matter. They subside when drained, forming large cracks that remain after rewetting. These soils become strongly acid if exposed to air. A yellow efflorescence or jarosite is in drained areas of Reyes soils.

References

(1) American Association of State Highway and Transportation Officials. 1970. Standard specifications for highway materials and methods of sampling and testing. Ed. 10, 2 vol., illus.

(2) American Society for Testing and Materials. 1974. Method for classification of soils for engineering purposes. ASTM Stand. D 2487-69. *In* 1974 Annual Book of ASTM Standards, Part 19, 464 pp., illus.

(3) United States Department of Agriculture. 1951. Soil survey manual. U.S. Dep. Agric. Handb. 18, 503 pp., illus. Supplements replacing pp. 173-188 issued May 1962

(4) United States Department of Agriculture. 1966. Soil Survey of Alameda Area, California. Series 1961, No. 41. 95 pp., illus., maps.

(5) United States Department of Agriculture. 1975. Soil taxonomy: a basic system of soil classification for making and interpreting soil surveys. U.S. Dep. Agric. Handb. 436, 754 pp., illus.

Glossary

Aeration, soil. The exchange of air in soil with air from the atmosphere. The air in a well aerated soil is similar to that in the atmosphere; the air in a poorly aerated soil is considerably higher in carbon dioxide and lower in oxygen.

Alkali (sodic) soil. A soil having so high a degree of alkalinity (pH 8.5 or higher), or so high a percentage of exchangeable sodium (15 percent or more of the total exchangeable bases), or both, that plant growth is restricted.

Alkaline soil. Any soil that has a pH greater than 7.3. (See Reaction, soil.)

Alluvium. Material, such as sand, silt, or clay, deposited on land by streams.

Amendment. Any material that is worked into the soil to make it more productive. Lime, gypsum, sawdust, or synthetic conditioners are examples. Fertilizers constitute a special group of soil amendments.

Anaerobic. The absence of molecular oxygen. Growing in the absence of molecular oxygen (anaerobic bacteria).

Available water capacity (available moisture capacity). The capacity of soils to hold water available for use by most plants. It is commonly defined as the difference between the amount of soil water at field moisture capacity and the amount at wilting point. It is commonly expressed as inches of water per inch of soil. The capacity, in inches, in a 60-inch profile or to a limiting layer is expressed as—

	Inches
Very low	0 to 2.5
Low	2.5 to 5.0
Moderate	5.0 to 7.5
High	More than 7.5

Base saturation. The degree to which material having base exchange properties is saturated with exchangeable bases (sum of Ca, Mg, Na, K), expressed as a percentage of the exchange capacity.

Bedrock. The solid rock that underlies the soil and other unconsolidated material or that is exposed at the surface.

Bottom land. The normal flood plain of a stream, subject to frequent flooding.

Buried soil. A developed soil that was once exposed but is now overlain by a more recently formed soil.

Calcareous soil. A soil containing enough calcium carbonate (commonly with magnesium carbonate) to effervesce (fizz) visibly when treated with cold, dilute hydrochloric acid. A soil having measurable amounts of calcium carbonate or magnesium carbonate.

Cat clay. Wet clay soils that are high in content of reduced forms of sulfur. If drained, these soils become extremely acid because of the oxidation of sulfur compounds.

Clay. As a soil separate, the mineral soil particles less than 0.002 millimeter in diameter. As a soil textural class, soil material that is 40 percent or more clay, less than 45 percent sand, and less than 40 percent silt.

Clay film. A thin coating of oriented clay on the surface of a soil aggregate or lining pores or root channels. Synonyms: clay coat, clay skin.

Claypan. A slowly permeable soil horizon that contains much more clay than the horizons above it. A claypan is commonly hard when dry and plastic or stiff when wet.

Coarse fragments. Mineral or rock particles up to 3 inches (2 millimeters to 7.5 centimeters) in diameter.

Coarse textured (light textured) soil. Sand or loamy sand.

Complex, soil. A map unit of two or more kinds of soil occurring in such an intricate pattern that they cannot be shown separately on a soil map at the selected scale of mapping and publication.

Concretions. Grains, pellets, or nodules of various sizes, shapes, and colors consisting of concentrated compounds or cemented soil grains. The composition of most concretions is unlike that of the surrounding soil. Calcium carbonate and iron oxide are common compounds in concretions.

Consistence, soil. The feel of the soil and the ease with which a lump can be crushed by the fingers. Terms commonly used to describe consistence are—

Loose.—Noncoherent when dry or moist; does not hold together in a mass.

Friable.—When moist, crushes easily under gentle pressure between thumb and forefinger and can be pressed together into a lump.

Firm.—When moist, crushes under moderate pressure between thumb and forefinger, but resistance is distinctly noticeable.

Plastic.—When wet, readily deformed by moderate pressure but can be pressed into a lump; will form a "wire" when rolled between thumb and forefinger.

Sticky.—When wet, adheres to other material and tends to stretch somewhat and pull apart rather than to pull free from other material.

Hard.—When dry, moderately resistant to pressure; can be broken with difficulty between thumb and forefinger.

Soft.—When dry, breaks into powder or individual grains under very slight pressure.

Cemented.—Hard; little affected by moistening.

Corrosive. High risk of corrosion to uncoated steel or deterioration of concrete.

Cover crop. A close-growing crop grown primarily to improve and protect the soil between periods of regular crop production, or a crop grown between trees and vines in orchards and vineyards.

Cutbanks cave. Unstable walls of cuts made by earth-moving equipment. The soil sloughs easily.

Depth to rock. Bedrock at a depth that adversely affects the specified use.

Diversion (or diversion terrace). A ridge of earth, generally a terrace, built to protect downslope areas by diverting runoff from its natural course.

Drainage class (natural). Refers to the frequency and duration of periods of saturation or partial saturation during soil formation, as opposed to altered drainage, which is commonly the result of artificial drainage or irrigation but may be caused by the sudden deepening of channels or the blocking of drainage

outlets. Seven classes of natural soil drainage are recognized:

Excessively drained.—Water is removed from the soil very rapidly. Excessively drained soils are commonly very coarse textured, rocky, or shallow. Some are steep. All are free of the mottling related to wetness.

Somewhat excessively drained.—Water is removed from the soil rapidly. Many somewhat excessively drained soils are sandy and rapidly pervious. Some are shallow. Some are so steep that much of the water they receive is lost as runoff. All are free of the mottling related to wetness.

Well drained.—Water is removed from the soil readily, but not rapidly. It is available to plants throughout most of the growing season, and wetness does not inhibit growth of roots for significant periods during most growing seasons. Well drained soils are commonly medium textured. They are mainly free of mottling.

Moderately well drained.—Water is removed from the soil somewhat slowly during some periods. Moderately well drained soils are wet for only a short time during the growing season, but periodically for long enough that most mesophytic crops are affected. They commonly have a slowly pervious layer within or directly below the solum, or periodically receive high rainfall, or both.

Somewhat poorly drained.—Water is removed slowly enough that the soil is wet for significant periods during the growing season. Wetness markedly restricts the growth of mesophytic crops unless artificial drainage is provided. Somewhat poorly drained soils commonly have a slowly pervious layer, a high water table, additional water from seepage, nearly continuous rainfall, or a combination of these.

Poorly drained.—Water is removed so slowly that the soil is saturated periodically during the growing season or remains wet for long periods. Free water is commonly at or near the surface for long enough during the growing season that most mesophytic crops cannot be grown unless the soil is artificially drained. The soil is not continuously saturated in layers directly below plow depth. Poor drainage results from a high water table, a slowly pervious layer within the profile, seepage, nearly continuous rainfall, or a combination of these.

Very poorly drained.—Water is removed from the soil so slowly that free water remains at or on the surface during most of the growing season. Unless the soil is artificially drained, most mesophytic crops cannot be grown. Very poorly drained soils are commonly level or depressed and are frequently ponded. Yet, where rainfall is high and nearly continuous, they can have moderate or high slope gradients, as for example in "hillpeats" and "climatic moors."

Drainage, surface. Runoff, or surface flow of water, from an area.

Eolian soil material. Earthy parent material accumulated through wind action; commonly refers to sandy material in dunes or to loess in blankets on the surface.

Erosion. The wearing away of the land surface by running water, wind, ice, or other geologic agents and by such processes as gravitational creep.

Erosion (geologic). Erosion caused by geologic processes acting over long geologic periods and resulting in the wearing away of mountains and the building up of such landscape features as flood plains and coastal plains. Synonym: natural erosion.

Erosion (accelerated). Erosion much more rapid than geologic erosion, mainly as a result of the activities of man or other animals or of a catastrophe in nature, for example, fire, that exposes a bare surface.

Excess salts. Excess water soluble salts. Excessive salts restrict the growth of most plants.

Fertility, soil. The quality that enables a soil to provide plant nutrients, in adequate amounts and in proper balance, for the growth of specified plants when light, moisture, temperature, tilth, and other growth factors are favorable.

Field moisture capacity. The moisture content of a soil, expressed as a percentage of the ovendry weight, after the gravitational, or free, water has drained away; the field moisture content 2 or 3 days after a soaking rain; also called *normal field capacity, normal moisture capacity,* or *capillary capacity.*

Fine textured (heavy textured) soil. Sandy clay, silty clay, and clay.

Flooding. The temporary covering of soil with water from overflowing streams, runoff from adjacent slopes, and tides. Frequency, duration, and probable dates of occurrence are estimated. Frequency is expressed as none, rare, occasional, and frequent. *None* means that flooding is not probable; *rare* that it is unlikely but possible under unusual weather conditions; *occasional* that it occurs on an average of once or less in 2 years; and *frequent* that it occurs on an average of more than once in 2 years. Duration is expressed as *very brief* if less than 2 days, *brief* if 2 to 7 days, and *long* if more than 7 days. Probable dates are expressed in months; *November-May*, for example, means that flooding can occur during the period November through May. Water standing for short periods after rainfall or commonly covering swamps and marshes is not considered flooding.

Flood plain. A nearly level alluvial plain that borders a stream and is subject to flooding unless protected artificially.

Foot slope. The inclined surface at the base of a hill.

Forb. Any herbaceous plant not a grass or a sedge.

Genesis, soil. The mode of origin of the soil. Refers especially to the processes or soil-forming factors responsible for the formation of the solum, or true soil, from the unconsolidated parent material.

Gleyed soil. A soil having one or more neutral gray horizons as a result of waterlogging and lack of oxygen. The term "gleyed" also designates gray horizons and horizons having yellow and gray mottles as a result of intermittent waterlogging.

Grassed waterway. A natural or constructed waterway, typically broad and shallow, seeded to grass as protection against erosion. Conducts surface water away from cropland.

Gravel. Rounded or angular fragments of rock up to 3 inches (2 millimeters to 7.5 centimeters) in diameter. An individual piece is a pebble.

Gravelly soil material. Material from 15 to 35 percent, by volume, rounded or angular rock fragments, not predominantly flattened, up to 3 inches (7.5 centimeters) in diameter.

Ground water (geology). Water filling all the unblocked pores of underlying material below the water table, which is the upper limit of saturation.

Gully. A miniature valley with steep sides cut by running water and through which water ordinarily runs only after rainfall. The distinction between a gully and a rill is one of depth. A gully generally is an obstacle to farm machinery and is too deep to be obliterated by ordinary tillage; a rill is of lesser depth and can be smoothed over by ordinary tillage.

Gypsum. Hydrous calcium sulphate.

Habitat. The natural abode of a plant or animal; refers to the kind of environment in which a plant or animal normally lives, as opposed to the range or geographical distribution.

Horizon, soil. A layer of soil, approximately parallel to the surface, having distinct characteristics produced by soil-forming processes. The major horizons of mineral soil are as follows:

O horizon.—An organic layer, fresh and decaying plant residue, at the surface of a mineral soil.

A horizon.—The mineral horizon, formed or forming at or near the surface, in which an accumulation of humified organic matter is mixed with the mineral material. Also, a plowed surface horizon most of which was originally part of a B horizon.

A2 horizon.—A mineral horizon, mainly a residual concentration of sand and silt high in content of resistant minerals as a result of the loss of silicate clay, iron, aluminum, or a combination of these.

B horizon.—The mineral horizon below an A horizon. The B horizon is in part a layer of change from the overlying A to the underlying C horizon. The B horizon also has distinctive characteristics caused (1) by accumulation of clay, sesquioxides, humus, or a combination of these; (2) by prismatic or blocky structure; (3) by redder or browner colors than those in the A horizon; or (4) by a combination of these. The combined A and B horizons are generally called the solum, or true soil. If a soil lacks a B horizon, the A horizon alone is the solum.

C horizon.—The mineral horizon or layer, excluding indurated bedrock, that is little affected by soil-forming processes and does not have the properties typical of the A or B horizon. The material of a C horizon may be either like or unlike that from which the solum is presumed to have formed. If the material is known to differ from that in the solum the Roman numeral II precedes the letter C.

R layer.—Consolidated rock beneath the soil. The rock commonly underlies a C horizon, but can be directly below an A or a B horizon.

Hummocky. Refers to a landscape of hillocks, separated by low sags, having sharply rounded tops and steep sides. Hummocky relief resembles rolling or undulating relief, but the tops of ridges are narrower and the sides are shorter and less even.

Humus. The well decomposed, more or less stable part of the organic matter in mineral soils.

Hydrologic soil groups. Refers to soils grouped according to their runoff-producing characteristics. The chief consideration is the inherent capacity of soil bare of vegetation to permit infiltration. The slope and the kind of plant cover are not considered, but are separate factors in predicting runoff. Soils are assigned to four groups. In group A are soils having a high infiltration rate when thoroughly wet and having a low runoff potential. They are mainly deep, well drained, and sandy or gravelly. In group D, at the other extreme, are soils having a very slow infiltration rate and thus a high runoff potential. They have a claypan or clay layer at or near the surface, have a permanent high water table, or are shallow over nearly impervious bedrock or other material. A soil is assigned to two hydrologic groups if part of the acreage is artificially drained and part is undrained.

Infiltration. The downward entry of water into the immediate surface of soil or other material, as contrasted with percolation, which is movement of water through soil layers or material.

Irrigation. Application of water to soils to assist in production of crops. Methods of irrigation are—

Drip.—Applying water at a very slow rate of about 30 drops per minute or by using specially designed commercial sprinkler heads for drip or trickle irrigation.

Furrow.—Water is applied in small ditches made by cultivation implements. Furrows are used for tree and row crops.

Sprinkler.—Water is sprayed over the soil surface through pipes or nozzles from a pressure system.

Landslide. The rapid downhill movement of a mass of soil and loose rock generally when wet or saturated.

The speed and distance of movement, as well as the amount of soil and rock material, vary greatly.

Leaching. The removal of soluble material from soil or other material by percolating water.

Light textured soil. Sand and loamy sand.

Liquid limit. The moisture content at which the soil passes from a plastic to a liquid state.

Loam. Soil material that is 7 to 27 percent clay particles, 28 to 50 percent silt particles, and less than 52 percent sand particles.

Low strength. Inadequate strength for supporting loads.

Medium textured soil. Very fine sandy loam, loam, silt loam, or silt.

Metamorphic rock. Rock of any origin altered in mineralogical composition, chemical composition, or structure by heat, pressure, and movement. Nearly all such rocks are crystalline.

Minimum tillage. Only the tillage essential to crop production and prevention of soil damage.

Moderately coarse textured (moderately light textured) soil. Sandy loam and fine sandy loam.

Moderately fine textured (moderately heavy textured) soil. Clay loam, sandy clay loam, and silty clay loam.

Montmorillonite. A fine, platy, alumino-silicate clay mineral that expands and contracts with the absorption and loss of water. It has a high cation-exchange capacity and is plastic and sticky when moist.

Morphology, soil. The physical makeup of the soil, including the texture, structure, porosity, consistence, color, and other physical, mineral, and biological properties of the various horizons, and the thickness and arrangement of those horizons in the soil profile.

Mottling, soil. Irregular spots of different colors that vary in number and size. Mottling generally indicates poor aeration and impeded drainage. Descriptive terms are as follows: abundance—*few, common,* and *many*; size—*fine, medium,* and *coarse*; and contrast—*faint, distinct,* and *prominent*. The size measurements are of the diameter along the greatest dimension. *Fine* indicates less than 5 millimeters (about 0.2 inch); *medium*, from 5 to 15 millimeters (about 0.2 to 0.6 inch); and *coarse*, more than 15 millimeters (about 0.6 inch).

Munsell notation. A designation of color by degrees of the three single variables—hue, value, and chroma. For example, a notation of 10YR 6/4 is a color of 10YR hue, value of 6, and chroma of 4.

Neutral soil. A soil having a pH value between 6.6 and 7.3.

Nutrient, plant. Any element taken in by a plant, essential to its growth, and used by it in the production of food and tissue. Plant nutrients are nitrogen, phosphorus, potassium, calcium, magnesium, sulfur, iron, manganese, copper, boron, zinc, and perhaps other elements obtained from the soil; and carbon, hydrogen, and oxygen obtained largely from the air and water.

Parent material. The great variety of unconsolidated organic and mineral material in which soil forms. Consolidated bedrock is not yet parent material by this concept.

Ped. An individual natural soil aggregate, such as a granule, a prism, or a block.

Pedon. The smallest volume that can be called "a soil." A pedon is three dimensional and large enough to permit study of all horizons. Its area ranges from about 10 to 100 square feet (1 square meter to 10 square meters), depending on the variability of the soil.

Percolation. The downward movement of water through the soil.

Percs slowly. The slow movement of water through the soil adversely affecting the specified use.

Permeability. The quality that enables the soil to transmit water or air, measured as the number of inches per hour that water moves through the soil. Terms describing permeability are *very slow* (less than 0.06 inch), *slow* (0.06 to 0.20 inch), *moderately slow* (0.2 to 0.6 inch), *moderate* (0.6 to 2.0 inches), *moderately rapid* (2.0 to 6.0 inches), *rapid* (6.0 to 20 inches), and *very rapid* (more than 20 inches).

Phase, soil. A subdivision of a soil series or other unit in the soil classification system based on differences in the soil that affect its management. A soil series, for example, may be divided into phases on the bases of differences in slope, stoniness, thickness, or some other characteristic that affects management. These differences are too small to justify separate series.

pH value. (See Reaction, soil). A numerical designation of acidity and alkalinity in soil.

Piping. Moving water of subsurface tunnels or pipelike cavities in the soil.

Plasticity index. The numerical difference between the liquid limit and the plastic limit; the range of moisture content within which the soil remains plastic.

Plastic limit. The moisture content at which a soil changes from a semisolid to a plastic state.

Poorly graded. Refers to soil material consisting mainly of particles of nearly the same size. Because there is little difference in size of the particles, density can be increased only slightly by compaction.

Poor outlets. Surface or subsurface drainage outlets difficult or expensive to install.

Productivity (soil). The capability of a soil for producing a specified plant or sequence of plants under a specified system of management. Productivity is measured in terms of output, or harvest, in relation to input.

Profile, soil. A vertical section of the soil extending through all its horizons and into the parent material.

Range (or rangeland). Land that, for the most part, produces native plants suitable for grazing by livestock; includes land supporting some forest trees.

Reaction, soil. The degree of acidity or alkalinity of a soil, expressed in pH values. A soil that tests to pH 7.0 is described as precisely neutral in reaction because it is neither acid nor alkaline. The degree of acidity or alkalinity is expressed as—

	pH
Extremely acid	Below 4.5
Very strongly acid	4.5 to 5.0
Strongly acid	5.1 to 5.5
Medium acid	5.6 to 6.0
Slightly acid	6.1 to 6.5
Neutral	6.6 to 7.3
Mildly alkaline	7.4 to 7.8
Moderately alkaline	7.9 to 8.4
Strongly alkaline	8.5 to 9.0
Very strongly alkaline	9.1 and higher

Relief. The elevations or inequalities of a land surface, considered collectively.

Rock fragments. Rock or mineral fragments having a diameter of 2 millimeters or more; for example, pebbles, cobbles, stones, and boulders.

Rooting depth. Shallow root zone. The soil is shallow over a layer that greatly restricts roots. See Root zone.

Root zone. The part of the soil that can be penetrated by plant roots.

Runoff. The precipitation discharged in stream channels from a drainage area. The water that flows off the land surface without sinking in is called surface runoff; that which enters the ground before reaching surface streams is called ground-water runoff or seepage flow from ground water.

Saline-alkali soil. A soil that contains a harmful concentration of salts and exchangeable sodium; contains harmful salts and is strongly alkaline; or contains harmful salts and exchangeable sodium and is very strongly alkaline. The salts, exchangeable sodium, and alkaline reaction are in the soil in such location that growth of most crop plants is less than normal.

Saline soil. A soil containing soluble salts in an amount that impairs growth of plants. A saline soil does not contain excess exchangeable sodium.

Sand. As a soil separate, individual rock or mineral fragments from 0.05 millimeter to 2.0 millimeters in diameter. Most sand grains consist of quartz. As a soil textural class, a soil that is 85 percent or more sand and not more than 10 percent clay.

Sandstone. Sedimentary rock containing dominantly sand-size particles.

Sedimentary rock. Rock made up of particles deposited from suspension in water. The chief kinds of sedimentary rock are conglomerate, formed from gravel; sandstone, formed from sand; shale, formed from clay; and limestone, formed from soft masses of calcium carbonate. There are many intermediate types. Some wind-deposited sand is consolidated into sandstone.

Seepage. The rapid movement of water through the soil. Seepage adversely affects the specified use.

Series, soil. A group of soils, formed from a particular type of parent material, having horizons that, except for the texture of the A or surface horizon, are similar in all profile characteristics and in arrangement in the soil profile. Among these characteristics are color, texture, structure, reaction, consistence, and mineralogical and chemical composition.

Shale. Sedimentary rock formed by the hardening of a clay deposit.

Sheet erosion. The removal of a fairly uniform layer of soil material from the land surface by the action of rainfall and runoff water.

Shrink-swell. The shrinking of soil when dry and the swelling when wet. Shrinking and swelling can damage roads, dams, building foundations, and other structures. It can also damage plant roots.

Silt. As a soil separate, individual mineral particles that range in diameter from the upper limit of clay (0.002 millimeter) to the lower limit of very fine sand (0.05 millimeter). As a soil textural class, soil that is 80 percent or more silt and less than 12 percent clay.

Slickensides. Polished and grooved surfaces produced by one mass sliding past another. In soils, slickensides may occur at the bases of slip surfaces on the steeper slopes; on faces of blocks, prisms, and columns; and in swelling clayey soils, where there is marked change in moisture content.

Slope. The inclination of the land surface from the horizontal. Percentage of slope is the vertical distance divided by horizontal distance, then multiplied by 100. Thus, a slope of 20 percent is a drop of 20 feet in 100 feet of horizontal distance.

Slow intake. The slow movement of water into the soil.

Small stones. Rock fragments 3 to 10 inches (7.5 to 25 centimeters) in diameter. Small stones adversely affect the specified use.

Soil. A natural, three-dimensional body at the earth's surface that is capable of supporting plants and has properties resulting from the integrated effect of climate and living matter acting on earthy parent material, as conditioned by relief over periods of time.

Soil separates. Mineral particles less than 2 millimeters in equivalent diameter and ranging between specified size limits. The names and sizes of separates recognized in the United States are as follows: *very coarse sand* (2.0 millimeters to 1.0 millimeter); *coarse sand* (1.0 to 0.5 millimeter); *medium sand* (0.5 to 0.25 millimeter); *fine sand* (0.25 to 0.10 millimeter); *very fine sand* (0.10 to 0.05 millimeter); *silt* (0.005 to 0.002 millimeter); and *clay* (less than 0.002 millimeter).

Solum. The upper part of a soil profile, above the C horizon, in which the processes of soil formation are

active. The solum in mature soil consists of the A and B horizons. Generally, the characteristics of the material in these horizons are unlike those of the underlying material. The living roots and other plant and animal life characteristics of the soil are largely confined to the solum.

Stones. Rock fragments 10 to 24 inches (25 to 60 centimeters) in diameter.

Stratified. Arranged in strata, or layers. The term refers to geologic material. Layers in soils that result from the processes of soil formation are called horizons; those inherited from the parent material are called strata.

Structure, soil. The arrangement of primary soil particles into compound particles or aggregates that are separated from adjoining aggregates. The principal forms of soil structure are—*platy* (laminated), *prismatic* (vertical axis of aggregates longer than horizontal), *columnar* (prisms with rounded tops), *blocky* (angular or subangular), and *granular*. *Structureless* soils are either *single grained* (each grain by itself. as in dune sand) or *massive* (the particles adhering without any regular cleavage, as in many hardpans).

Subsoil. Technically, the B horizon; roughly, the part of the solum below plow depth.

Substratum. The part of the soil below the solum.

Subsurface layer. Technically, the A2 horizon. Generally refers to a leached horizon lighter in color and lower in content of organic matter than the overlying surface layer.

Surface soil. The soil ordinarily moved in tillage, or its equivalent in uncultivated soil, ranging in depth from 4 to 10 inches (10 to 25 centimeters). Frequently designated as the "plow layer," or the "Ap horizon."

Taxadjuncts. Soils that cannot be classified in a series recognized in the classification system. Such soils are named for a series they strongly resemble and are designated as taxadjuncts to that series because they differ in ways too small to be of consequence in interpreting their use or management.

Terrace (geologic). An old alluvial plain, ordinarily flat or undulating, bordering a river, a lake, or the sea. A stream terrace is frequently called a second bottom, in contrast with a flood plain, and is seldom subject to overflow. A marine terrace, generally wide, was deposited by the sea.

Texture, soil. The relative proportions of sand, silt, and clay particles in a mass of soil. The basic textural classes, in order of increasing proportion of fine particles, are *sand, loamy sand, sandy loam, loam, silt, silt loam, sandy clay loam, clay loam, silty clay loam, sandy clay, silty clay,* and *clay*. The sand, loamy sand, and sandy loam classes may be further divided by specifying "coarse," "fine," or " very fine."

Thin layer. Otherwise suitable soil material too thin for the specified use.

Tilth, soil. The condition of the soil, especially the soil structure, as related to the growth of plants. Good tilth refers to the friable state and is associated with high noncapillary porosity and stable structure. A soil in poor tilth is nonfriable, hard, nonaggregated, and difficult to till.

Topsoil (engineering). Presumably a fertile soil or soil material, or one that responds to fertilization, ordinarily rich in organic matter, used to topdress roadbanks, lawns, and gardens.

Trace elements. The chemical elements in soils, in only extremely small amounts, essential to plant growth. Examples are zinc, cobalt, manganese, copper, and iron.

Unstable fill. Risk of caving or sloughing in banks of fill material.

Upland (geology). Land at a higher elevation, in general, than the alluvial plain or stream terrace; land above the lowlands along streams.

Valley fill. In glaciated regions, material deposited in stream valleys by glacial melt water. In nonglaciated regions, alluvium deposited by heavily loaded streams emerging from hills or mountains and spreading sediments onto the lowland as a series of adjacent alluvial fans.

Variant, soil. A soil having properties sufficiently different from those of other known soils to justify a new series name, but the limited geographic soil area does not justify creation of a new series.

Variegation. Refers to patterns of contrasting colors assumed to be inherited from the parent material rather than to be the result of poor drainage.

Water table. The upper limit of the soil or underlying rock material that is wholly saturated with water.
Water table, apparent. A thick zone of free water in the soil. An apparent water table is indicated by the level at which water stands in an uncased borehole after adequate time is allowed for adjustment in the surrounding soil.
Water table, perched. A water table standing above an unsaturated zone. In places, an upper, or perched water table is separated from a lower one by a dry zone.

Weathering. All physical and chemical changes produced in rocks or other deposits at or near the earth's surface by atmospheric agents. These changes result in disintegration and decomposition of the material.

Well graded. Refers to a soil or soil material consisting of particles well distributed over a wide range in size or diameter. Such a soil normally can be easily increased in density and bearing properties by compaction. Contrasts with poorly graded soil.

Wilting point (or permanent wilting point). The moisture content of soil, on an ovendry basis, at which a plant (specifically sunflower) wilts so much that it does not recover when placed in a humid, dark chamber.

TABLES

TABLE 1.--TEMPERATURE DATA FROM FIVE WEATHER STATIONS

Month	Temperature				
	Highest	Mean maximum	Mean	Mean minimum	Lowest
	°F	°F	°F	°F	°F
ALVARADO, CALIFORNIA					
January	74	58.4	49.8	41.3	23
February	76	60.7	52.5	44.2	33
March	83	65.0	55.8	46.7	35
April	87	66.9	57.6	48.3	35
May	96	70.5	61.1	51.7	38
June	96	72.5	63.2	53.9	42
July	99	73.7	64.6	55.4	43
August	92	73.4	64.3	55.3	45
September	109	75.7	65.1	54.5	45
October	96	72.8	61.9	51.0	38
November	91	66.7	55.5	44.4	30
December	79	60.2	50.9	41.6	23
Annual	109	67.5	58.5	49.0	23
HAYWARD, CALIFORNIA					
January	71	55.9	47.6	39.2	22
February	77	58.9	50.0	41.2	28
March	84	61.9	52.4	42.9	30
April	86	65.4	55.7	46.0	33
May	94	68.5	59.0	49.4	36
June	104	71.6	62.2	52.8	40
July	99	74.3	64.4	54.4	40
August	98	73.4	64.1	54.8	40
September	99	75.4	64.8	54.1	42
October	94	71.1	60.3	49.5	35
November	85	63.8	53.7	43.6	30
December	78	57.7	49.4	41.0	23
Annual	104	66.5	57.0	47.4	22

TABLE 1.--TEMPERATURE DATA FROM FIVE WEATHER STATIONS--Continued

NEWARK, CALIFORNIA

Month	Temperature				
	Highest	Mean maximum	Mean	Mean minimum	Lowest
	°F	°F	°F	°F	°F
January	75	59.6	45.4	33.8	22
February	78	59.7	48.8	38.0	25
March	79	62.6	51.7	40.7	29
April	87	68.2	56.0	43.7	32
May	97	70.4	59.1	47.7	35
June	99	74.6	63.0	51.4	41
July	97	76.7	64.9	53.1	41
August	99	77.0	64.8	52.6	41
September	101	78.3	64.5	50.7	40
October	88	72.6	59.7	46.8	33
November	84	64.6	52.8	41.0	26
December	75	59.4	49.1	38.9	26
Annual	101	68.4	56.7	44.9	22
OAKLAND AIRPORT, CALIFORNIA					
January	72	56.0	47.2	38.4	24
February	82	60.0	50.7	41.3	25
March	85	63.4	53.4	43.3	32
April	88	65.9	55.6	45.3	31
May	94	65.8	58.4	48.3	36
June	107	71.6	61.6	51.6	41
July	102	72.0	62.7	53.4	46
August	95	72.0	62.9	53.7	47
September	102	74.0	63.3	52.6	41
October	94	71.0	60.0	48.9	34
November	86	64.3	53.8	43.2	27
December	74	57.3	48.6	39.8	23
Annual	107	66.3	56.5	46.7	23

TABLE 1.--TEMPERATURE DATA FROM FIVE WEATHER STATIONS--Continued

OAKLAND (CHABOT), CALIFORNIA

Month	Temperature				
	Highest	Mean maximum	Mean	Mean minimum	Lowest
	°F	°F	°F	°F	°F
January	73	54.3	47.8	41.2	24
February	75	57.3	50.4	43.3	28
March	87	61.4	53.3	45.3	32
April	88	64.9	56.1	47.4	36
May	97	68.3	59.2	50.1	38
June	97	71.2	62.2	53.1	41
July	98	73.0	63.9	54.8	48
August	99	73.4	63.9	54.5	47
September	103	74.6	64.6	54.6	44
October	98	70.6	61.3	52.0	36
November	83	63.4	55.3	47.1	32
December	69	55.9	49.5	43.2	25
Annual	103	65.0	56.7	48.9	24

TABLE 2.--AVERAGE MONTHLY AND ANNUAL PRECIPITATION DATA

Month	Station							
	Alvarado (near)	Alviso	Hayward High School	Hayward (near)	Newark	Niles	Oakland	Sunol
	In	In	In	In	In	In	In	In
January	3.54	2.41	4.08	5.13	1.86	3.69	3.30	3.98
February	3.47	1.71	3.84	4.05	2.57	3.07	3.51	3.89
March	2.32	1.90	2.70	3.68	2.47	2.94	2.31	2.56
April	1.13	0.92	1.54	2.31	0.85	1.40	1.46	1.40
May	0.43	0.42	0.86	1.12	0.46	0.74	0.61	0.70
June	0.11	0.12	0.19	0.16	0.11	0.19	0.15	0.15
July	0	0.01	0.01	0.03	0.03	0	0.01	0
August	0.03	0.01	0.04	0.04	0.01	0.03	0.02	0.02
September	0.11	0.21	0.32	0.31	0.03	0.29	0.09	0.40
October	0.68	0.50	0.92	1.34	0.99	1.01	0.91	0.95
November	0.94	1.46	1.89	2.03	1.89	2.08	1.95	1.77
December	3.30	2.69	3.99	5.22	2.37	3.35	3.42	3.72
Annual	16.06	12.36	20.38	25.42	13.64	18.79	17.74	19.54

TABLE 3.--ACREAGE AND PROPORTIONATE EXTENT OF THE SOILS

Map symbol	Soil name	Acres	Percent
100	Altamont clay, 5 to 15 percent slopes	100	0.1
101	Altamont clay, 15 to 30 percent slopes	215	0.1
102	Altamont clay, 30 to 50 percent slopes	355	0.2
103	Azule clay loam, 9 to 30 percent slopes	1,290	0.9
104	Azule clay loam, 30 to 50 percent slopes	170	0.1
105	Baywood Variant, sand	220	0.2
106	Botella loam, 0 to 2 percent slopes	4,625	3.2
107	Clear Lake clay, 0 to 2 percent slopes, drained	8,140	5.6
108	Clear Lake clay, 2 to 9 percent slopes, drained	1,710	1.2
109	Climara clay, 30 to 50 percent slopes	370	0.3
110	Contra Costa clay loam, 30 to 50 percent slopes	320	0.2
111	Danville silty clay loam, 0 to 2 percent slopes	10,660	7.4
112	Danville silty clay loam, 2 to 9 percent slopes	725	0.5
113	Diablo clay, 9 to 15 percent slopes	890	0.6
114	Diablo clay, 15 to 30 percent slopes	325	0.2
115	Diablo clay, 30 to 50 percent slopes	65	*
116	Gaviota-Rock outcrop complex, 15 to 50 percent slopes	215	0.1
117	Laugenour loam, drained	760	0.5
118	Los Gatos-Los Osos complex, 30 to 50 percent slopes	130	0.1
119	Los Gatos-Los Osos complex, 50 to 75 percent slopes	545	0.4
120	Los Osos silty clay loam, 9 to 30 percent slopes	305	0.2
121	Los Osos silty clay loam, 30 to 50 percent slopes	270	0.2
122	Los Osos-Millsholm complex, 9 to 30 percent slopes	1,675	1.2
123	Los Osos-Millsholm complex, 30 to 50 percent slopes	945	0.7
124	Los Osos-Millsholm complex, 50 to 75 percent slopes	265	0.2
125	Marvin silt loam, saline-alkali	3,115	2.2
126	Maymen loam, 30 to 75 percent slopes	3,790	2.6
127	Maymen-Los Gatos complex, 30 to 75 percent slopes	1,845	1.3
128	Millsholm silt loam, 30 to 50 percent slopes	1,565	1.1
129	Millsholm silt loam, 50 to 75 percent slopes	965	0.7
130	Montara-Rock outcrop complex, 30 to 75 percent slopes	525	0.4
131	Omni silty clay loam, drained	4,800	3.3
132	Omni silty clay loam, strongly saline	125	0.1
133	Pescadero clay, drained	1,940	1.3
134	Pescadero clay, ponded	1,050	0.7
135	Pits, gravel	685	0.5
136	Pleasanton gravelly loam, 0 to 5 percent slopes	145	0.1
137	Reyes clay	3,830	2.7
138	Reyes clay, ponded	15,700	10.9
139	Reyes clay, drained	3,560	2.5
140	Rincon clay loam, 0 to 2 percent slopes	2,665	1.8
141	Riverwash	190	0.1
142	Quarry	150	0.1
143	Sycamore silt loam, drained	5,100	3.5
144	Sycamore silt loam, clay substratum	3,255	2.3
145	Tierra loam, 0 to 5 percent slopes	340	0.2
146	Urban land	8,460	5.9
147	Urban land-Baywood complex	4,025	2.8
148	Urban land-Clear Lake complex	5,620	3.9
149	Urban land-Danville complex	2,560	1.8
150	Urban land-Tierra complex, 2 to 5 percent slopes	4,435	3.1
151	Urban land-Tierra complex, 5 to 15 percent slopes	2,630	1.8
152	Urban land-Tierra complex, 15 to 30 percent slopes	1,920	1.3
153	Vallecitos-Rock outcrop complex, 30 to 50 percent slopes	170	0.1
154	Willows clay, drained	2,225	1.5
155	Xerorthents, clayey	1,060	0.7
156	Xeropsamments, fill	6,115	4.2
157	Xerorthents-Altamont complex, 30 to 50 percent slopes	1,120	0.8
158	Xerorthents-Los Osos complex, 30 to 50 percent slopes	3,465	2.4
159	Xerorthents-Millsholm complex, 30 to 50 percent slopes	3,135	2.2
160	Xerorthents-Millsholm complex, 50 to 75 percent slopes	595	0.4
161	Yolo silt loam, 0 to 2 percent slopes	5,955	4.1
	Total	144,120	100.0

* Less than 0.1 percent.

TABLE 4.--BUILDING SITE DEVELOPMENT

[Some terms that describe restrictive soil features are defined in the Glossary. See text for definitions of "slight," "moderate," and "severe." Absence of an entry indicates that the soil was not rated]

Soil name and map symbol	Shallow excavations	Dwellings without basements	Dwellings with basements	Small commercial buildings	Local roads and streets
100---------- Altamont	Severe: too clayey.	Severe: shrink-swell, low strength.	Severe: shrink-swell, low strength.	Severe: shrink-swell, low strength, slope.	Severe: shrink-swell, low strength.
101, 102---------- Altamont	Severe: too clayey, slope.	Severe: shrink-swell, low strength, slope.	Severe: shrink-swell, low strength, slope.	Severe: shrink-swell, low strength, slope.	Severe: shrink-swell, low strength, slope.
103, 104---------- Azule	Severe: slope, too clayey.	Severe: slope, low strength, shrink-swell.	Severe: slope, low strength, shrink-swell.	Severe: slope, shrink-swell, low strength.	Severe: slope, shrink-swell, low strength.
105---------- Baywood Variant	Severe: cutbanks cave, wetness.	Moderate: wetness.	Severe: wetness.	Moderate: wetness.	Moderate: wetness.
106---------- Botella	Moderate: too clayey.	Moderate: low strength, shrink-swell.	Moderate: low strength, shrink-swell.	Moderate: low strength, shrink-swell.	Severe: low strength.
107---------- Clear Lake	Severe: too clayey.	Severe: floods, shrink-swell, low strength.	Severe: floods, wetness, shrink-swell.	Severe: floods, shrink-swell, low strength.	Severe: shrink-swell, low strength.
108---------- Clear Lake	Severe: too clayey.	Severe: shrink-swell, low strength, floods.	Severe: shrink-swell, low strength, floods.	Severe: shrink-swell, floods, low strength.	Severe: shrink-swell, low strength.
109---------- Climara	Severe: slope, depth to rock, too clayey.	Severe: slope, shrink-swell, low strength.	Severe: slope, depth to rock, shrink-swell.	Severe: slope, shrink-swell, low strength.	Severe: slope, shrink-swell, low strength.
110---------- Contra Costa	Severe: slope, depth to rock, too clayey.	Severe: slope, shrink-swell, low strength.	Severe: slope, shrink-swell, depth to rock.	Severe: slope, shrink-swell, low strength.	Severe: slope, low strength, shrink-swell.
111, 112---------- Danville	Severe: too clayey.	Severe: shrink-swell, low strength.	Severe: shrink-swell, low strength.	Severe: shrink-swell, low strength.	Severe: shrink-swell, low strength.
113---------- Diablo	Severe: too clayey.	Severe: shrink-swell, low strength.	Severe: shrink-swell, low strength.	Severe: shrink-swell, slope, low strength.	Severe: shrink-swell, low strength.
114, 115---------- Diablo	Severe: too clayey, slope.	Severe: slope, shrink-swell, low strength.	Severe: slope, shrink-swell, low strength.	Severe: shrink-swell, slope, low strength.	Severe: shrink-swell, low strength, slope.
116*: Gaviota---------- Rock outcrop.	Severe: slope, depth to rock.	Severe: slope, depth to rock.	Severe: slope, depth to rock.	Severe: depth to rock, slope.	Severe: slope, depth to rock.

See footnote at end of table.

TABLE 4.--BUILDING SITE DEVELOPMENT--Continued

Soil name and map symbol	Shallow excavations	Dwellings without basements	Dwellings with basements	Small commercial buildings	Local roads and streets
117--- Laugenour	Slight---	Moderate: low strength, shrink-swell.	Moderate: shrink-swell, low strength, wetness.	Moderate: low strength, shrink-swell.	Moderate: low strength, shrink-swell.
118*, 119*:					
Los Gatos---	Severe: depth to rock, slope.	Severe: slope.	Severe: slope, depth to rock.	Severe: slope.	Severe: slope, low strength.
Los Osos---	Severe: slope, too clayey.	Severe: slope, shrink-swell, low strength.	Severe: slope, shrink-swell, low strength.	Severe: slope, shrink-swell, low strength.	Severe: slope, low strength, shrink-swell.
120, 121--- Los Osos	Severe: slope, too clayey.	Severe: slope, shrink-swell, low strength.	Severe: slope, shrink-swell, low strength.	Severe: slope, shrink-swell, low strength.	Severe: slope, low strength, shrink-swell.
122*, 123*, 124*:					
Los Osos---	Severe: slope, too clayey.	Severe: slope, shrink-swell, low strength.	Severe: slope, shrink-swell, low strength.	Severe: slope, shrink-swell, low strength.	Severe: slope, low strength, shrink-swell.
Millsholm---	Severe: slope, depth to rock.	Severe: slope, depth to rock.	Severe: slope, depth to rock.	Severe: slope, depth to rock.	Severe: depth to rock, slope.
125--- Marvin	Severe: too clayey.	Severe: low strength, shrink-swell.	Severe: shrink-swell, low strength.	Severe: low strength, shrink-swell.	Severe: shrink-swell, low strength.
126--- Maymen	Severe: slope, depth to rock.	Severe: slope, depth to rock.	Severe: slope, depth to rock.	Severe: slope, depth to rock.	Severe: slope, depth to rock.
127*:					
Maymen---	Severe: slope, depth to rock.	Severe: slope, depth to rock.	Severe: slope, depth to rock.	Severe: slope, depth to rock.	Severe: slope, depth to rock.
Los Gatos---	Severe: depth to rock, slope.	Severe: slope.	Severe: slope, depth to rock.	Severe: slope.	Severe: slope, low strength.
128, 129--- Millsholm	Severe: slope, depth to rock.	Severe: slope, depth to rock.	Severe: slope, depth to rock.	Severe: slope, depth to rock.	Severe: depth to rock, slope.
130*:					
Montara---	Severe: depth to rock, slope.	Severe: slope, depth to rock.	Severe: slope, depth to rock.	Severe: slope, depth to rock.	Severe: slope, depth to rock, low strength.
Rock outcrop.					
131--- Omni	Severe: too clayey.	Severe: shrink-swell, low strength.	Severe: shrink-swell, low strength.	Severe: shrink-swell, low strength.	Severe: shrink-swell, low strength.
132--- Omni	Severe: floods, too clayey.	Severe: floods, shrink-swell, low strength.	Severe: floods, shrink-swell, low strength.	Severe: floods, shrink-swell, low strength.	Severe: floods, low strength, shrink-swell.

See footnote at end of table.

TABLE 4.--BUILDING SITE DEVELOPMENT--Continued

Soil name and map symbol	Shallow excavations	Dwellings without basements	Dwellings with basements	Small commercial buildings	Local roads and streets
133--- Pescadero	Severe: too clayey.	Severe: low strength, shrink-swell.	Severe: shrink-swell, low strength.	Severe: low strength, shrink-swell.	Severe: low strength, shrink-swell.
134--- Pescadero	Severe: floods, too clayey, wetness.	Severe: floods, wetness, low strength.	Severe: floods, wetness, low strength.	Severe: floods, wetness, low strength.	Severe: floods, shrink-swell, low strength.
135*. Pits					
136--- Pleasanton	Moderate: too clayey.	Moderate: shrink-swell.	Moderate: shrink-swell.	Moderate: shrink-swell.	Moderate: shrink-swell, low strength.
137--- Reyes	Severe: too clayey, floods, wetness.	Severe: wetness, shrink-swell, floods.	Severe: wetness, shrink-swell, floods.	Severe: wetness, shrink-swell, floods.	Severe: wetness, floods, low strength.
138--- Reyes	Severe: floods, wetness, too clayey.	Severe: floods, shrink-swell, wetness.	Severe: floods, wetness, shrink-swell.	Severe: floods, wetness, shrink-swell.	Severe: floods, wetness, low strength.
139--- Reyes	Severe: too clayey, wetness.	Severe: shrink-swell, low strength.	Severe: wetness, shrink-swell.	Severe: shrink-swell, low strength.	Severe: low strength, shrink-swell.
140--- Rincon	Moderate: too clayey.	Severe: low strength, shrink-swell.	Severe: low strength, shrink-swell.	Severe: low strength, shrink-swell.	Severe: low strength, shrink-swell.
141*. Riverwash					
142*. Quarry					
143--- Sycamore	Slight---	Moderate: low strength, shrink-swell.	Moderate: low strength, shrink-swell.	Moderate: low strength, shrink-swell.	Moderate: low strength, shrink-swell.
144--- Sycamore	Severe: too clayey.	Moderate: low strength.	Severe: low strength, shrink-swell.	Moderate: low strength.	Moderate: low strength.
145--- Tierra	Severe: too clayey.	Severe: shrink-swell, low strength.	Severe: shrink-swell.	Severe: shrink-swell, low strength.	Severe: shrink-swell, low strength.
146*. Urban land					
147*: Urban land.					
Baywood---	Severe: cutbanks cave.	Slight---	Slight---	Moderate: slope.	Slight.
148*: Urban land.					

See footnote at end of table.

TABLE 4.--BUILDING SITE DEVELOPMENT--Continued

Soil name and map symbol	Shallow excavations	Dwellings without basements	Dwellings with basements	Small commercial buildings	Local roads and streets
148*:					
Clear Lake	Severe: too clayey.	Severe: floods, shrink-swell, low strength.	Severe: floods, wetness, shrink-swell.	Severe: floods, shrink-swell, low strength.	Severe: shrink-swell, low strength.
149*:					
Urban land.					
Danville	Severe: too clayey.	Severe: shrink-swell, low strength.	Severe: shrink-swell, low strength.	Severe: shrink-swell, low strength.	Severe: shrink-swell, low strength.
150*:					
Urban land.					
Tierra	Severe: too clayey.	Severe: shrink-swell, low strength.	Severe: shrink-swell.	Severe: shrink-swell, low strength.	Severe: shrink-swell, low strength.
151*:					
Urban land.					
Tierra	Severe: too clayey.	Severe: shrink-swell, low strength.	Severe: shrink-swell.	Severe: slope, shrink-swell, low strength.	Severe: shrink-swell, low strength.
152*:					
Urban land.					
Tierra	Severe: slope, too clayey.	Severe: slope, shrink-swell, low strength.	Severe: slope, shrink-swell.	Severe: slope, shrink-swell, low strength.	Severe: slope, shrink-swell, low strength.
Azule	Severe: slope, too clayey.	Severe: slope, low strength, shrink-swell.	Severe: slope, low strength, shrink-swell.	Severe: slope, low strength, shrink-swell.	Severe: slope, low strength, shrink-swell.
153*:					
Vallecitos	Severe: slope, depth to rock.	Severe: slope, depth to rock.	Severe: slope, depth to rock.	Severe: slope, depth to rock.	Severe: slope, depth to rock, low strength.
Rock outcrop.					
154					
Willows	Severe: too clayey.	Severe: floods, shrink-swell, low strength.	Severe: shrink-swell, low strength.	Severe: floods, shrink-swell, low strength.	Severe: low strength, shrink-swell.
155*					
Xerorthents	Severe: slope, too clayey, depth to rock.	Severe: slope, shrink-swell, low strength.	Severe: shrink-swell, low strength, slope.	Severe: shrink-swell, low strength, slope.	Severe: shrink-swell, low strength, slope.
156*					
Xeropsamments	Severe: cutbanks cave, wetness.	Moderate: wetness.	Severe: wetness.	Moderate: wetness.	Moderate: wetness.
157*:					
Xerorthents	Severe: slope, too clayey, depth to rock.	Severe: slope, shrink-swell, low strength.	Severe: shrink-swell, low strength, slope.	Severe: shrink-swell, low strength, slope.	Severe: shrink-swell, low strength, slope.
Altamont	Severe: too clayey, slope.	Severe: shrink-swell, low strength, slope.	Severe: shrink-swell, low strength, slope.	Severe: shrink-swell, low strength, slope.	Severe: shrink-swell, low strength, slope.

See footnote at end of table.

TABLE 4.--BUILDING SITE DEVELOPMENT--Continued

Soil name and map symbol	Shallow excavations	Dwellings without basements	Dwellings with basements	Small commercial buildings	Local roads and streets
158*:					
Xerorthents	Severe: slope, depth to rock.	Severe: slope.	Severe: slope, depth to rock.	Severe: slope.	Severe: slope.
Los Osos	Severe: slope, too clayey.	Severe: slope, shrink-swell, low strength.	Severe: slope, shrink-swell, low strength.	Severe: slope, shrink-swell, low strength.	Severe: slope, low strength, shrink-swell.
159*, 160*:					
Xerorthents	Severe: slope.	Severe: slope.	Severe: slope.	Severe: slope.	Severe: slope.
Millsholm	Severe: slope, depth to rock.	Severe: slope, depth to rock.	Severe: slope, depth to rock.	Severe: slope, depth to rock.	Severe: depth to rock, slope.
161 Yolo	Slight	Moderate: low strength, shrink-swell.	Moderate: low strength, shrink-swell.	Moderate: low strength, shrink-swell.	Moderate: low strength, shrink-swell.

* See description of the map unit for composition and behavior characteristics of the map unit.

TABLE 5.--SANITARY FACILITIES

[Some terms that describe restrictive soil features are defined in the Glossary. See text for definitions of "slight," "moderate," "good," and "fair." Absence of an entry indicates that the soil was not rated]

Soil name and map symbol	Septic tank absorption fields	Sewage lagoon areas	Trench sanitary landfill	Area sanitary landfill	Daily cover for landfill
100 Altamont	Severe: percs slowly, depth to rock.	Severe: slope.	Severe: too clayey, depth to rock.	Moderate: slope.	Poor: too clayey.
101 Altamont	Severe: percs slowly, depth to rock, slope.	Severe: slope.	Severe: too clayey, depth to rock.	Severe: slope.	Poor: too clayey, slope.
102 Altamont	Severe: percs slowly, depth to rock, slope.	Severe: slope.	Severe: too clayey, depth to rock, slope.	Severe: slope.	Poor: too clayey, slope.
103 Azule	Severe: slope, percs slowly, depth to rock.	Severe: slope.	Severe: too clayey, depth to rock.	Severe: slope.	Poor: slope, too clayey, area reclaim.
104 Azule	Severe: slope, percs slowly, depth to rock.	Severe: slope.	Severe: slope, too clayey, depth to rock.	Severe: slope.	Poor: slope, too clayey, area reclaim.
105 Baywood Variant	Severe: wetness.	Severe: wetness, seepage.	Severe: wetness, seepage.	Severe: wetness, seepage.	Poor: too sandy.
106 Botella	Severe: percs slowly.	Slight	Moderate: too clayey.	Slight	Fair: too clayey.
107 Clear Lake	Severe: wetness, percs slowly.	Moderate: wetness.	Severe: wetness, too clayey.	Severe: wetness.	Poor: too clayey.
108 Clear Lake	Severe: percs slowly.	Slight	Severe: too clayey.	Moderate: floods.	Poor: too clayey.
109 Climara	Severe: slope, percs slowly, depth to rock.	Severe: slope, depth to rock.	Severe: slope, depth to rock, too clayey.	Severe: slope.	Poor: slope, too clayey, area reclaim.
110 Contra Costa	Severe: slope, percs slowly, depth to rock.	Severe: slope, depth to rock.	Severe: slope, too clayey, depth to rock.	Severe: slope.	Poor: slope, too clayey, area reclaim.
111 Danville	Severe: percs slowly.	Slight	Severe: too clayey.	Slight	Poor: too clayey.
112 Danville	Severe: percs slowly.	Moderate: slope.	Severe: too clayey.	Slight	Poor: too clayey.
113 Diablo	Severe: percs slowly.	Severe: slope.	Severe: depth to rock, too clayey.	Moderate: slope.	Poor: too clayey.
114 Diablo	Severe: slope, percs slowly.	Severe: slope.	Severe: depth to rock, too clayey.	Severe: slope.	Poor: slope, too clayey.

TABLE 5.--SANITARY FACILITIES--Continued

Soil name and map symbol	Septic tank absorption fields	Sewage lagoon areas	Trench sanitary landfill	Area sanitary landfill	Daily cover for landfill
115---------- Diablo	Severe: slope, percs slowly.	Severe: slope.	Severe: slope, depth to rock, too clayey.	Severe: slope.	Poor: slope, too clayey.
116*: Gaviota----------	Severe: slope, depth to rock.	Severe: seepage, depth to rock, slope.	Severe: slope, depth to rock, seepage.	Severe: slope, seepage.	Poor: slope, thin layer, area reclaim.
Rock outcrop.					
117---------- Laugenour	Severe: percs slowly, wetness.	Severe: seepage.	Severe: wetness.	Severe: seepage.	Good.
118*, 119*: Los Gatos----------	Severe: slope, depth to rock, percs slowly.	Severe: slope, depth to rock.	Severe: slope, depth to rock.	Severe: slope.	Poor: slope.
Los Osos----------	Severe: slope, depth to rock, percs slowly.	Severe: slope.	Severe: slope, depth to rock, too clayey.	Severe: slope.	Poor: area reclaim, slope, too clayey.
120---------- Los Osos	Severe: slope, depth to rock, percs slowly.	Severe: slope.	Severe: depth to rock, too clayey.	Severe: slope.	Poor: area reclaim, slope, too clayey.
121---------- Los Osos	Severe: slope, depth to rock, percs slowly.	Severe: slope.	Severe: slope, depth to rock, too clayey.	Severe: slope.	Poor: area reclaim, slope, too clayey.
122*: Los Osos----------	Severe: slope, depth to rock, percs slowly.	Severe: slope.	Severe: depth to rock, too clayey.	Severe: slope.	Poor: area reclaim, slope, too clayey.
Millsholm----------	Severe: slope, depth to rock.	Severe: slope, depth to rock.	Severe: depth to rock.	Severe: slope.	Poor: slope, thin layer, area reclaim.
123*, 124*: Los Osos----------	Severe: slope, depth to rock, percs slowly.	Severe: slope.	Severe: slope, depth to rock, too clayey.	Severe: slope.	Poor: area reclaim, slope, too clayey.
Millsholm----------	Severe: slope, depth to rock.	Severe: slope, depth to rock.	Severe: slope, depth to rock.	Severe: slope.	Poor: slope, thin layer, area reclaim.
125---------- Marvin	Severe: percs slowly, wetness.	Moderate: wetness.	Severe: too clayey, wetness.	Moderate: wetness.	Poor: too clayey.
126---------- Maymen	Severe: slope, depth to rock.	Severe: slope, depth to rock.	Severe: slope, depth to rock.	Severe: slope.	Poor: slope, thin layer, area reclaim.

See footnote at end of table.

TABLE 5.--SANITARY FACILITIES--Continued

Soil name and map symbol	Septic tank absorption fields	Sewage lagoon areas	Trench sanitary landfill	Area sanitary landfill	Daily cover for landfill
127*: Maymen	Severe: slope, depth to rock.	Severe: slope, depth to rock.	Severe: slope, depth to rock.	Severe: slope.	Poor: slope, thin layer, area reclaim.
Los Gatos	Severe: slope, depth to rock, percs slowly.	Severe: slope, depth to rock.	Severe: slope, depth to rock.	Severe: slope.	Poor: slope.
128, 129 Millsholm	Severe: slope, depth to rock.	Severe: slope, depth to rock.	Severe: slope, depth to rock.	Severe: slope.	Poor: slope, thin layer, area reclaim.
130*: Montara	Severe: depth to rock, slope.	Severe: depth to rock, slope.	Severe: depth to rock, slope.	Severe: slope.	Poor: slope, thin layer, area reclaim.
Rock outcrop.					
131, 132 Omni	Severe: percs slowly.	Slight	Severe: too clayey, wetness.	Slight	Poor: too clayey.
133 Pescadero	Severe: percs slowly.	Slight	Severe: wetness, too clayey.	Slight	Poor: too clayey.
134 Pescadero	Severe: floods, percs slowly, wetness.	Severe: floods, wetness.	Severe: floods, too clayey, wetness.	Severe: floods, wetness.	Poor: wetness, too clayey.
135*. Pits					
136 Pleasanton	Severe: percs slowly.	Moderate: slope, seepage.	Slight	Slight	Fair: small stones.
137 Reyes	Severe: percs slowly, floods, wetness.	Severe: floods, wetness.	Severe: wetness, too clayey, floods.	Severe: floods, wetness.	Poor: too clayey, wetness.
138 Reyes	Severe: floods, wetness, percs slowly.	Severe: floods, wetness.	Severe: floods, wetness, too clayey.	Severe: floods, wetness.	Poor: wetness, too clayey.
139 Reyes	Severe: wetness, percs slowly.	Severe: wetness.	Severe: wetness, too clayey.	Severe: wetness.	Poor: too clayey.
140 Rincon	Severe: percs slowly.	Slight	Moderate: too clayey.	Slight	Fair: too clayey.
141*. Riverwash					
142*. Quarry					
143 Sycamore	Severe: percs slowly.	Severe: seepage.	Severe: seepage.	Slight	Good.

See footnote at end of table.

TABLE 5.--SANITARY FACILITIES--Continued

Soil name and map symbol	Septic tank absorption fields	Sewage lagoon areas	Trench sanitary landfill	Area sanitary landfill	Daily cover for landfill
144---------- Sycamore	Severe: percs slowly.	Moderate: seepage.	Slight----------	Slight----------	Fair: thin layer.
145---------- Tierra	Severe: percs slowly.	Moderate: slope.	Moderate: too clayey.	Slight----------	Fair: too clayey.
146*. Urban land					
147*: Urban land.					
Baywood----------	Slight----------	Severe: seepage.	Severe: seepage.	Severe: seepage.	Fair: too sandy.
148*: Urban land.					
Clear Lake----------	Severe: wetness, percs slowly.	Moderate: wetness.	Severe: wetness, too clayey.	Severe: wetness.	Poor: too clayey.
149*: Urban land.					
Danville----------	Severe: percs slowly.	Moderate: slope.	Severe: too clayey.	Slight----------	Poor: too clayey.
150*: Urban land.					
Tierra----------	Severe: percs slowly.	Moderate: slope.	Moderate: too clayey.	Slight----------	Fair: too clayey.
151*: Urban land.					
Tierra----------	Severe: percs slowly.	Severe: slope.	Moderate: too clayey.	Moderate: slope.	Fair: too clayey.
152*: Urban land.					
Tierra----------	Severe: slope, percs slowly.	Severe: slope.	Moderate: slope, too clayey.	Severe: slope.	Poor: slope, too clayey.
Azule----------	Severe: slope, percs slowly, depth to rock.	Severe: slope.	Severe: depth to rock.	Severe: slope.	Poor: slope, too clayey, area reclaim.
153*: Vallecitos----------	Severe: slope, depth to rock, percs slowly.	Severe: slope, depth to rock.	Severe: slope, depth to rock.	Severe: slope.	Poor: slope, thin layer, area reclaim.
Rock outcrop.					
154---------- Willows	Severe: percs slowly.	Slight----------	Severe: wetness, too clayey.	Slight----------	Poor: too clayey.
155*---------- Xerorthents	Severe: slope, percs slowly, depth to rock.	Severe: slope, depth to rock.	Severe: slope, depth to rock.	Severe: slope.	Poor: slope, too clayey.

See footnote at end of table.

TABLE 5.--SANITARY FACILITIES--Continued

Soil name and map symbol	Septic tank absorption fields	Sewage lagoon areas	Trench sanitary landfill	Area sanitary landfill	Daily cover for landfill
156*---------- Xeropsamments	Severe: wetness.	Severe: wetness, seepage.	Severe: wetness, seepage.	Severe: wetness, seepage.	Poor: too sandy, seepage.
157*: Xerorthents---------	Severe: slope, percs slowly, depth to rock.	Severe: slope, depth to rock.	Severe: slope, depth to rock, too clayey.	Severe: slope.	Poor: slope, too clayey.
Altamont----------	Severe: percs slowly, depth to rock, slope.	Severe: slope.	Severe: too clayey, depth to rock, slope.	Severe: slope.	Poor: too clayey, slope.
158*: Xerorthents---------	Severe: slope, depth to rock.	Severe: slope, depth to rock.	Severe: slope, depth to rock.	Severe: slope.	Poor: slope, thin layer.
Los Osos----------	Severe: slope, depth to rock, percs slowly.	Severe: slope.	Severe: slope, depth to rock, too clayey.	Severe: slope.	Poor: area reclaim, slope, too clayey.
159*, 160*: Xerorthents---------	Severe: slope.	Severe: slope.	Severe: slope, depth to rock.	Severe: slope.	Poor: slope.
Millsholm----------	Severe: slope, depth to rock.	Severe: slope, depth to rock.	Severe: slope, depth to rock.	Severe: slope.	Poor: slope, thin layer, area reclaim.
161---------- Yolo	Moderate: percs slowly.	Moderate: seepage.	Moderate: too clayey.	Slight----------	Fair: too clayey.

* See description of the map unit for composition and behavior characteristics of the map unit.

TABLE 6.--WATER MANAGEMENT

[Some terms that describe restrictive soil features are defined in the Glossary. Absence of an entry indicates that the soil was not evaluated]

Soil name and map symbol	Pond reservoir areas	Embankments, dikes, and levees	Drainage	Irrigation	Grassed waterways
100, 101, 102----- Altamont	Slope, depth to rock.	Low strength, hard to pack.	Slope, percs slowly, depth to rock.	Slope, slow intake, percs slowly.	Slope, percs slowly.
103, 104---------- Azule	Slope, depth to rock.	Low strength, hard to pack.	Slope, percs slowly, depth to rock.	Slope, percs slowly, rooting depth.	Slope, erodes easily, depth to rock.
105---------- Baywood Variant	Wetness, seepage.	Piping, seepage.	Favorable--------	Droughty, seepage, wetness.	Droughty.
106---------- Botella	Favorable---------	Favorable---------	Favorable--------	Favorable--------	Erodes easily.
107---------- Clear Lake	Favorable---------	Low strength, hard to pack.	Percs slowly, floods.	Slow intake, percs slowly.	Percs slowly.
108---------- Clear Lake	Favorable---------	Low strength, hard to pack.	Percs slowly, slope.	Percs slowly, slow intake, slope.	Percs slowly.
109---------- Climara	Slope, depth to rock.	Low strength, hard to pack, thin layer.	Slope, percs slowly, depth to rock.	Slope, percs slowly, rooting depth.	Slope, depth to rock, percs slowly.
110---------- Contra Costa	Slope, depth to rock.	Low strength, hard to pack.	Slope, depth to rock, percs slowly.	Slope, rooting depth, percs slowly.	Slope, percs slowly, depth to rock.
111---------- Danville	Favorable---------	Hard to pack------	Percs slowly-----	Percs slowly-----	Percs slowly.
112---------- Danville	Favorable---------	Hard to pack------	Percs slowly, slope.	Percs slowly, slope.	Percs slowly.
113, 114, 115----- Diablo	Slope----------	Low strength, hard to pack.	Percs slowly, slope.	Slope, slow intake, percs slowly.	Slope, percs slowly.
116*: Gaviota----------	Slope, depth to rock.	Thin layer, piping.			Slope, depth to rock, erodes easily.
Rock outcrop.					
117---------- Laugenour	Seepage----------	Piping, seepage.	Favorable--------	Favorable--------	Erodes easily.
118*, 119*: Los Gatos--------	Slope, depth to rock.	Thin layer--------	Slope, depth to rock.	Slope, rooting depth.	Slope, erodes easily, depth to rock.
Los Osos---------	Slope, depth to rock.	Hard to pack, thin layer.	Complex slope, depth to rock, percs slowly.	Slope, rooting depth, percs slowly.	Slope, erodes easily, depth to rock.
120, 121---------- Los Osos	Slope, depth to rock.	Hard to pack, thin layer.	Complex slope, depth to rock, percs slowly.	Slope, rooting depth, percs slowly.	Slope, erodes easily, depth to rock.

See footnote at end of table.

TABLE 6.--WATER MANAGEMENT--Continued

Soil name and map symbol	Pond reservoir areas	Embankments, dikes, and levees	Drainage	Irrigation	Grassed waterways
122*, 123*, 124*: Los Osos	Slope, depth to rock.	Hard to pack, thin layer.	Complex slope, depth to rock, percs slowly.	Slope, rooting depth, percs slowly.	Slope, erodes easily, depth to rock.
Millsholm	Slope, depth to rock.	Thin layer	Slope, depth to rock.		Slope, rooting depth, erodes easily.
125--- Marvin	Favorable	Hard to pack	Percs slowly, excess salt.	Percs slowly, excess salt, erodes easily.	Percs slowly, excess salt, erodes easily.
126--- Maymen	Slope, depth to rock.	Thin layer, low strength.	Slope, depth to rock.	Slope, droughty, rooting depth.	Slope, rooting depth, droughty.
127*: Maymen	Slope, depth to rock.	Thin layer, low strength.	Slope, depth to rock.	Slope, droughty, rooting depth.	Slope, rooting depth, droughty.
Los Gatos	Slope, depth to rock.	Thin layer	Slope, depth to rock.	Slope, rooting depth.	Slope, erodes easily, depth to rock.
128, 129--- Millsholm	Slope, depth to rock.	Thin layer	Slope, depth to rock.		Slope, rooting depth, erodes easily.
130*: Montara	Slope, depth to rock.	Thin layer			Slope, depth to rock.
Rock outcrop.					
131, 132--- Omni	Favorable	Hard to pack	Percs slowly, poor outlets.	Percs slowly, erodes easily.	Percs slowly, erodes easily.
133--- Pescadero	Favorable	Low strength, hard to pack.	Excess sodium, excess salt, percs slowly.		Excess sodium, excess salt, percs slowly.
134--- Pescadero	Favorable	Low strength, compressible.	Excess salt, percs slowly, excess sodium.	Excess salt, excess sodium, percs slowly.	Excess salt, wetness, percs slowly.
135*. Pits					
136--- Pleasanton	Seepage	Favorable	Slope	Droughty	Droughty.
137--- Reyes	Favorable	Hard to pack, piping, wetness.	Excess salt, percs slowly, floods.	Floods, slow intake, wetness.	Excess salt, percs slowly, wetness.
138--- Reyes	Favorable	Hard to pack, wetness, piping.	Percs slowly, excess salt, floods.	Wetness, excess salt, slow intake.	Excess salt, excess sodium, wetness.
139--- Reyes	Favorable	Hard to pack, excess salt.	Excess salt, percs slowly, poor outlets.	Wetness, excess salt, slow intake.	Excess salt, percs slowly, droughty.
140--- Rincon	Favorable	Hard to pack	Percs slowly	Percs slowly	Erodes easily, percs slowly.

See footnote at end of table.

TABLE 6.--WATER MANAGEMENT--Continued

Soil name and map symbol	Pond reservoir areas	Embankments, dikes, and levees	Drainage	Irrigation	Grassed waterways
141*. Riverwash					
142*. Quarry					
143---------- Sycamore	Seepage----------	Piping----------	Favorable--------	Favorable--------	Erodes easily.
144---------- Sycamore	Favorable---------	Thin layer, piping.	Percs slowly-----	Percs slowly-----	Percs slowly, erodes easily.
145---------- Tierra	Favorable---------	Hard to pack------	Slope, percs slowly.	Percs slowly-----	Percs slowly, erodes easily.
146*. Urban land					
147*: Urban land.					
Baywood----------	Seepage----------	Piping, seepage.	Slope, cutbanks cave.	Droughty, fast intake.	Droughty.
148*: Urban land.					
Clear Lake-------	Favorable---------	Low strength, hard to pack.	Percs slowly, floods.	Slow intake, percs slowly.	Percs slowly.
149*: Urban land.					
Danville---------	Favorable---------	Hard to pack------	Percs slowly, slope.	Percs slowly, slope.	Percs slowly.
150*: Urban land.					
Tierra----------	Favorable---------	Hard to pack------	Slope, percs slowly.	Percs slowly, slope.	Percs slowly, erodes easily.
151*: Urban land.					
Tierra----------	Slope-------------	Hard to pack------	Slope, percs slowly.	Percs slowly, slope.	Slope, erodes easily, percs slowly.
152*: Urban land.					
Tierra----------	Slope-------------	Hard to pack------	Slope, percs slowly.	Slope, percs slowly.	Slope, erodes easily, percs slowly.
Azule------------	Slope, depth to rock.	Low strength, hard to pack.	Slope, percs slowly, depth to rock.	Slope, percs slowly, rooting depth.	Slope, erodes easily, depth to rock.
153*: Vallecitos-------	Slope, depth to rock.	Thin layer--------			Slope, rooting depth, percs slowly.
Rock outcrop.					
154---------- Willows	Favorable---------	Hard to pack, piping, excess salt.	Percs slowly, poor outlets.	Slow intake, percs slowly, droughty.	Excess salt, excess sodium, droughty.

See footnote at end of table.

TABLE 6.--WATER MANAGEMENT--Continued

Soil name and map symbol	Pond reservoir areas	Embankments, dikes, and levees	Drainage	Irrigation	Grassed waterways
155*---------- Xerorthents	Slope, depth to rock.	Low strength, thin layer.	Percs slowly, poor outlets.	Percs slowly, slow intake.	Slope, percs slowly.
156*---------- Xeropsamments	Seepage----------	Seepage----------	Favorable--------	Wetness, droughty.	Droughty.
157*: Xerorthents------	Slope, depth to rock.	Low strength, thin layer.	Percs slowly, slope, depth to rock.	Percs slowly, slope, rooting depth.	Slope, percs slowly.
Altamont---------	Slope, depth to rock.	Low strength, hard to pack.	Slope, percs slowly, depth to rock.	Slope, slow intake, percs slowly.	Slope, percs slowly.
158*: Xerorthents------	Slope----------	Thin layer--------	Slope, percs slowly, depth to rock.	Slope, percs slowly, rooting depth.	Slope, thin layer.
Los Osos---------	Slope, depth to rock.	Hard to pack, thin layer.	Complex slope, depth to rock, percs slowly.	Slope, rooting depth, percs slowly.	Slope, erodes easily, depth to rock.
159*, 160*: Xerorthents------	Slope----------	Piping, low strength.	Slope, depth to rock.	Slope, rooting depth.	Slope.
Millsholm--------	Slope, depth to rock.	Thin layer--------	Slope, depth to rock.	Slope, rooting depth.	Slope, rooting depth, erodes easily.
161---------- Yolo	Seepage----------	Favorable---------	Favorable--------	Favorable--------	Erodes easily.

* See description of the map unit for composition and behavior characteristics of the map unit.

TABLE 7.--RECREATIONAL DEVELOPMENT

[Some terms that describe restrictive soil features are defined in the Glossary. See text for definitions of "slight," "moderate," and "severe." Absence of an entry indicates that the soil was not rated]

Soil name and map symbol	Camp areas	Picnic areas	Playgrounds	Paths and trails
100 Altamont	Moderate: too clayey, slope.	Moderate: too clayey, slope.	Severe: too clayey, slope.	Moderate: too clayey.
101 Altamont	Severe: slope.	Severe: too clayey, slope.	Severe: too clayey, slope.	Moderate: too clayey, slope.
102 Altamont	Severe: slope.	Severe: too clayey, slope.	Severe: too clayey, slope.	Severe: too clayey, slope.
103 Azule	Severe: slope.	Severe: slope.	Severe: slope.	Moderate: slope.
104 Azule	Severe: slope.	Severe: slope.	Severe: slope.	Severe: slope.
105 Baywood Variant	Severe: too sandy.	Severe: too sandy.	Severe: too sandy.	Severe: too sandy.
106 Botella	Slight	Slight	Moderate: small stones.	Slight.
107, 108 Clear Lake	Severe: floods.	Moderate: too clayey.	Severe: too clayey.	Moderate: too clayey.
109 Climara	Severe: slope.	Severe: slope.	Severe: slope, too clayey.	Severe: slope.
110 Contra Costa	Severe: slope.	Severe: slope.	Severe: slope.	Severe: slope.
111 Danville	Slight	Slight	Moderate: too clayey.	Slight.
112 Danville	Slight	Slight	Moderate: slope, too clayey.	Slight.
113 Diablo	Moderate: slope, too clayey.	Moderate: slope, too clayey.	Severe: slope, too clayey.	Moderate: too clayey.
114 Diablo	Severe: slope.	Severe: slope.	Severe: slope, too clayey.	Moderate: too clayey, slope.
115 Diablo	Severe: slope.	Severe: slope.	Severe: slope, too clayey.	Severe: slope.
116*: Gaviota	Severe: slope.	Severe: slope.	Severe: slope, depth to rock.	Severe: slope.
Rock outcrop.				
117 Laugenour	Moderate: percs slowly.	Slight	Moderate: percs slowly.	Slight.

See footnote at end of table.

TABLE 7.--RECREATIONAL DEVELOPMENT--Continued

Soil name and map symbol	Camp areas	Picnic areas	Playgrounds	Paths and trails
118*, 119*:				
Los Gatos	Severe: slope.	Severe: slope.	Severe: slope.	Severe: slope.
Los Osos	Severe: slope.	Severe: slope.	Severe: slope.	Severe: slope.
120	Severe:	Severe:	Severe:	Moderate:
Los Osos	slope.	slope.	slope.	slope.
121	Severe:	Severe:	Severe:	Severe:
Los Osos	slope.	slope.	slope.	slope.
122*:				
Los Osos	Severe: slope.	Severe: slope.	Severe: slope.	Moderate: slope.
Millsholm	Severe: slope.	Severe: slope.	Moderate: slope.	
123*, 124*:				
Los Osos	Severe: slope.	Severe: slope.	Severe: slope.	Severe: slope.
Millsholm	Severe: slope.	Severe: slope.	Severe: slope.	Severe: slope.
125	Moderate:	Slight	Moderate:	
Marvin	percs slowly.		percs slowly.	
126	Severe:	Severe:	Severe:	Severe:
Maymen	slope.	slope.	slope, depth to rock.	slope.
127*:				
Maymen	Severe: slope.	Severe: slope.		Severe: slope.
Los Gatos	Severe: slope.	Severe: slope.	Severe: slope.	Severe: slope.
128, 129	Severe:	Severe:	Severe:	Severe:
Millsholm	slope.	slope.	slope.	slope.
130*:				
Montara	Severe: slope, depth to rock.	Severe: slope.	Severe: depth to rock, slope.	Severe: slope.
Rock outcrop.				
131	Moderate:	Moderate:	Severe:	Moderate:
Omni	percs slowly, too clayey.	too clayey.	too clayey.	too clayey.
132	Severe:	Severe:	Severe:	Moderate:
Omni	floods.	floods.	floods.	too clayey.
133	Moderate:	Slight	Moderate:	Slight.
Pescadero	too clayey, percs slowly.		too clayey.	
134	Severe:	Severe:	Severe:	Severe:
Pescadero	floods, percs slowly.	floods, wetness.	floods, wetness.	floods, wetness.

See footnote at end of table.

TABLE 7.--RECREATIONAL DEVELOPMENT--Continued

Soil name and map symbol	Camp areas	Picnic areas	Playgrounds	Paths and trails
135*. Pits				
136---------- Pleasanton	Moderate: small stones.	Moderate: small stones.	Severe: small stones.	Moderate: small stones.
137---------- Reyes	Severe: floods, percs slowly, wetness.	Severe: wetness.	Severe: floods, wetness, too clayey.	Severe: wetness.
138---------- Reyes	Severe: floods, wetness, percs slowly.	Severe: wetness.	Severe: wetness, floods, too clayey.	Severe: wetness.
139---------- Reyes	Severe: too clayey, percs slowly.	Moderate: too clayey.	Severe: too clayey, percs slowly.	Moderate: too clayey.
140---------- Rincon	Slight----------	Slight----------	Moderate: too clayey.	Slight.
141*. Riverwash				
142*. Quarry				
143, 144---------- Sycamore	Moderate: dusty.	Moderate: dusty.	Moderate: dusty.	Moderate: dusty.
145---------- Tierra	Moderate: percs slowly.	Slight----------	Moderate: percs slowly, slope.	Slight.
146*. Urban land				
147*: Urban land.				
Baywood----------	Moderate: too sandy, soil blowing.	Moderate: too sandy, soil blowing.	Severe: too sandy, soil blowing.	Moderate: too sandy, soil blowing.
148*: Urban land.				
Clear Lake----------	Severe: floods.	Moderate: too clayey.	Severe: too clayey.	Moderate: too clayey.
149*: Urban land.				
Danville----------	Slight----------	Slight----------	Moderate: slope, too clayey.	Slight.
150*: Urban land.				
Tierra----------	Moderate: percs slowly.	Slight----------	Moderate: percs slowly, slope.	Slight.
151*: Urban land.				

See footnote at end of table.

TABLE 7.--RECREATIONAL DEVELOPMENT--Continued

Soil name and map symbol	Camp areas	Picnic areas	Playgrounds	Paths and trails
151*: Tierra	Moderate: percs slowly, slope.	Moderate: slope.	Severe: slope, percs slowly.	Slight.
152*: Urban land.				
Tierra	Severe: slope.	Severe: slope.	Severe: slope, percs slowly.	Moderate: slope.
Azule	Severe: slope.	Severe: slope.	Severe: slope.	Moderate: slope.
153*: Vallecitos	Severe: slope.	Severe: slope.	Severe: slope, depth to rock.	Severe: slope.
Rock outcrop.				
154 Willows	Moderate: too clayey, percs slowly.	Moderate: too clayey.	Severe: too clayey.	Moderate: too clayey.
155* Xerorthents	Severe: too clayey, slope.	Severe: slope.	Severe: too clayey, slope.	Severe: slope.
156* Xeropsamments	Severe: too sandy.	Severe: too sandy.	Severe: too sandy.	Severe: too sandy.
157*: Xerorthents	Severe: too clayey, slope.	Severe: slope.	Severe: too clayey, slope.	Severe: slope.
Altamont	Severe: slope.	Severe: slope.	Severe: too clayey, slope.	Severe: slope.
158*: Xerorthents	Severe: slope.	Severe: slope.	Severe: slope.	Severe: slope.
Los Osos	Severe: slope.	Severe: slope.	Severe: slope.	Severe: slope.
159*, 160*: Xerorthents	Severe: slope.	Severe: slope.	Severe: slope.	Severe: slope.
Millsholm	Severe: slope.	Severe: slope.	Severe: slope.	Severe: slope.
161 Yolo	Slight	Slight	Slight	Slight.

* See description of the map unit for composition and behavior characteristics of the map unit.

TABLE 8.--WILDLIFE HABITAT POTENTIALS

[See text for definitions of "good," "fair," "poor," and "very poor." Absence of an entry indicates that the soil was not rated]

Soil name and map symbol	Potential for habitat elements						Potential as habitat for--		
	Grain and seed crops	Grasses and legumes	Wild herbaceous plants	Shrubs	Wetland plants	Shallow water areas	Openland wildlife	Wetland wildlife	Rangeland wildlife
100---------- Altamont	Fair	Good	Good	Poor	Poor	Very poor	Fair	Very poor	Fair.
101---------- Altamont	Fair	Fair	Good	Poor	Poor	Very poor	Fair	Very poor	Fair.
102---------- Altamont	Poor	Fair	Good	Poor	Poor	Very poor	Poor	Very poor	Fair.
103---------- Azule	Fair	Good	Good	Good	Very poor	Very poor	Good	Very poor	Good.
104---------- Azule	Poor	Fair	Good	Good	Very poor	Very poor	Fair	Very poor	Good.
105---------- Baywood Variant	Fair	Fair	Fair	Fair	Poor	Very poor	Fair	Very poor	Fair.
106---------- Botella	Good	Good	Good	Good	Fair	Fair	Good	Fair	Good.
107---------- Clear Lake	Fair	Good	Poor	Poor	Poor	Good	Fair	Fair	Poor.
108---------- Clear Lake	Good	Good	Fair	Poor	Poor	Very poor	Good	Very poor	Fair.
109---------- Climara	Poor	Fair	Good	Poor	Very poor	Very poor	Poor	Very poor	Fair.
110---------- Contra Costa	Poor	Fair	Good	Good	Very poor	Very poor	Fair	Very poor	Good.
111---------- Danville	Good	Good	Good	Good	Good	Fair	Good	Fair	Good.
112---------- Danville	Good	Good	Good	Good	Poor	Very poor	Good	Very poor	Good.
113, 114---------- Diablo	Fair	Good	Poor	Poor	Very poor	Very poor	Fair	Very poor	Poor.
115---------- Diablo	Poor	Fair	Poor	Poor	Very poor	Very poor	Poor	Very poor	Poor.
116*: Gaviota----------	Very poor	Very poor	Fair	Fair	Very poor	Very poor	Poor	Very poor	Poor.
Rock outcrop.									
117---------- Laugenour	Good	Good	Good	Good	Poor	Good	Good	Fair	Good.
118*: Los Gatos----------	Poor	Poor	Good	Good	Very poor	Very poor	Poor	Very poor	---
Los Osos----------	Poor	Fair	Good	Good	Very poor	Very poor	Fair	Very poor	Good.
119*: Los Gatos----------	Very poor	Very poor	Good	Good	Very poor	Very poor	Very poor	Very poor	---
Los Osos----------	Very poor	Very poor	Good	Good	Very poor	Very poor	Poor	Very poor	Good.

See footnote at end of table.

TABLE 8.--WILDLIFE HABITAT POTENTIALS--Continued

Soil name and map symbol	Potential for habitat elements						Potential as habitat for--		
	Grain and seed crops	Grasses and legumes	Wild herbaceous plants	Shrubs	Wetland plants	Shallow water areas	Openland wildlife	Wetland wildlife	Rangeland wildlife
120---------- Los Osos	Fair	Good	Good	Good	Very poor	Very poor	Good	Very poor	Good.
121---------- Los Osos	Poor	Fair	Good	Good	Very poor	Very poor	Fair	Very poor	Good.
122*: Los Osos----------	Fair	Good	Good	Good	Very poor	Very poor	Good	Very poor	Good.
Millsholm----------	Very poor	Poor	Fair	Poor	Very poor	Very poor	Poor	Very poor	Poor.
123*: Los Osos----------	Poor	Fair	Good	Good	Very poor	Very poor	Fair	Very poor	Good.
Millsholm----------	Very poor	Poor	Fair	Poor	Very poor	Very poor	Poor	Very poor	Poor.
124*: Los Osos----------	Very poor	Very poor	Good	Good	Very poor	Very poor	Poor	Very poor	Good.
Millsholm----------	Very poor	Very poor	Poor	Poor	Very poor	Very poor	Very poor	Very poor	Poor.
125---------- Marvin	Fair	Fair	Poor	Fair	Good	Good	Fair	Good	Fair.
126---------- Maymen	Very poor	Very poor	Poor	Good	Very poor	Very poor	Fair	Very poor	---
127*: Maymen----------	Very poor	Very poor	Poor	Good	Very poor	Very poor	Fair	Very poor	---
Los Gatos----------	Very poor	Very poor	Good	Good	Very poor	Very poor	Very poor	Very poor	---
128---------- Millsholm	Very poor	Poor	Fair	Poor	Very poor	Very poor	Poor	Very poor	Poor.
129---------- Millsholm	Very poor	Very poor	Poor	Poor	Very poor	Very poor	Very poor	Very poor	Poor.
130*: Montara----------	Very poor	Very poor	Poor	Fair	Very poor	Very poor	Very poor	Very poor	Poor.
Rock outcrop.									
131---------- Omni	Good	Good	Good	Poor	Poor	Poor	Good	Poor	Fair.
132---------- Omni	Poor	Poor	Poor	Poor	Fair	Fair	Poor	Fair	---
133---------- Pescadero	Poor	Fair	Very poor	Very poor	Good	Fair	Poor	Fair	Very poor.
134---------- Pescadero	Very poor	Very poor	Poor	Poor	Poor	Poor	Very poor	Poor	---
135*. Pits									
136---------- Pleasanton	Good	Good	Good	Good	Poor	Very poor	Good	Very poor	Good.
137---------- Reyes	Poor	Fair	Good	Good	Poor	Fair	Fair	Fair	Good.
138---------- Reyes	Very poor	Very poor	Very poor	Very poor	Poor	Good	Very poor	Fair	Very poor.

See footnote at end of table.

TABLE 8.--WILDLIFE HABITAT POTENTIALS--Continued

Soil name and map symbol	Potential for habitat elements						Potential as habitat for--		
	Grain and seed crops	Grasses and legumes	Wild herbaceous plants	Shrubs	Wetland plants	Shallow water areas	Openland wildlife	Wetland wildlife	Rangeland wildlife
139---------- Reyes	Poor	Fair	Poor	Poor	Fair	Good	Poor	Fair	Poor.
140---------- Rincon	Fair	Good	Fair	Good	Poor	Poor	Good	Poor	Fair.
141*. Riverwash									
142*. Quarry									
143---------- Sycamore	Good	Good	Good	Good	Poor	Poor	Good	Poor	Good.
144---------- Sycamore	Good	Good	Good	Good	Fair	Fair	Good	Fair	---
145---------- Tierra	Fair	Fair	Fair	Fair	Very poor	Very poor	Fair	Very poor	Fair.
146*. Urban land									
147*: Urban land.									
Baywood----------	Fair	Good	Fair	Fair	Very poor	Very poor	Fair	Very poor	Fair.
148*: Urban land.									
Clear Lake---------	Fair	Good	Poor	Poor	Poor	Good	Fair	Fair	Poor.
149*: Urban land.									
Danville----------	Fair	Good	Good	Good	Very poor	Very poor	Good	Very poor	Good.
150*, 151*: Urban land.									
Tierra----------	Fair	Fair	Fair	Fair	Very poor	Very poor	Fair	Very poor	Fair.
152*: Urban land.									
Tierra----------	Poor	Fair	Fair	Fair	Very poor	Very poor	Fair	Very poor	Fair.
Azule----------	Poor	Fair	Good	Good	Very poor	Very poor	Fair	Very poor	Good.
153*: Vallecitos--------	Very poor	Very poor	Fair	Fair	Very poor	Very poor	Poor	Very poor	Fair.
Rock outcrop.									
154---------- Willows	Good	Good	Poor	Poor	Good	Good	Fair	Good	Poor.
155*---------- Xerorthents	Very poor	Very poor	Poor	Poor	Very poor	Very poor	Very poor	Very poor	Poor.
156*---------- Xeropsamments	Very poor	Very poor	Very poor	Very poor	Poor	Very poor	Very poor	Poor	Very poor.
157*: Xerorthents-------	Very poor	Very poor	Poor	Poor	Very poor	Very poor	Very poor	Very poor	Poor.
Altamont----------	Poor	Fair	Good	Poor	Poor	Very poor	Poor	Very poor	Fair.

See footnote at end of table.

TABLE 8.--WILDLIFE HABITAT POTENTIALS--Continued

Soil name and map symbol	Potential for habitat elements						Potential as habitat for--		
	Grain and seed crops	Grasses and legumes	Wild herba-ceous plants	Shrubs	Wetland plants	Shallow water areas	Openland wildlife	Wetland wildlife	Rangeland wildlife
158*:									
Xerorthents	Very poor	Very poor	Good	Good	Very poor	Very poor	Very poor	Very poor	Good.
Los Osos	Poor	Fair	Good	Good	Very poor	Very poor	Fair	Very poor	Good.
159*:									
Xerorthents	Very poor	Very poor	Poor	Poor	Very poor	Very poor	Very poor	Very poor	Very poor.
Millsholm	Very poor	Poor	Fair	Poor	Very poor	Very poor	Poor	Very poor	Poor.
160*:									
Xerorthents	Very poor	Very poor	Poor	Poor	Very poor	Very poor	Very poor	Very poor	Very poor.
Millsholm	Very poor	Very poor	Poor	Poor	Very poor	Very poor	Very poor	Very poor	Poor.
161--- Yolo	Fair	Good	Good	Good	Very poor	Very poor	Good	Very poor	Good.

* See description of the map unit for composition and behavior characteristics of the map unit.

TABLE 9.--ENGINEERING PROPERTIES AND CLASSIFICATIONS

[The symbol > means more than. Absence of an entry indicates that data were not estimated]

Soil name and map symbol	Depth	USDA texture	Classification		Fragments > 3 inches	Percentage passing sieve number--				Liquid limit	Plasticity index
			Unified	AASHTO		4	10	40	200		
	In				Pct					Pct	
100, 101, 102----- Altamont	0-28	Clay----------	CH, CL	A-7	0	100	95-100	95-100	75-95	40-60	20-35
	28-50	Clay, silty clay, clay loam.	CH, CL	A-7	0	100	95-100	95-100	75-95	40-60	20-35
	50	Weathered bedrock.	---	---	---	---	---	---	---	---	---
103, 104----- Azule	0-6	Clay loam-------	CL	A-6	0	80-100	75-100	70-100	60-95	30-40	10-20
	6-25	Clay, sandy clay	CL, CH	A-7	0	80-100	75-100	70-100	50-95	45-60	25-40
	25	Weathered bedrock.	---	---	---	---	---	---	---	---	---
105----- Baywood Variant	0-60	Sand----------	SM, SP-SM	A-2, A-3	0	100	100	50-75	5-15	---	NP
106----- Botella	0-9	Loam----------	CL-ML, CL	A-4, A-6	0	80-100	75-100	65-95	50-70	25-35	5-15
	9-33	Silty clay loam, clay loam.	CL	A-6, A-7	0	90-100	85-100	70-95	60-80	35-45	15-25
	33-60	Sandy clay loam, clay loam, silt loam.	SC, CL	A-6	0	90-100	85-100	70-90	35-65	30-40	10-20
107, 108----- Clear Lake	0-26	Clay----------	CH, CL	A-7	0	100	100	95-100	85-95	40-60	20-30
	26-60	Clay, silty clay	CH, CL	A-7	0	100	100	95-100	85-95	40-60	20-30
109----- Climara	0-27	Clay----------	CL, CH	A-7	0-10	95-100	75-95	80-90	70-85	40-60	20-30
	27-33	Gravelly clay, clay.	CL, CH	A-7	0-10	70-100	60-95	60-90	50-75	40-60	20-30
	33	Unweathered bedrock.	---	---	---	---	---	---	---	---	---
110----- Contra Costa	0-24	Clay loam-------	CL	A-6	0	75-100	75-100	75-100	60-80	20-40	10-25
	24-30	Clay, clay loam	CL, CH	A-7, A-6	0	85-100	85-100	80-100	75-95	35-60	15-35
	30-35	Gravelly clay, gravelly clay loam.	CL, CH	A-7	5-15	85-100	60-75	50-70	50-70	40-60	25-35
	35	Unweathered bedrock.	---	---	---	---	---	---	---	---	---
111, 112----- Danville	0-21	Silty clay loam	CL	A-6	0	90-100	80-100	70-85	55-70	25-40	15-25
	21-53	Clay, silty clay, silty clay loam.	CL, CH	A-7	0	100	95-100	70-85	55-70	40-60	20-30
	53-80	Clay loam, silty clay loam.	CL	A-6	0	85-100	75-90	65-90	50-75	20-40	10-25
113, 114, 115----- Diablo	0-15	Clay----------	CL, CH	A-7	0	100	95-100	95-100	85-95	45-70	20-40
	15-42	Silty clay, clay, clay loam.	CL, CH	A-7	0	100	95-100	95-100	85-95	45-70	20-40
	42-50	Silty clay, silty clay loam, clay.	CL, CH	A-7, A-6	0	90-100	85-100	85-100	75-95	35-70	15-40
	50	Weathered bedrock.	---	---	---	---	---	---	---	---	---
116*: Gaviota-----	0-11	Sandy loam------	SM	A-4, A-2	0-5	75-100	75-100	55-70	30-50	20-30	NP-5
	11	Unweathered bedrock.	---	---	---	---	---	---	---	---	---
Rock outcrop.											

See footnote at end of table.

TABLE 9.--ENGINEERING PROPERTIES AND CLASSIFICATIONS--Continued

Soil name and map symbol	Depth	USDA texture	Classification		Fragments > 3 inches	Percentage passing sieve number--				Liquid limit	Plasticity index
			Unified	AASHTO		4	10	40	200		
	In				Pct					Pct	
117	0-8	Loam	ML, CL-ML	A-4	0	100	100	85-95	60-75	20-30	NP-10
Laugenour	8-23	Fine sandy loam	SM	A-4	0	100	100	75-85	40-50	15-25	NP-5
	23-40	Loam	CL-ML, ML	A-4	0	100	100	80-90	50-60	15-25	NP-10
	40-60	Silty clay loam	CL	A-7, A-6	0	100	100	95-100	85-95	35-45	15-25
118*, 119*:											
Los Gatos	0-19	Loam	CL	A-6	0-5	90-100	80-100	75-85	60-75	25-40	10-20
	19-40	Clay loam, loam	CL	A-6	0-5	80-100	75-100	60-80	50-65	30-40	15-20
	40	Unweathered bedrock.	---	---	---	---	---	---	---	---	---
Los Osos	0-8	Silty clay loam	CL	A-6, A-7	0	95-100	90-100	80-100	70-95	30-50	10-20
	8-30	Silty clay loam, clay loam, clay.	CL, CH	A-7	0	95-100	90-100	75-100	55-90	45-60	20-30
	30	Weathered bedrock.	---	---	---	---	---	---	---	---	---
120, 121	0-8	Silty clay loam	CL	A-6, A-7	0	95-100	90-100	80-100	70-95	30-50	10-20
Los Osos	8-30	Silty clay loam, clay loam, clay.	CL, CH	A-7	0	95-100	90-100	75-100	55-90	45-60	20-30
	30	Weathered bedrock.	---	---	---	---	---	---	---	---	---
122*, 123*, 124*:											
Los Osos	0-8	Silty clay loam	CL	A-6, A-7	0	95-100	90-100	80-100	70-95	30-50	10-20
	8-30	Silty clay loam, clay loam, clay.	CL, CH	A-7	0	95-100	90-100	75-100	55-90	45-60	20-30
	30	Weathered bedrock.	---	---	---	---	---	---	---	---	---
Millsholm	0-20	Silt loam	ML, CL-ML	A-4	0	80-100	80-100	70-100	50-75	25-35	NP-10
	20	Unweathered bedrock.	---	---	---	---	---	---	---	---	---
125	0-4	Silt loam	CL, CL-ML	A-4	0	100	100	85-95	70-90	25-30	5-10
Marvin	4-36	Silty clay, clay	CL, CH	A-7	0	100	100	90-100	75-95	40-60	20-35
	36-60	Silty clay loam, clay loam.	CL, CL-ML	A-6	0	100	100	95-100	75-95	30-40	10-20
126	0-19	Loam	SM, ML	A-4, A-2	0	100	95-100	55-85	30-70	15-25	NP-5
Maymen	19	Unweathered bedrock.	---	---	---	---	---	---	---	---	---
127*:											
Maymen	0-19	Loam	SM, ML	A-4, A-2	0	100	95-100	55-85	30-70	15-25	NP-5
	19	Unweathered bedrock.	---	---	---	---	---	---	---	---	---
Los Gatos	0-19	Loam	CL	A-6	0-5	90-100	80-95	75-85	60-75	25-40	10-20
	19-40	Clay loam, loam	CL	A-6	0-5	75-95	70-95	60-80	50-65	30-40	15-20
	40	Unweathered bedrock.	---	---	---	---	---	---	---	---	---
128, 129	0-20	Silt loam	ML, CL-ML	A-4	0	80-100	80-100	70-100	50-75	25-35	NP-10
Millsholm	20	Unweathered bedrock.	---	---	---	---	---	---	---	---	---
130*:											
Montara	0-14	Clay loam	CL	A-6, A-7	0-5	90-100	75-100	75-90	70-80	30-50	10-25
	14	Unweathered bedrock.	---	---	---	---	---	---	---	---	---
Rock outcrop.											

See footnote at end of table.

TABLE 9.--ENGINEERING PROPERTIES AND CLASSIFICATIONS--Continued

Soil name and map symbol	Depth	USDA texture	Classification		Fragments > 3 inches	Percentage passing sieve number--				Liquid limit	Plasticity index
			Unified	AASHTO		4	10	40	200		
	In				Pct					Pct	
131, 132---------- Omni	0-6	Silty clay loam	CL, ML	A-6, A-7	0	100	100	90-100	70-90	35-45	10-20
	6-52	Silty clay, clay	CL, CH	A-7	0	100	100	90-100	75-95	45-70	20-45
	52-60	Stratified clay loam to silty clay.	CL, CH	A-7	0	100	100	90-100	75-95	45-60	20-40
133---------- Pescadero	0-2	Clay loam--------	CH	A-7	0	100	100	95-100	85-95	50-60	30-45
	2-30	Clay, silty clay	CH	A-7	0	100	100	95-100	85-95	50-60	30-45
	30-60	Clay loam, silty clay loam.	CL	A-7	0	95-100	95-100	90-100	80-95	40-50	15-25
134---------- Pescadero	0-2	Clay loam--------	CL	A-7, A-6	0	100	100	90-100	70-80	30-60	10-45
	2-30	Clay------------	CH, CL	A-7, A-6	0	100	100	90-100	75-95	35-60	20-45
	30-60	Clay loam--------	CL	A-7, A-6	0	100	100	90-100	70-80	30-45	10-20
135*. Pits											
136---------- Pleasanton	0-21	Gravelly loam---	GC, SC	A-6	0-5	55-80	50-75	45-70	35-50	30-40	10-20
	21-64	Gravelly loam, gravelly sandy clay loam, gravelly clay loam.	GC, SC, CL	A-6	0-10	55-80	50-75	40-70	35-55	25-40	10-20
	64-72	Gravelly fine sandy loam, gravelly loam, gravelly sandy clay loam.	GM, GC, GM-GC	A-4, A-6, A-2, A-1	0-10	55-75	50-75	45-65	20-50	15-35	NP-15
137, 138, 139------ Reyes	0-6	Clay------------	MH	A-7	0	100	100	90-100	80-95	50-70	20-30
	6-72	Clay, silty clay, silty clay loam.	ML, MH	A-7	0	100	100	85-100	85-95	45-70	15-30
140---------- Rincon	0-16	Clay loam--------	CL	A-6, A-7	0	100	95-100	90-100	80-90	30-40	10-20
	16-52	Sandy clay, clay, clay loam.	CL, CH	A-7	0	100	95-100	90-100	75-90	40-60	25-35
	52-60	Stratified sandy loam to clay loam.	SC, CL	A-6	0	90-100	85-100	80-90	35-70	20-40	10-25
141*. Riverwash											
142*. Quarry											
143---------- Sycamore	0-18	Silt loam--------	ML	A-4	0	100	100	90-100	75-90	20-35	NP-10
	18-60	Silt loam, loam	ML	A-4	0	100	100	85-100	60-90	20-35	NP-10
144---------- Sycamore	0-44	Silt loam--------	ML, CL-ML	A-4	0	100	100	90-100	70-90	25-35	5-10
	44-60	Clay------------	CL, CH	A-7	0	100	100	90-100	75-95	40-60	20-35
145---------- Tierra	0-12	Loam------------	CL, CL-ML	A-4, A-6	0	95-100	80-100	70-95	50-65	20-35	5-15
	12-32	Clay, clay loam, sandy clay.	CH, CL	A-6, A-7	0	100	85-100	70-100	50-95	35-55	15-30
	32-60	Clay loam, sandy clay loam.	CL, SC	A-6	0	95-100	80-100	70-95	45-75	25-40	10-20
146*. Urban land.											
147*: Urban land.											
Baywood-----------	0-16	Loamy sand------	SM	A-2	0	100	100	50-90	15-35	---	NP
	16-60	Loamy sand, loamy fine sand.	SM	A-2	0	100	100	50-95	15-35	---	NP

See footnote at end of table.

TABLE 9.--ENGINEERING PROPERTIES AND CLASSIFICATIONS--Continued

Soil name and map symbol	Depth	USDA texture	Classification		Frag-ments > 3 inches	Percentage passing sieve number--				Liquid limit	Plas-ticity index
			Unified	AASHTO		4	10	40	200		
	In				Pct					Pct	
148*:											
Urban land.											
Clear Lake	0-26	Clay	CH, CL	A-7	0	100	100	95-100	85-95	40-60	20-30
	26-60	Clay, silty clay	CH, CL	A-7	0	100	100	95-100	85-95	40-60	20-30
149*:											
Urban land.											
Danville	0-21	Clay loam	CL	A-6	0	90-100	80-100	70-85	55-70	25-40	15-25
	21-53	Clay, sandy clay, silty clay.	CL, CH	A-7	0	100	95-100	70-85	55-70	40-60	20-30
	53-80	Clay loam, silty clay loam.	CL	A-6	0	85-100	75-90	65-90	50-75	20-40	10-25
150*, 151*:											
Urban land.											
Tierra	0-12	Loam	CL, CL-ML	A-4, A-6	0	95-100	80-100	70-95	50-65	20-35	5-15
	12-32	Clay, clay loam, sandy clay.	CH, CL	A-6, A-7	0	100	85-100	70-100	50-95	35-55	15-30
	32-60	Clay loam, sandy clay loam.	CL, SC	A-6	0	95-100	80-100	70-95	45-75	25-40	10-20
152*:											
Urban land.											
Tierra	0-12	Loam	CL, CL-ML	A-4, A-6	0	95-100	80-100	70-95	50-65	20-35	5-15
	12-32	Clay	CH, CL	A-6, A-7	0	100	85-100	70-100	50-95	35-55	15-30
	32-60	Sandy clay loam	CL, SC	A-6	0	95-100	80-100	70-95	45-75	25-40	10-20
Azule	0-6	Clay loam	CL	A-6	0	80-100	75-100	70-100	60-95	30-40	10-20
	6-25	Clay	CL, CH	A-7	0	80-100	75-100	70-100	50-95	45-60	25-40
	25	Weathered bedrock.	---	---	---	---	---	---	---	---	---
153*:											
Vallecitos	0-6	Gravelly loam	SC, SM-SC	A-2	0-5	70-80	60-70	50-60	25-35	25-35	5-15
	6-16	Clay loam	CL	A-7, A-6	0	90-100	80-90	65-75	55-75	35-45	15-20
	16	Unweathered bedrock.	---	---	---	---	---	---	---	---	---
Rock outcrop.											
154	0-19	Clay	CH	A-7	0	100	100	90-100	85-95	50-70	25-40
Willows	19-72	Clay, silty clay	CH	A-7	0	100	100	90-100	85-95	50-70	25-40
155*	0-60	Clay	CL, CH	A-7	0-20	80-100	80-100	75-100	65-95	40-60	20-35
Xerorthents											
156*	0-60	Sand	SM, SP-SM	A-2, A-3	0	100	100	50-75	5-15	---	NP
Xeropsamments											
157*:											
Xerorthents	0-24	Clay	CL, CH	A-7	0-20	80-100	80-100	75-100	65-95	40-60	20-35
	24	Weathered bedrock.	---	---	---	---	---	---	---	---	---
157*:											
Altamont	0-28	Clay	CH, CL	A-7	0	100	95-100	95-100	75-95	40-60	20-35
	28-50	Clay, silty clay, clay loam.	CH, CL	A-7	0	100	95-100	95-100	75-95	40-60	20-35
	50	Weathered bedrock.	---	---	---	---	---	---	---	---	---
158*:											
Xerorthents	0-60		---	---	---	---	---	---	---	---	---

See footnote at end of table.

TABLE 9.--ENGINEERING PROPERTIES AND CLASSIFICATIONS--Continued

Soil name and map symbol	Depth	USDA texture	Classification		Fragments > 3 inches	Percentage passing sieve number--				Liquid limit	Plasticity index
			Unified	AASHTO		4	10	40	200		
	In				Pct					Pct	
158*:											
Los Osos	0-10	Clay loam	CL	A-6, A-7	0	95-100	90-100	80-100	70-95	30-50	10-20
	10-30	Silty clay loam, clay loam, clay.	CL, CH	A-7	0	95-100	90-100	75-100	55-90	45-60	20-30
	30	Weathered bedrock.	---	---	---	---	---	---	---	---	---
159*:											
Xerorthents	0-60	Silt loam	CL-ML	A-4	0-35	80-100	75-100	65-80	50-70	20-30	5-10
	60	Unweathered bedrock.	---	---	---	---	---	---	---	---	---
Millsholm	0-20	Silt loam	ML, CL-ML	A-4	0	80-100	80-100	70-100	50-75	25-35	NP-10
	20	Unweathered bedrock.	---	---	---	---	---	---	---	---	---
160*:											
Xerorthents	0-60	Loam	CL-ML	A-4	0-35	80-100	75-100	65-80	50-70	20-30	5-10
	60	Unweathered bedrock.	---	---	---	---	---	---	---	---	---
Millsholm	0-20	Silt loam	ML, CL-ML	A-4	0	80-100	80-100	70-100	50-75	25-35	NP-10
	20	Unweathered bedrock.	---	---	---	---	---	---	---	---	---
161	0-8	Silt loam	ML, CL-ML	A-4	0	100	100	85-100	70-85	20-30	NP-10
Yolo	8-60	Silt loam, silty clay loam.	CL	A-6, A-4	0	100	100	85-100	70-95	25-40	5-20

* See description of the map unit for composition and behavior characteristics of the map unit.

TABLE 10.--PHYSICAL AND CHEMICAL PROPERTIES OF SOILS

[The symbol < means less than; > means more than. Entries under "Erosion factors--T" apply to the entire profile. Absence of an entry indicates that data were not available or were not estimated]

Soil name and map symbol	Depth	Permeability	Available water capacity	Soil reaction	Salinity	Shrink-swell potential	Erosion factors	
							K	T
	In	In/hr	In/in	pH	Mmhos/cm			
100, 101, 102----	0-28	0.06-0.2	0.12-0.16	6.1-7.8	<2	High------	0.24	3
Altamont	28-50	0.06-0.2	0.12-0.16	7.4-8.4	<2	High------	0.24	
	50	---	---	---	---	----------	---	
103, 104---------	0-6	0.2-0.6	0.15-0.18	5.6-7.3	<2	Moderate	0.43	2
Azule	6-25	0.06-0.2	0.15-0.18	5.6-7.3	<2	High------	0.20	
	25	---	---	---	---	----------	---	
105----------	0-60	6.0-20	0.05-0.08	6.6-8.4	<2	Low-------	0.15	5
Baywood Variant								
106----------	0-9	0.6-2.0	0.14-0.16	6.6-7.8	<2	Moderate	0.43	5
Botella	9-33	0.2-0.6	0.16-0.19	6.6-7.8	<2	Moderate	0.32	
	33-60	0.2-0.6	0.15-0.18	7.4-8.4	<2	Moderate	0.32	
107----------	0-26	0.06-0.2	0.12-0.16	6.1-8.4	<2	High------	0.24	5
Clear Lake	26-60	0.06-0.2	0.12-0.16	7.4-8.4	<4	High------	0.24	
108----------	0-26	0.06-0.2	0.12-0.16	6.1-8.4	<2	High------	0.24	5
Clear Lake	26-60	0.06-0.2	0.12-0.16	7.4-8.4	<4	High------	0.24	
109----------	0-27	0.06-0.2	0.12-0.15	6.6-8.4	<2	High------	0.24	2
Climara	27-33	0.06-0.2	0.10-0.14	7.4-8.4	<2	High------	0.17	
	33	---	---	---	---	----------	---	
110----------	0-24	0.6-2.0	0.15-0.19	6.1-7.3	<2	Moderate	0.24	3
Contra Costa	24-30	0.06-0.2	0.15-0.19	5.6-7.3	<2	High------	0.24	
	30-35	0.06-0.2	0.13-0.16	5.6-7.3	<2	High------	0.24	
	35	---	---	---	---	----------	---	
111, 112---------	0-21	0.2-0.6	0.16-0.19	6.1-7.3	<2	Moderate	0.32	5
Danville	21-53	0.06-0.2	0.12-0.16	6.1-7.3	<2	High------	0.24	
	53-80	0.2-0.6	0.15-0.18	6.6-8.4	<2	Moderate	0.28	
113, 114, 115----	0-15	0.06-0.2	0.12-0.15	6.1-7.8	<2	High------	0.24	3
Diablo	15-42	0.06-0.2	0.14-0.19	7.4-8.4	<2	High------	0.24	
	42-50	0.06-0.2	0.14-0.19	7.9-8.4	<8	High------	0.24	
	50	---	---	---	---	----------	---	
116*:								
Gaviota---------	0-11	2.0-6.0	0.07-0.12	5.6-7.3	<2	Low-------	0.43	1
	11	---	---	---	---	----------	---	
Rock outcrop.								
117----------	0-8	0.6-2.0	0.14-0.16	7.9-8.4	<2	Low-------	0.37	5
Laugenour	8-23	2.0-6.0	0.10-0.12	7.9-8.4	<2	Low-------	0.32	
	23-40	2.0-6.0	0.14-0.16	7.9-8.4	<2	Moderate	0.37	
	40-60	0.2-0.6	0.16-0.18	7.9-8.4	<2	Moderate	0.32	
118*, 119*:								
Los Gatos--------	0-19	0.6-2.0	0.15-0.20	5.6-7.3	<2	Moderate	0.32	2
	19-40	0.2-0.6	0.14-0.20	5.6-7.3	<2	Moderate	0.37	
	40	---	---	---	---	----------	---	
Los Osos---------	0-8	0.2-0.6	0.17-0.19	5.6-6.5	<2	Moderate	0.32	2
	8-30	0.06-0.2	0.12-0.16	5.6-7.3	<2	High------	0.28	
	30	---	---	---	---	----------	---	
120, 121---------	0-8	0.2-0.6	0.17-0.19	5.6-6.5	<2	Moderate	0.32	2
Los Osos	8-30	0.06-0.2	0.12-0.16	5.6-7.3	<2	High------	0.28	
	30	---	---	---	---	----------	---	

See footnote at end of table.

TABLE 10.--PHYSICAL AND CHEMICAL PROPERTIES OF SOILS--Continued

Soil name and map symbol	Depth	Permeability	Available water capacity	Soil reaction	Salinity	Shrink-swell potential	Erosion factors	
							K	T
	In	In/hr	In/in	pH	Mmhos/cm			
122*, 123*, 124*:								
Los Osos	0-8	0.2-0.6	0.17-0.19	5.6-6.5	<2	Moderate	0.32	2
	8-30	0.06-0.2	0.12-0.16	5.6-7.3	<2	High	0.28	
	30	---	---	---	---	---	---	
Millsholm	0-20	0.6-2.0	0.14-0.17	5.6-6.5	<2	Low	0.43	1
	20	---	---	---	---	---	---	
125	0-4	0.06-0.2	0.15-0.17	6.6-7.8	<4	Moderate	0.43	5
Marvin	4-36	0.06-0.2	0.15-0.17	7.9-8.4	4-8	High	0.24	
	36-60	0.06-0.2	0.19-0.21	7.9-8.4	4-8	High	0.37	
126	0-19	0.6-2.0	0.12-0.14	4.5-6.5	<2	Low	0.17	1
Maymen	19	---	---	---	---	---	---	
127*:								
Maymen	0-19	0.6-2.0	0.12-0.14	4.5-6.5	<2	Low	0.17	1
	19	---	---	---	---	---	---	
Los Gatos	0-19	0.6-2.0	0.15-0.20	5.6-7.3	<2	Moderate	0.32	2
	19-40	0.2-0.6	0.14-0.20	5.6-7.3	<2	Moderate	0.37	
	40	---	---	---	---	---	---	
128, 129	0-20	0.6-2.0	0.14-0.17	5.6-6.5	<2	Low	0.43	1
Millsholm	20	---	---	---	---	---	---	
130*:								
Montara	0-14	0.2-0.6	0.17-0.20	6.6-8.4	<2	Moderate	0.32	1
	14	---	---	---	---	---	---	
Rock outcrop.								
131	0-6	0.2-0.6	0.14-0.19	7.4-8.4	<2	Moderate	0.43	5
Omni	6-52	0.06-0.2	0.12-0.16	7.9-8.4	<2	High	0.37	
	52-60	0.06-0.2	0.12-0.18	7.9-8.4	<2	High	0.37	
132	0-6	0.2-0.6	0.12-0.16	8.5-9.0	>8	Moderate	0.43	5
Omni	6-52	0.06-0.2	0.06-0.10	8.5-9.0	>8	High	0.37	
	52-60	0.06-0.2	0.06-0.10	8.5-9.0	>8	High	0.37	
133	0-2	0.2-0.6	0.14-0.16	6.1-8.4	4-8	High	0.28	5
Pescadero	2-30	<0.06	0.05-0.10	7.9-9.0	8-16	High	0.28	
	30-60	0.06-0.2	0.05-0.10	7.9-9.0	8-16	Moderate	0.32	
134	0-2	0.06-0.2	0.02-0.05	8.5-9.0	>16	Moderate	0.28	5
Pescadero	2-30	<0.06	0.02-0.05	8.5-9.0	>16	High	0.17	
	30-60	0.06-0.2	0.02-0.05	8.5-9.0	>16	Moderate	0.28	
135*.								
Pits								
136	0-21	0.6-2.0	0.07-0.11	5.6-7.3	<2	Low	0.28	5
Pleasanton	21-64	0.2-0.6	0.10-0.14	6.6-7.8	<2	Moderate	0.37	
	64-72	0.6-2.0	0.08-0.11	6.6-7.8	<2	Low	0.37	
137	0-6	0.06-0.2	0.06-0.10	6.6-8.4	>8	High	0.15	5
Reyes	6-72	<0.06	0.03-0.05	6.6-8.4	>16	High	0.28	
138	0-6	<0.06	0.-0.03	7.9-9.0	>16	High	0.15	5
Reyes	6-72	<0.06	0.-0.03	7.9-9.0	>16	High	0.28	
139	0-6	<0.06	0.06-0.14	6.1-8.4	4-8	High	0.15	5
Reyes	6-72	<0.06	0.03-0.05	3.6-6.0	>16	High	0.28	
140	0-16	0.2-0.6	0.17-0.19	6.1-7.3	<2	Moderate	0.37	4
Rincon	16-52	0.06-0.2	0.12-0.15	6.6-8.4	<2	High	0.43	
	52-60	0.2-0.6	0.13-0.17	7.4-8.4	<2	Moderate	0.37	

See footnote at end of table.

TABLE 10.--PHYSICAL AND CHEMICAL PROPERTIES OF SOILS--Continued

Soil name and map symbol	Depth	Permeability	Available water capacity	Soil reaction	Salinity	Shrink-swell potential	Erosion factors	
							K	T
	In	In/hr	In/in	pH	Mmhos/cm			
141*. Riverwash								
142*. Quarry								
143----------	0-18	0.6-2.0	0.13-0.15	6.6-8.4	<2	Moderate	0.49	5
Sycamore	18-60	0.6-2.0	0.13-0.18	6.6-8.4	<2	Moderate	0.49	
144----------	0-40	0.6-2.0	0.14-0.18	6.6-8.4	<2	Low-------	0.49	5
Sycamore	40-60	0.06-0.2	0.12-0.14	7.4-8.4	<2	High------	0.24	
145----------	0-12	0.6-2.0	0.13-0.16	5.6-6.5	<2	Low-------	0.37	1
Tierra	12-32	<0.06	0.02-0.04	5.6-7.3	<2	High------	0.28	
	32-60	0.06-0.2	0.15-0.18	5.6-8.4	<2	Moderate	0.37	
146*. Urban land								
147*: Urban land.								
Baywood----------	0-16	6.0-20	0.07-0.10	5.1-7.3	<2	Low-------	0.15	5
	16-60	6.0-20	0.06-0.09	5.1-7.3	<2	Low-------	0.15	
148*: Urban land.								
Clear Lake------	0-26	0.06-0.2	0.12-0.16	6.1-8.4	<2	High------	0.24	5
	26-60	0.06-0.2	0.12-0.16	7.4-8.4	<4	High------	0.24	
149*: Urban land.								
Danville---------	0-21	0.2-0.6	0.16-0.19	6.1-7.3	<2	Moderate	0.32	5
	21-53	0.06-0.2	0.12-0.16	6.1-7.3	<2	High------	0.24	
	53-80	0.2-0.6	0.15-0.18	6.6-8.4	<2	Moderate	0.28	
150*, 151*: Urban land.								
Tierra----------	0-12	0.6-2.0	0.13-0.16	5.6-6.5	<2	Low-------	0.37	1
	12-32	<0.06	0.02-0.04	5.6-7.3	<2	High------	0.28	
	32-60	0.06-0.2	0.15-0.18	5.6-8.4	<2	Moderate	0.37	
152*: Urban land.								
Tierra----------	0-12	0.6-2.0	0.13-0.16	5.6-6.5	<2	Low-------	0.37	1
	12-32	<0.06	0.02-0.04	5.6-7.3	<2	High------	0.28	
	32-60	0.06-0.2	0.15-0.18	5.6-8.4	<2	Moderate	0.37	
Azule----------	0-6	0.2-0.6	0.15-0.18	5.6-7.3	<2	Moderate	0.43	2
	6-25	0.06-0.2	0.15-0.18	5.6-7.3	<2	High------	0.20	
	25	---	---	---	---	----------	---	
153*: Vallecitos------	0-6	0.6-2.0	0.11-0.13	6.1-6.5	<2	Low-------	0.37	1
	6-16	0.06-0.2	0.14-0.16	6.6-7.3	<2	Moderate	0.24	
	16	---	---	---	---	----------	---	
Rock outcrop.								
154----------	0-19	<0.06	0.10-0.12	7.4-9.0	2-8	High------	0.28	2
Willows	19-72	<0.06	0.05-0.10	8.5-9.0	>4	High------	0.28	
155*----------	0-60	<0.2	0.10-0.12	6.1-8.4	<2	High------	0.28	1
Xerorthents								
156*----------	0-60	6.0-20	0.05-0.07	6.6-8.4	<4	Low-------	0.24	5
Xeropsamments								

See footnote at end of table.

TABLE 10.--PHYSICAL AND CHEMICAL PROPERTIES OF SOILS--Continued

Soil name and map symbol	Depth	Permeability	Available water capacity	Soil reaction	Salinity	Shrink-swell potential	Erosion factors	
							K	T
	In	In/hr	In/in	pH	Mmhos/cm			
157*:								
Xerorthents-----	0-24	<0.2	0.10-0.12	6.1-8.4	<2	High------	0.28	1
	24	---	---	---	---	----------	---	
Altamont--------	0-28	0.06-0.2	0.12-0.16	6.1-7.8	<2	High------	0.24	3
	28-50	0.06-0.2	0.12-0.16	7.4-8.4	<2	High------	0.24	
	50	---	---	---	---	----------	---	
158*:								
Xerorthents-----	0-60	---	---	---	---	----------	---	---
Los Osos--------	0-10	0.2-0.6	0.17-0.19	5.6-6.5	<2	Moderate	0.32	2
	10-30	0.06-0.2	0.12-0.16	5.6-7.3	<2	High------	0.28	
	30	---	---	---	---	----------	---	
159*, 160*:								
Xerorthents-----	0-60	0.6-2.0	0.12-0.16	5.6-7.8	<2	Low-------	0.32	1
	60	---	---	---	---	----------	---	
Millsholm-------	0-20	0.6-2.0	0.14-0.17	5.6-6.5	<2	Low-------	0.43	1
	20	---	---	---	---	----------	---	
161---------------	0-8	0.6-2.0	0.14-0.17	6.1-7.3	<2	Moderate	0.37	5
Yolo	8-60	0.6-2.0	0.16-0.19	6.1-8.4	<2	Moderate	0.37	

* See description of the map unit for composition and behavior characteristics of the map unit.

TABLE 11.--SOIL AND WATER FEATURES

[The definitions of "flooding" and "water table" in the Glossary explain terms such as "rare," "brief," "apparent," and "perched." The symbol > means more than. Absence of an entry indicates that the feature is not a concern]

Soil name and map symbol	Hydrologic group	Flooding			High water table			Bedrock	
		Frequency	Duration	Months	Depth	Kind	Months	Depth	Hardness
					Ft			In	
100, 101, 102----- Altamont	D	None--------	---	---	>6.0	---	---	40-60	Rippable
103, 104---------- Azule	C	None--------	---	---	>6.0	---	---	24-40	Rippable
105---------- Baywood Variant	B	None--------	---	---	3.0-5.0	Apparent	Jan-Dec	>60	---
106---------- Botella	B	None--------	---	---	>6.0	---	---	>60	---
107---------- Clear Lake	D	Rare--------	Brief-----	Nov-Mar	3.0-6.0	Apparent	Dec-Mar	>60	---
108---------- Clear Lake	D	None to rare	---	---	>6.0	---	---	>60	---
109---------- Climara	D	None--------	---	---	>6.0	---	---	20-40	Hard
110---------- Contra Costa	C	None--------	---	---	>6.0	---	---	20-40	Rippable
111, 112---------- Danville	C	None--------	---	---	>6.0	---	---	>60	---
113, 114, 115----- Diablo	D	None--------	---	---	>6.0	---	---	40-60	Rippable
116*:									
Gaviota----------	D	None--------	---	---	>6.0	---	---	10-20	Hard
Rock outcrop.									
117---------- Laugenour	B	None--------	---	---	3.5-6.0	Apparent	Jan-Dec	>60	---
118*, 119*:									
Los Gatos--------	C	None--------	---	---	>6.0	---	---	24-40	Hard
Los Osos---------	C	None--------	---	---	>6.0	---	---	24-40	Rippable
120, 121---------- Los Osos	C	None--------	---	---	>6.0	---	---	24-40	Rippable
122*, 123*, 124*:									
Los Osos---------	C	None--------	---	---	>6.0	---	---	24-40	Rippable
Millsholm--------	D	None--------	---	---	>6.0	---	---	10-20	Hard
125---------- Marvin	C	None--------	---	---	3.5-6.0	Perched	Dec-Jul	>60	---
126---------- Maymen	D	None--------	---	---	>6.0	---	---	10-20	Hard
127*:									
Maymen-----------	D	None--------	---	---	>6.0	---	---	10-20	Hard
Los Gatos--------	C	None--------	---	---	>6.0	---	---	24-40	Hard

See footnotes at end of table.

TABLE 11.--SOIL AND WATER FEATURES--Continued

Soil name and map symbol	Hydrologic group	Flooding			High water table			Bedrock	
		Frequency	Duration	Months	Depth	Kind	Months	Depth	Hardness
					Ft			In	
128, 129---------- Millsholm	D	None---------	---	---	>6.0	---	---	10-20	Hard
130*: Montara----------	D	None---------	---	---	>6.0	---	---	10-20	Hard
Rock outcrop.									
131---------- Omni	D	None---------	---	---	>5.0	Apparent	Jan-Dec	>60	---
132---------- Omni	D	None---------	---	---	>4.0	Apparent	Jan-Dec	>60	---
133---------- Pescadero	C	----------	---	---	4.0-6.0	Apparent	Jan-Dec	>60	---
134---------- Pescadero	D	Common------	Very long	Jan-Dec	1.5-3.0	Apparent	Jan-Dec	>60	---
135*. Pits									
136---------- Pleasanton	B	None---------	---	---	>6.0	---	---	>60	---
137---------- Reyes	C/D	Frequent----	Very brief	Jan-Dec	0-2.0	Apparent	Jan-Dec	>60	---
138**---------- Reyes	D	Frequent----	Very long	Jan-Dec	+2-0.0	Apparent	Jan-Dec	>60	---
139---------- Reyes	D	Frequent----	Very brief	Jan-Dec	2.0-4.0	Apparent	Jan-Dec	>60	---
140---------- Rincon	C	None---------	---	---	>6.0	---	---	>60	---
141*. Riverwash									
142*. Quarry									
143, 144---------- Sycamore	B	None---------	---	---	>6.0	---	---	>60	---
145---------- Tierra	D	None---------	---	---	>6.0	---	---	>60	---
146*. Urban land									
147*: Urban land.									
Baywood----------	A	None---------	---	---	>6.0	---	---	>60	---
148*: Urban land.									
Clear Lake--------	D	Rare---------	Brief-----	Nov-Mar	4.0-5.0	Apparent	Dec-Mar	>60	---
149*: Urban land.									
Danville----------	C	None---------	---	---	>6.0	---	---	>60	---
150*, 151*: Urban land.									

See footnotes at end of table.

TABLE 11.--SOIL AND WATER FEATURES--Continued

Soil name and map symbol	Hydrologic group	Flooding			High water table			Bedrock	
		Frequency	Duration	Months	Depth	Kind	Months	Depth	Hardness
					Ft			In	
150*, 151*: Tierra	D	None	---	---	>6.0	---	---	>60	---
152*: Urban land.									
Tierra	D	None	---	---	>6.0	---	---	>60	---
Azule	C	None	---	---	>6.0	---	---	24-40	Rippable
153*: Vallecitos	D	None	---	---	>6.0	---	---	10-20	Hard
Rock outcrop.									
154 Willows	D	None to rare	---	---	5.0-6.0	Apparent	Jan-Dec	>60	---
155* Xerorthents	D	None	---	---	>6.0	---	---	>60	---
156* Xeropsamments	D	None	---	---	3.5-6.0	Apparent	Jan-Dec	>60	---
157*: Xerorthents	D	None	---	---	>6.0	---	---	>24	Rippable
Altamont	D	None	---	---	>6.0	---	---	40-60	Rippable
158*: Xerorthents	C	None	---	---	>6.0	---	---	10-60	Hard
Los Osos	C	None	---	---	>6.0	---	---	24-40	Rippable
159*, 160*: Xerorthents	B	None	---	---	>6.0	---	---	>20	Rippable
Millsholm	D	None	---	---	>6.0	---	---	10-20	Hard
161 Yolo	B	None	---	---	>6.0	---	---	>60	---

* See description of the map unit for composition and behavior characteristics of the map unit.

**In the "High water table--Depth" column, a plus sign preceding the range in depth indicates that the water table is above the surface of the soil. The first numeral in the range indicates how high the water rises above the surface. The second numeral indicates the depth below the surface.

TABLE 12.--CLASSIFICATION OF THE SOILS

Soil name	Family or higher taxonomic class
Altamont	Fine, montmorillonitic, thermic Typic Chromoxererts
Azule	Fine, montmorillonitic, thermic Mollic Haploxeralfs
Baywood	Sandy, mixed, thermic Entic Haploxerolls
Baywood Variant	Sandy, mixed, thermic Aquic Haploxerolls
Botella*	Fine-loamy, mixed, thermic Pachic Argixerolls
Clear Lake	Fine, montmorillonitic, thermic Typic Pelloxererts
Climara	Fine, montmorillonitic, thermic Chromic Pelloxererts
Contra Costa	Fine, mixed, thermic Mollic Haploxeralfs
Danville	Fine, montmorillonitic, thermic Pachic Argixerolls
Diablo	Fine, montmorillonitic, thermic Chromic Pelloxererts
Gaviota	Loamy, mixed, nonacid, thermic Lithic Xerorthents
Laugenour	Coarse-loamy, mixed (calcareous), thermic Aeric Fluvaquents
Los Gatos	Fine-loamy, mixed, mesic Typic Argixerolls
Los Osos	Fine, montmorillonitic, thermic Typic Argixerolls
Marvin	Fine, montmorillonitic, thermic Aquic Haploxeralfs
Maymen	Loamy, mixed, mesic Dystric Lithic Xerochrepts
Millsholm	Loamy, mixed, thermic Lithic Xerochrepts
Montara	Loamy, serpentinitic, thermic Lithic Haploxerolls
Omni	Fine, montmorillonitic (calcareous), thermic Fluvaquentic Haplaquolls
Pescadero	Fine, montmorillonitic, thermic Aquic Natrixeralfs
Pleasanton	Fine-loamy, mixed, thermic Mollic Haploxeralfs
Reyes	Fine, mixed, acid, thermic Sulfic Haplaquepts
Rincon	Fine, montmorillonitic, thermic Mollic Haploxeralfs
Sycamore	Fine-silty, mixed, nonacid, thermic Aeric Haplaquepts
Tierra	Fine, montmorillonitic, thermic Mollic Palexeralfs
Vallecitos	Clayey, montmorillonitic, thermic Lithic Ruptic-Xerochreptic Haploxeralfs
Willows	Fine, montmorillonitic, thermic Typic Pelloxererts
Xeropsamments	Xeropsaments
Xerorthents	Xerorthents
Yolo	Fine-silty, mixed, nonacid, thermic Typic Xerorthents

*This soil is a taxadjunct to the series. See text for a description of those characteristics of the soil that are outside the range of the series.

☆U.S. GOVERNMENT PRINTING OFFICE : 1981—273-058/62

Accessibility Statement

This document is not accessible by screen-reader software. The Natural Resources Conservation Service (NRCS) is committed to making its information accessible to all of its customers and employees. If you are experiencing accessibility issues and need assistance, please contact our Helpdesk by phone at 1-800-457-3642 or by e-mail at ServiceDesk-FTC@ftc.usda.gov. For assistance with publications that include maps, graphs, or similar forms of information, you may also wish to contact our State or local office. You can locate the correct office and phone number at http://offices.sc.egov.usda.gov/locator/app.

The U.S. Department of Agriculture (USDA) prohibits discrimination in all its programs and activities on the basis of race, color, national origin, age, disability, and where applicable, sex, marital status, familial status, parental status, religion, sexual orientation, genetic information, political beliefs, reprisal, or because all or a part of an individual's income is derived from any public assistance program. (Not all prohibited bases apply to all programs.) Persons with disabilities who require alternative means for communication of program information (Braille, large print, audiotape, etc.) should contact USDA's TARGET Center at (202) 720-2600 (voice and TDD). To file a complaint of discrimination write to USDA, Director, Office of Civil Rights, 1400 Independence Avenue, S.W., Washington, D.C. 20250-9410, or call (800) 795-3272 (voice) or (202) 720-6382 (TDD). USDA is an equal opportunity provider and employer.