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February 21, 1996

Diane K. Mims
California Regional Water
Quality Control Board
2101 Webster, Suite 500
Oakland, CA 94612

Bay Mud Evaluation - Task 1B Technical Report
Response to Board Order 95-018
San Francisco International Airport

Dear Diane,

A final copy of the Task 1B (Bay Mud Evaluation) Technical Report is enclosed. This report is being submitted on behalf of the members of the Consolidated Tenant Group at the San Francisco International Airport.

This final copy of the Technical Report does not vary substantially from the draft we provided on September 15, 1995 for your review. The major conclusion is the same: the Westside Basin is not at significant risk from airport contamination, even when and where the integrity of the Bay Mud is or will be compromised.

If you have any questions, please call me at (816) 822-3491.

Sincerely,

Stephen L. Meek
Project Manager

SLM:ses976
cc: Gail Lee
Sam Mehta
CTG Members

10881 Lowell, Overland Park, Kansas 66210
Phone (816)333-8787 Fax (816)822-3463
ESTABLISHED 1898

BAY MUD EVALUATION
AT THE
SAN FRANCISCO INTERNATIONAL AIRPORT
SAN MATEO COUNTY

IN RESPONSE TO:
Regional Water Quality Control Board
Order 95-018

PREPARED FOR:
San Francisco International Airport Tenant Group

PREPARED BY:
Burns & McDonnell Waste Consultants, Inc.

February 1996

J. David Langford, P.E.
Program Manager

Stephen L. Meek
Project Manager

Reynold Tomes, R.G.
Project Geologist

Paul J. Niebergall, P.E.
Project Engineer

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EXECUTIVE SUMMARY

The evaluation of the potential lateral and vertical migration of contaminants through the Young Bay Mud and into the underlying A-Sand Zone at the San Francisco International Airport (SFIA) consisted of the following tasks:

- Preparation of a Bay Mud thickness map, a historic tidal stream channel map, and six geologic profiles.
- Calculations for each of five conceptual case models to estimate the potential rate of infiltration and mass transfer of contamination from the A-Fill Zone, through the Young Bay Mud, and into the A-Sand Zone.
- Development of analytical computer models to evaluate the hypothetical migration of contaminants laterally through the A-Sand Zone.

Young Bay Mud deposits in excess of five feet thick prevail over the vast majority of the SFIA area. However, three small areas of relatively thin (two to 4 feet thick) Young Bay Mud deposits have been identified.

From review of the six geologic profiles and the Bay Mud thickness map it is apparent that excessive scouring of the Young Bay Mud did not occur within the former tidal stream channels and the thickness of the Young Bay Mud beneath the tidal stream channel areas has not been significantly reduced. Materials encountered in borings drilled within the former tidal stream channels were not distinguishable from the relatively low permeability A-Fill Zone materials. Continuous deposits of clean sand, or other highly permeable materials which may provide corridors for groundwater and contaminant movement, were not observed in the borings reviewed.

Computer analysis of five conceptual case models (Natural Features, Intact Piles, Degraded Piles, Boreholes, and Excavations) was performed to evaluate contaminant migration along these potential pathways. The development of each conceptual case was based upon conservative assumptions. This resulted in the generation of idealized models of contaminant migration with conditions that are worse (more conducive to contaminant migration) than any that have been encountered at the site. The results of the evaluation indicated that no significant levels of contamination would be introduced into the A-Sand Zone as a result of any of these unlikely and conservative scenarios.

Among the five conservative scenarios evaluated, the Case 1 scenario (an idealized, sand-filled tidal channel partially penetrating the Bay Mud) was determined to yield the highest levels of potential contamination to down gradient receptors.

Computer modeling was performed on the Case 1 scenario using chemical specific input parameters to simulate the migration of 13 indicator chemicals (chlorinated organic compounds). The duration of the simulation was limited to 1000 years.

The purpose of the chemical specific computer modeling was to determine which of the indicator chemicals would yield the highest potential levels of dissolved contamination to downgradient receptors. Potential concentrations of chloroform, 1,2-dichloroethene, and vinyl chloride were the highest (at levels well below 1 ppb). Computer modeling of the remaining indicator chemicals resulted in levels of potential contamination below practical analytical laboratory detection or quantification limits.

Additional computer modeling was performed using various initial concentrations of the chemical yielding the highest levels of contamination for the Case 1 modeling (1,2-dichloroethene). The results of this modeling indicated that even at initially high concentrations of 1,2-dichloroethene dissolved in groundwater (up to 10,000 ppb or 10 ppm), the maximum potential downgradient concentration in groundwater after 1,000 years would not exceed 1 ppb at lateral migration distances of 1,000 feet or greater.

In summary, five conceptual case models (developed from very conservative assumptions) were evaluated. Of the five cases evaluated, it was determined that a highly idealized, sand-filled, tidal stream channel partially penetrating the Bay Mud presented the greatest theoretical risk to downgradient receptors. Thirteen indicator chemicals were then modeled for a duration of 1,000 years based on this conceptual case to determine the highest levels of potential contamination to downgradient receptors. Additional computer simulations were performed using initial concentrations of 1,2-dichloroethene as high as 10,000 ppb (10 ppm). An initial concentration of 10,000 ppb exceeds levels permissible in either Migration Management Zone according to the Tier 1 cleanup objectives adopted in RWQCB Order 95-136 (issued June 1995). Even at the elevated initial concentration of 10,000 ppb, levels of dissolved 1,2-dichloroethene in groundwater did not exceed 1 ppb at migration distances greater than 1,000 feet. It was concluded that for the potentially mobile indicator chemicals the cleanup levels in Order 95-136 would be more than adequately protective of deeper aquifers at SFIA.

* * * * *

1.0 INTRODUCTION

1.1 SITE LOCATION AND DESCRIPTION

The San Francisco International Airport (SFIA) is located in unincorporated San Mateo County, and it is owned and operated by the City and County of San Francisco. The airport is bounded on the north, east, and south by San Francisco Bay and is approximately 12 miles south of midtown San Francisco.

Several municipalities surround SFIA, including South San Francisco to the northwest, San Bruno to the west, and Millbrae to the south. Burlingame is located within a half-mile of the airport's southern boundary.

The site location has operated as an airfield since approximately 1930, when it was known as Mills Field. Historical aerial photographs reveal that portions of the early airfield were constructed on fill material imported to the site in 1927. Airfield expansion activities progressed through the 1940's with levees being constructed at locations east of the original San Francisco Bay shoreline. Toward the late 1940's, SFIA facility boundaries resembled the current boundaries. Figure 1-1 shows the current SFIA boundaries and the immediate area surrounding the airport.

1.2 RWQCB SITE CLEANUP ORDER

The Regional Water Quality Control Board (RWQCB) adopted an Order for Site Cleanup (Order) at SFIA on January 18, 1995 (RWQCB, 1995). The Order identifies four principal tasks to be performed by each Discharger or group of Dischargers at SFIA. The four tasks are listed below:

Task 1A: Bay Mud Technical Report

Task 1B: Workplan and Schedule for Additional Evaluation of Bay Mud as a Barrier to Vertical Migration

Task 2: Fuel Hydrant System Workplan

Task 3: Remedial Management Zones and Implementation Schedule

Task 4: Ground Transportation Center and new International Terminal Area Remediation Plan and Implementation Schedule

1.3 DISCHARGER AREA DESIGNATION

Twenty-three Discharger Areas have been designated by the RWQCB for SFIA. These Discharger Areas are not intended to be inclusive of all areas of potential subsurface contamination at SFIA and are subject to modification as additional information becomes available to the RWQCB. The Discharger Areas have been designated as follows:

- Site I, Former Pan Am Facility
- Site II, Trans World Airlines Cargo/Freight
- Site III, National Car Rental Facility
- Site IV, Hertz Car Rental Facility
- Site V, Avis Car Rental Facility
- Site VI, Chevron Station
- Site VII, United Airlines Service Center
- Site VIII, South Terminal
- Site IX, North Terminal
- Site X, United Parking Area
- Site XI, American Cargo Facility
- Site XII, Eastern Airlines Facility
- Site XIII, American Superbay Hangar
- Site XIV, ASI Building/FAA Hangar
- Site XV, Former Treatment Plant
- Site XVI, United Airlines Maintenance Operations Center

- Site XVII, US Coast Guard
- Site XVIII, Federal Express
- Site XIX, Bulk Tank Farm Area
- Site XX, FAA Spill Area
- Site XXI, North Storm Water Retention Pond
- Site XXII, South Storm Water Holding & Oxidation Pond
- Site XXIII, Satellite II Facility

Figure 1-1 shows the locations of the RWQCB designated Discharger Areas.

1.4 TENANT GROUP RESPONSE TO ORDER

The RWQCB requested that the individual tenants work as a group to prepare responses to the Order. To accommodate the RWQCB and to work with Airport officials, a Tenant Group was formed. This group is comprised of the following participants:

- American Airlines
- Avis Rent A Car System, Inc.
- Chevron USA Products Company
- Delta Air Lines
- Federal Express
- The Hertz Corporation
- Japan Airlines/Pacific Fuel Trading Corporation
- National Car Rental System, Inc.
- PS Group
- Santa Fe Pacific Pipeline Partners
- SFO International Terminal Fuel Subcommittee (SFOITFS)
- Shell Oil Company
- Trans World Airlines
- United Airlines

Burns & McDonnell Waste Consultants, Inc. (B&McD) has been retained by the Tenant Group to prepare reports and workplans for Tasks 1A, 1B, 2, and 3 of the Order. On behalf of the Tenant Group, and in response to the January 1995 Order, B&McD has prepared and submitted to the RWQCB the following workplans or reports on the dates listed:

- Task 1A Report - February 15, 1995
- Task 1B Workplan - March 7, 1995
- Task 2 Workplan - February 15, 1995
- Task 3 Report - May 1995 (Draft)

1.5 SCOPE OF THE BAY MUD EVALUATION

This report presents the results of a study and evaluation of the Bay Mud geologic unit beneath the SFIA. The purpose of the study and evaluation was to collect additional information and provide the necessary analysis to support Task 3. The scope of work for this report is outlined in the Task 1B - Bay Mud Evaluation Workplan prepared by B&McD in March 1995 (B&McD, 1995a) for the Tenant Group.

The Task 1B Workplan identifies five cases which represent the most probable features or disturbances which may impact the ability of the Bay Mud to limit the migration of contamination into lower water bearing units (A-Sand Zone and Westside Basin). The five cases are listed below:

- CASE 1 - Natural Features
- CASE 2 - Intact Piles
- CASE 3 - Degraded Piles
- CASE 4 - Borings
- CASE 5 - Excavations

To expedite the evaluation of the impact of construction on the ability of the Bay Mud to limit the migration of contamination, the evaluation was divided into two phases. The Phase I evaluation (consisting of the analysis of Cases 2, 4 and 5) was initially provided as an appendix to the Task 3 Report (B&McD, 1995b). These cases were selected because construction activities such as the installation of piles and borings will have a direct impact on the Bay Mud.

Phase II of the Bay Mud Evaluation included the evaluation of Cases 1 and 3. This report presents the complete evaluation of both the Phase I cases (2, 4 and 5), and the Phase II cases (1 and 3).

* * * * *

2.0 GEOLOGY AND PHYSICAL CHARACTERISTICS OF SUBSURFACE UNITS

2.1 REGIONAL GEOLOGY

The San Francisco Bay region lies within the Coast Ranges Geomorphic Province. The province is characterized by a series of nearly parallel mountain ranges that trend obliquely to the Pacific coast in a northwesterly direction. About 65 percent of the bay region consists of rugged mountain uplands with many ridge crests rising to elevations above 4,000 feet. Almost 11 percent of the bay region consists of open water and tidal marshlands at elevations close to sea level. The remaining 24 percent consists of a relatively flat lowland area that constitutes a broad plain surrounding the bay (Helly et al., 1979).

Northeast-southwest compressional forces created a northwest alignment of major fault zones and fold axes. The major active faults in the San Francisco area are the San Andreas, Hayward, and Calaveras faults (Goldman, 1969). The closest active major fault, the San Andreas, is located approximately 2 miles west of SFIA. A less prominent fault (an extension of the northwest-southeast trending San Bruno Fault) may exist within the Franciscan bedrock beneath SFIA (USGS, 1994). However, this fault is not mapped as extending into the Quaternary sediments beneath SFIA (USGS, 1994).

The Franciscan Formation was deposited in a large, trough-like, downwarping of the earth's crust. After deposition, the formation was folded and faulted into the northwest-trending structural pattern of the Central Coast Range. The San Francisco-Marin block was tilted downward toward the east, with the western edge forming the bay (Goldman, 1969). As a result, the east side of the bay has accumulated a relatively thick alluvial sedimentary sequence while the western side (the area beneath SFIA) has only a fringe of alluvium overlying the Franciscan bedrock.

2.2 LOCAL GEOLOGY

Test borings drilled at SFIA penetrate three general types of subsurface materials: fills, unconsolidated Quaternary sediments, and Franciscan bedrock. The Task 1A - Preliminary Bay Mud Evaluation Report (B&McD, 1995c) provides detailed information concerning the local geology of the SFIA area. The Task 1A Report evaluates and presents subsurface data obtained from hundreds of borings and numerous monitoring wells installed at SFIA. Thirteen detailed geologic profiles are included in the Task 1A Report.

The following paragraphs provide a summary of the local geology and a discussion of the individual geologic units found beneath SFIA.

SFIA is underlain by the following layers or geologic units (from youngest to oldest):

- Construction fill
- Young Bay Mud
- A-Sand Zone
- Old Bay Mud
- B-Sand Zone
- Franciscan Bedrock

2.2.1 <u>Construction Fill (A-Fill Zone)</u>

The majority of SFIA is constructed on fill materials overlying a former tidal marsh. These fill materials are referred to as the A-Fill Zone. A tidal marsh is a regularly inundated, sheltered coastal area and is typically composed of clays and silts with a resistant mat of salt-tolerant plants. A reconnaissance soil survey performed in 1914 indicates a large portion of the western margin of the bay (including the current airport area) was originally classified as tidal marsh (Holmes, 1914).

During airport construction, large portions of the tidal marsh were filled. The fill materials are heterogenous and comprised of differing mixtures of clays, silts, sands, and gravels. Portions of the fill material used during airport construction was imported from quarries located in Millbrae (USGS, 1994). Based on boring log data, the fill thickness varies from a few feet to approximately 35 feet.

A former levee at the airport separated drained marshlands from the bay. Marshlands west of the levee (landward) eventually dried and formed a desiccated surface commonly termed the "Bay Mud crust." East of the levee (toward the bay), the tidal flat surface remained water-saturated and was generally subject to settlement from the weight of overlying fill. Typically, fill placed after the 1940's and east of the levee was placed on saturated soft mud (RCCE, 1980).

Early attempts at placing fill over saturated Young Bay Mud sometimes resulted in "mud waves". Mud waves can form as a result of the displacement of the mud by fill materials when large amounts of fill are rapidly placed in relatively small areas. The mud flowed from beneath such areas, with the final surface of the fill settling to the approximate original elevation of the tidal flat surface. Subsequently, grading contractors began placing fill material slowly, in relatively thin layers, and spread over larger areas to help avoid mud waves and minimize the quantity of fill required (RCCE, 1980).

Laboratory testing performed on samples of fill indicates an average natural moisture content of about 16 percent by weight. The average Liquid Limit of the fill was about 27 percent which indicated a relatively low plasticity. A maximum hydraulic conductivity of $1x10^{-04}$ cm/s was obtained from laboratory permeability tests performed on samples of fill material obtained from Discharger Site Numbers I and VII (Former Pan Am Facility and United Airlines Service Center).

The uppermost water bearing zone beneath SFIA is encountered near the fill material and Young Bay Mud interface (approximately 3 to 16 feet below ground surface - RWQCB, 1995).

Groundwater levels in shallow monitoring wells within the fill are highly variable, and a consistent groundwater flow direction is typically not observed. In addition, groundwater in this unit generally occurs as pockets of water perched on top of the Young Bay Mud and does not form a continuous groundwater surface. The heterogenous fill composition, combined with the potential influence from storm sewers, dewatering systems, and utility corridors contribute to the irregular groundwater surface.

2.2.2 Young Bay Mud

The construction fill at SFIA is underlain by Quaternary age sediments (Jennings, 1977). The youngest, or uppermost, geologic unit is the Young Bay Mud. The Young Bay Mud was deposited from 8,000 to 11,000 years ago (Rogers and Figures, 1992) and is generally described as a soft clay to silty clay of various colors (i.e., gray to greenish black), with a moderate to high content of organic materials. Thicknesses of a few feet to over 60 feet are reported in borings drilled at SFIA. In general, the Young Bay Mud thickens from west to east beneath SFIA.

Occasional thin sand lenses (1 to 5 feet) occur within the Young Bay Mud. Often these thin sands are isolated and are not interpreted as being hydraulically connected to lower water bearing zones beneath the Young Bay Mud.

The Young Bay Mud exhibits a relatively high moisture content, moderate to high plasticity, high clay content, low dry unit weight, and high cation exchange capacity. A maximum hydraulic conductivity of $4x10^{-07}$ cm/s was obtained from laboratory permeability tests performed on samples of Young Bay Mud obtained from Discharge Site Numbers I and VII (Former Pan Am Facility and United Airlines Service Center). Due to the highly plastic, clay-rich properties of the Young Bay Mud, this unit provides a barrier to the vertical migration of contaminants.

Review of visual descriptions and standard penetration test resistance (blow counts) recorded on drilling logs, indicate the Young Bay Mud unit has a consistency of soft to firm (3 to 8 blows per foot). Laboratory testing conducted on samples of Young Bay Mud indicates an average natural moisture content of about 70 percent by weight, with some samples containing over 100 percent moisture. The average Liquid Limit of the Young Bay Mud is about 72 percent. A soft consistency combined with high natural moisture conditions that are at or near the Liquid Limit indicate the Young Bay Mud has very low strength and is susceptible to flowing under low confining pressures. These properties have been well documented during numerous subsurface investigations performed at SFIA.

Table 2-1 summarizes physical properties of soil samples collected within the Young Bay Mud unit.

2.2.3 A-Sand Zone

The A-Sand Zone is encountered beneath the Young Bay Mud. Sand thicknesses of approximately 5 to 40 feet are described in boring logs at SFIA. The A-Sand Zone primarily consists of dense, fine, silty sand; however, these sands can grade laterally into clays or silts beneath portions of SFIA.

2.2.4 Old Bay Mud

The Old Bay Mud is generally described as a dark greenish-gray, silty clay, with varying amounts of sand and gravel. Regionally, the thickness of this unit ranges from less than a foot to more than 200 feet. Beneath SFIA, the Old Bay Mud occurs either as a very thick layer (i.e., 60 feet) or as multiple thin layers within the B-Sand zone. Based on the geologic profiles, individual Old Bay Mud layers range from 5 to 60 feet thick beneath SFIA.

An Old Bay Mud layer appears to separate the A-Sand Zone from B-Sand Zone. This clay layer thins beneath portions of SFIA and is not always noted in deep boring logs.

2.2.5 B-Sand Zone

When present beneath SFIA, the B-Sand Zone generally occurs beneath the Old Bay Mud. Based on geologic profiles, the B-Sand Zone varies from a single sand to a series of sands interlayered within the Old Bay Mud clays. The B-Sand Zone appears to thicken with increasing depth to bedrock beneath portions of SFIA. Near shallow bedrock areas, the B-Sand Zone can be completely absent.

2.2.6 Franciscan Bedrock

The Franciscan Formation, composed of clastic sedimentary rocks, volcanic rocks, bedded chert, ultramafic rocks, and metamorphic rocks, underlies the Quaternary deposits at SFIA. Depth to bedrock at SFIA ranges from zero feet (north end of SFIA) to approximately 235 feet (east side of SFIA). Clastic sedimentary rocks form 90 percent of the assemblage of Franciscan rocks, and nearly 90 percent of these are unsorted sandstones or graywackes, with the remainder being mainly siltstones or shales (Bailey et al., 1962). This Jurassic/Cretaceous age formation attains estimated thicknesses of up to 50,000 feet.

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3.0 POTENTIAL IMPACTS TO BAY MUD INTEGRITY

Potential impacts that may compromise the ability of the Bay Mud to limit contaminant migration have been divided into two categories: natural features and manmade disturbances. The natural features category includes former tidal stream channels and a bedrock high area. Manmade disturbances include construction activities that may physically breach the Bay Mud and provide pathways for contaminant migration such as piles, borings, and excavations.

The following sections discuss natural features, construction activities, and potential impacts to the integrity of the Bay Mud based on these two categories.

3.1 NATURAL FEATURES

3.1.1 Former Tidal Channels

An evaluation of former tidal stream channels was performed to determine the potential effects these may have on groundwater and contaminant migration. Prior to airport development, the tidal stream channels carried surface water runoff from the nearby highlands (west of SFIA), over the tidal flats, and eventually into the San Francisco Bay. The stream channels may have provided a transport mechanism for coarse grained clastic materials originating in the highlands. If coarse grained material was deposited along the bottom of these stream channels, a conduit for preferential groundwater (and contaminant) movement within the subsurface material above the Young Bay Mud might exist.

3.1.2 Bedrock High

Published information (USGS, 1899 and Goldman, 1969) indicates a localized region of thinner Young Bay Mud near Discharger Area XVI (United Airlines Maintenance Operations Center or MOC). Borehole data indicates that Franciscan bedrock occurs near the original (pre-developed) ground surface at the north end of the MOC. The Young Bay Mud immediately thickens to greater than five feet and attains a thickness of approximately 20 feet at the southern boundary of the MOC.

At the north end of the MOC, the bedrock high is visible (USGS, 1899) as a small topographic feature protruding above the general elevation of the pre-development tidal marsh. This bedrock high is unique to the northern MOC area. No other similar topographic features are identified in boring logs or published references for the remainder of the SFIA area.

3.2 CONSTRUCTION ACTIVITIES

According to the Master Plan for SFIA, major improvements to the existing terminal and transportation service facilities are planned over the next several years. Specific areas of construction include the new International Terminal, new Public Parking Structure, and Boarding Area G. These sites were selected for evaluation because they will incorporate a wide range of construction activities or practices that will be occurring at SFIA in the near future. This section summarizes construction details for the new International Terminal, the Ground Transportation Center, and Boarding Area G. This construction information was obtained from geotechnical reports issued by Dames & Moore (D&M, 1991 and D&M, 1993).

3.2.1 New International Terminal

The new International Terminal is planned to be a seven story structure constructed above the existing access roadways. The new International Terminal will connect proposed Boarding Areas A and G to the existing North and South Terminals. Minor excavations up to approximately 10 feet in total depth will be required for construction of pedestrian tunnels and expansion of the east underpass. These excavations are not expected to penetrate the Young Bay Mud which is 20 to 30 feet thick in this area. Approximately 2400 fourteen-inch square, pre-cast concrete, end-bearing displacement piles are planned for foundation support. Provided no new fill is placed, little or no downdrag loading is anticipated from areal settlement of the surrounding fill materials.

3.2.2 New Public Parking Structure

The new Public Parking Structure (PPS) will consist of two multi-story structures located to the north and south of the terminal access road. Vehicle access to the PPS will be via a ramp connected directly to Route 101. The PPS will house short term public parking. The PPS is currently planned to be built on grade with no excavation required. Piles will be installed for foundation support. Additionally, the new east tunnel is planned for construction to approximately 18 feet bgs, thereby reducing the Young Bay Mud thickness to about 10 feet.

3.2.3 Boarding Area G

New Boarding Area G will be located to the north of the International Terminal and will function as a pier accommodating aircraft gates and passenger lounges. This pier will be approximately 1,200 feet long and will have three levels: one for operations/service, one for arrivals, and one for departures. A combination of twelve-inch square, pre-cast concrete end-bearing piles and friction piles are planned for foundation support of Boarding Area G. A pile-supported tunnel (underpass) is planned to be constructed to a maximum depth of approximately 18 feet bgs. Since the current thickness of the Young Bay Mud in this area ranges from approximately 25 to 35 feet, a remaining Young Bay Mud thickness of approximately 10 feet is estimated (VSE, 1995) after the construction of the tunnel. Elevator pistons, placed to a depth of approximately 40 feet bgs would fully penetrate the Young Bay Mud (VSE, 1995).

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4.0 EVALUATION OF BAY MUD INTEGRITY

This Section discusses the integrity of the Young Bay Mud as a barrier to the potential lateral and downward migration of contaminants and presents the results of the evaluation. The following three tasks were performed during the evaluation:

- The preparation of a Bay Mud thickness map, historic tidal stream channel map, and six geologic profiles. These maps and profiles were prepared to evaluate the thickness and continuity of the Young Bay Mud unit.

- The development of a conceptual case model to define the concepts and parameters used in the evaluation of each of the five identified migration cases. Calculations were performed for each conceptual case model to estimate the potential rate of infiltration and mass transfer of contamination from the A-Fill Zone, through the Young Bay Mud, and into the A-Sand Zone.

- The development of analytical computer models to evaluate lateral contaminant migration within the A-Sand Zone.

The following subsections discuss these three areas of evaluation.

4.1 BAY MUD THICKNESS AND CONTINUITY

Thick undisturbed sections of Young Bay Mud provide adequate protection for lower water bearing units (A-Sand Zone and Westside Basin). However, as discussed in Section 3, natural features or manmade disturbances may compromise the ability of the Young Bay Mud to effectively limit the migration of contamination into the A-Sand Zone and Westside Basin.

In order to evaluate the thickness and continuity of the Young Bay Mud deposits, data obtained from borings and monitoring wells drilled across the SFIA area were analyzed and used to develop an airport-wide Young Bay Mud thickness map (Exhibit A). Exhibit A shows that Young Bay Mud thicknesses in excess of 10 feet prevail over the vast majority of the SFIA area. However, three small areas of relatively thin (two to 4 feet thick) Young Bay Mud deposits have been identified. The first area is the bedrock high which is located at the north end of United Airlines' MOC (Discharger Area XVI). The second area is located at the former Pan Am facility (Discharger Area I), and the third area is located along the east side of U.S. Highway 101 and west of the north storm water retention basin (Discharger Area XXI).

The locations of former tidal stream channels that carried surface water runoff from the nearby highlands west of SFIA to the bay were determined from maps contained in two reports published by the USGS (1899, 1994). The stream channels traversed the tidal flats and eventually drained into the San Francisco Bay. The stream channels may have provided a transport mechanism for coarse grained clastic materials originating in the highlands. If coarse grained material was deposited along the bottom of these stream channels, a conduit for preferential groundwater (and contaminant) movement within the subsurface material above the Young Bay Mud might exist.

Figure 4-1 shows the projection of the identified former tidal stream channels on a plan view of the present SFIA area.

Data obtained from borings drilled within the areas identified as former tidal stream channels were evaluated to determine the nature of the infilling materials. To determine if any significant differences existed, the thickness of Young Bay Mud deposits beneath former tidal stream channels was compared to the thickness observed adjacent to and outside of these areas. Six geologic profiles (Figures 4-3 through 4-8) were developed to evaluate the Young Bay Mud thickness within the former tidal stream channels. Figure 4-1 shows the locations of the geologic profiles developed from the borehole data, and Appendix A contains copies of the boring logs used to develop the geologic profiles.

Review of the six geologic profiles (Figures 4-3 through 4-8) and the Bay Mud thickness map (Exhibit A) indicates that excessive scouring of the Young Bay Mud did not occur within the former tidal stream channels and the thickness of the Young Bay Mud beneath the stream channels has not been significantly reduced. The physical characteristics (i.e., grain size, color, plasticity) of the materials deposited within the extent of the tidal stream channels are not distinguishable from the A-Zone fill. Continuous deposits of clean sand, or other highly permeable materials which may provide corridors for groundwater and contaminant movement, were not observed in the borings reviewed.

4.2 CONCEPTUAL CASE MODELS

Five conceptual case models were developed to reflect the most probable disturbances to the Young Bay Mud. Various geometric configurations and physical properties of the Young Bay Mud were considered in developing each case model. The following is a list of the case models that were developed:

- CASE 1 - Natural Features
- CASE 2 - Intact Piles
- CASE 3 - Degraded Piles
- CASE 4 - Borings
- CASE 5 - Excavations

Each of the five case models is discussed separately below.

4.2.1 <u>Case 1 - Natural Features</u>

Two features of specific concern at SFIA are areas with thin (or absent) Young Bay Mud deposits and previously unidentified infilled (former) tidal stream channels. The presence of these natural depositional features and their potential negative impacts on groundwater and contaminant migration were evaluated.

For analysis of this case, it was hypothetically assumed that a tidal stream channel partially penetrated the Young Bay Mud and was infilled with a relatively high permeability coarse grained material such as sand. The hydraulic conductivity of the infilling sand material was assumed to be $1x10^{-05}$ cm/s. The channel segment was assumed to have dimensions of 210 feet (64 m) wide by 66 feet (20 m) long by 52 feet (16 m) deep. A vertical gradient of 0.325 feet per foot (between the A-Fill Zone and the A-Sand) obtained from previous studies conducted at Discharger Site I (B&McD, 1995c) was assumed for the calculation.

Analysis of the Case 1 conceptual model using the above listed parameter values indicates a total volume of contaminated groundwater flowing into the A-Sand Zone of approximately 14 liters per hour (approximately 334 liters per day). Figure 4-9 illustrates the conceptual model used to evaluate the migration of contamination through an infilled tidal stream channel. The calculations used to determine the theoretical volumetric flow rate of groundwater entering the A-Sand Zone as a result of an infilled tidal stream channel are shown in Figure 4-14.

Results of groundwater studies performed at the Rental Car Sites (MF&G, 1993) and United Airlines Plots 4, 5, and 6 (B&McD, 1995d) indicate existing total VOC levels within the area of the proposed Public Parking Structure and new International Terminal are approximately 100 ppb (µg/L). Using this 100 ppb starting concentration for total VOCs in perched groundwater trapped within the A-Fill Zone and the calculated volumetric flow rate of 334 liters per day, the resulting mass loading rate of total VOC contamination to the A-Sand Zone is 0.033 grams per day for the Case 1 scenario.

Using the Summers equation for aquifer dilution (Summers, 1980), and the calculated mass loading rate discussed above, the resulting level of total VOCs dissolved in groundwater in the A-Sand Zone is 96 ppb. It was assumed the mass of contamination evenly distributes throughout a mixing zone of 12 feet (3.8 m) deep (one half the thickness of the A-Sand Zone) by 12 feet (3.8 m) wide. The level calculated by the Summers equation represents the maximum groundwater concentration directly under a sand filled tidal channel. Actual levels of groundwater contamination in areas downgradient of the source will be much lower. Table 4-1 shows the values used and the results of the dilution calculation

4.2.2 <u>Case 2 - Intact Piles</u>

To evaluate the potential for contaminant migration along newly installed piles, the following three scenarios were evaluated:

- Contaminated materials either adhering to piles or being driven downward by the piles into lower water bearing zones beneath SFIA.

- Liquefaction of sandy zones beneath the Young Bay Mud that would allow sandy materials to migrate up around a pile and establish a relatively high permeability zone between the pile and the fill materials or Young Bay Mud.

- Contaminated groundwater from the A-Fill Zone flowing down an open pre-drilled pile hole.

Geotechnical research was conducted to evaluate the first two scenarios listed above. This research consisted of the review of multiple geotechnical reports, telephone conversations with representatives of the USGS and the Santa Clara Water District, and extensive research into literature available on related topics. The results of the research indicate that a negative impact to lower water bearing units is highly unlikely due to either the downward movement of contaminated materials or liquefaction of sandy zones. A memorandum located in the Appendix B of this report discusses these two scenarios and the results of the geotechnical evaluation in detail.

The third scenario is an evaluation of the potential for vertical migration of contaminated groundwater flowing down open pre-drilled holes. For this scenario, the piles are considered intact or non-degraded and installed through the fill and Young Bay Mud layers and into the underlying A-Sand Zone. Previous pile installation practices (and proposed plans for the installation of new piles) indicate that typical pile installation includes pre-drilling through the fill and Young Bay Mud layers and then driving the pile into the underlying A-Sand Zone.

This scenario is based on an estimated 2,400 piles that will be installed during the construction of the new International Terminal. It was assumed that a 14-inch square, pre-cast concrete pile will be placed inside a 20-inch diameter pre-drilled hole. It was estimated that the pre-drilled hole will stay open for a maximum period of 3 hours before disturbances from adjacent pile driving activities cause the highly plastic Young Bay Mud to flow and seal the annular space around each pile.

Analysis of the Case 2 conceptual model using site specific properties of the fill material (B&McD, 1995c) and an equation for gravity flow through an open borehole (NAVFAC P-418), indicates a volumetric flow rate of contaminated groundwater flowing into the A-Sand Zone of approximately 4 liters per hour per pre-drilled hole. Assuming 20 piles are installed per day and each pre-drilled hole stays open for a period of 3 hours, the total volume of contaminated groundwater flowing into the A-Sand Zone is approximately 241 liters per day. Figure 4-10 shows the conceptual model used to evaluate the migration of contamination due to the presence of newly emplaced piles. Figure 4-15 shows the calculations used to determine the theoretical volumetric flow rate of groundwater entering the A-Sand Zone as a result of newly installed piles.

Using the 100 ppb starting concentration for total VOCs in perched groundwater (from previous studies discussed under Case 1 above), and the calculated volumetric flow rate of 241 liters per day, the resulting mass loading rate of total VOC contamination to the A-Sand Zone is 0.024 grams per day.

Using the Summers equation and the calculated mass loading rate of 0.024 grams per day, the resulting level of total VOCs dissolved in groundwater in the A-Sand Zone immediately below the Bay Mud and adjacent to the piles is 95 ppb. It was assumed the mass of contamination evenly distributes throughout a mixing zone of 12 feet (3.8 m) deep (one half the thickness of the A-Sand Zone) by 12 feet (3.8 m) wide. The level calculated by the Summers equation represents the maximum groundwater concentration directly under an area where piles are installed. Actual levels of groundwater contamination in areas downgradient of the source will be much lower. Table 4-1 shows the values used and the results of this calculation.

4.2.3 Case 3 - Degraded Piles

This case was used to evaluate vertical contaminant migration due to the presence of degraded piles existing in the Young Bay Mud. For this case, it was assumed that a 14-inch square degraded pile exhibits a greater hydraulic conductivity than the surrounding Young Bay Mud, completing a relatively high permeability pathway from the contaminated fill material down to the A-Sand Zone. The composition of the pile was not considered, but was assumed to degrade until the material had a hydraulic conductivity greater than that of Bay Mud (2×10^{-07} cm/s). Wood and concrete are possible types of pile material which may degrade.

The potential for groundwater flow down a zone of high permeability material is a function of the hydraulic conductivity of the flow media and the hydraulic head differential (gradient) between the two water bearing zones (Avci, 1992). For this case, it was assumed the hydraulic conductivity of the degraded pile was slightly greater than the surrounding Young Bay Mud material (1×10^{-06} cm/s). A vertical gradient of 0.325 feet per foot (between the A-Fill Zone and the A-Sand) obtained from previous studies conducted at Discharger Site I (B&McD, 1995c) was assumed for the calculation.

Analysis of the Case 3 conceptual model using the hydraulic conductivity and gradient values discussed above, indicates a rate of contaminated groundwater entering the A-Sand Zone per degraded pile of approximately 0.0015 liters per hour (approximately 0.036 liters per day). Figure 4-11 shows the conceptual model used to evaluate the migration of contamination due to the presence of degraded piles. Figure 4-16 shows the calculations used to determine the theoretical volumetric flow rate of groundwater entering the A-Sand Zone as a result of degraded piles.

Using the 100 ppb starting concentration for total VOCs in perched groundwater (from previous studies discussed under Case 1 above), and the calculated volumetric flow rate of 0.036 liters per day, the resulting mass loading rate of total VOC contamination to the A-Sand Zone is 3.55×10^{-06} grams per day.

Using the Summers equation and the calculated mass loading rate of 3.55×10^{-06} grams per day, the resulting level of total VOCs dissolved in groundwater in the A-Sand Zone is 0.3 ppb. It was assumed the mass of contamination evenly distributes throughout a mixing zone of 12 feet (3.8 m) deep (one half the thickness of the A-Sand Zone) by 12 feet (3.8 m) wide. The level calculated by the Summers equation represents the maximum groundwater concentration directly under a degraded pile. Actual levels of groundwater contamination in areas downgradient of the source will be much lower. Table 4-1 shows the values used and the results of this calculation.

4.2.4 Case 4 - Borings

This case was used to evaluate vertical contaminant migration due to improperly abandoned borings (geotechnical or otherwise) existing in the Young Bay Mud. For this case, it was assumed that a geotechnical boring with a diameter of eight inches was backfilled with sand thereby completing a relatively high permeability pathway from the contaminated fill material down to the A-Sand Zone.

The potential for groundwater flow down a borehole is primarily a function of the hydraulic conductivity of the flow media (backfill material) and the hydraulic head differential (gradient) between the two water bearing zones (Avci, 1992). For this case, it was assumed the hydraulic conductivity of the sand backfill material was the same as the underlying A-Sand Zone (1×10^{-04} cm/s) so that complete communication would be simulated in the calculations. A vertical gradient of 0.325 feet per foot (between the A-Fill Zone and the A-Sand) obtained from previous studies conducted at Discharger Site I (B&McD, 1995c) was assumed for the calculation.

Analysis of the Case 4 conceptual model using the hydraulic conductivity and gradient values discussed above, resulted in a rate of contaminated groundwater entering the A-Sand Zone per boring of approximately 0.038 liters per hour (approximately 0.91 liters per day). Figure 4-12 shows the conceptual model used to evaluate the migration of contamination due to the presence of improperly abandoned boreholes. Figure 4-17 shows the calculations used to determine the theoretical volumetric flow rate of groundwater entering the A-Sand Zone as a result of improperly abandoned boreholes.

Using the 100 ppb starting concentration for total VOCs in perched groundwater (from previous studies discussed under Case 1 above), and the calculated volumetric flow rate of 0.91 liters per day, the resulting mass loading rate of total VOC contamination to the A-Sand Zone is $9.1\text{x}10^{-05}$ grams per day.

Using the Summers equation and the calculated mass loading rate of $9.1\text{x}10^{-05}$ grams per day, the resulting level of total VOCs dissolved in groundwater in the A-Sand Zone was 6.8 ppb. It was assumed the mass of contamination evenly distributes throughout a mixing zone of 12 feet (3.8 m) deep (one half the thickness of the A-Sand Zone) by 12 feet (3.8 m). The level calculated by the Summers equation represents the maximum groundwater concentration directly under an abandoned borehole. Actual levels of groundwater contamination in areas downgradient of the source will be much lower. Table 4-1 shows the values used and the results of this calculation.

4.2.5 Case 5 - Excavations

Case 5 was used to evaluate contaminant migration laterally through the A-Fill Zone and vertically through the Young Bay Mud where the mud has been partially or completely removed through excavation. For this case, it was assumed that an idealized, gravel backfilled utility corridor (trench) is cut by excavation activities, and contaminated water contained within the trench is allowed to flow directly into an open excavation for a period of 10 days. The assumed dimensions of the utility trench are 1.6 feet (0.5 m) deep, 3.3 feet (1 m) wide, and 330 feet (100 m) long. The assumed area of the open excavation is 33 feet (10 m) by 33 feet (10 m).

Analysis of the Case 5 conceptual model using the properties of the utility trench backfill material listed above and an equation for gravity flow to a trench (NAVFAC P-418), a volumetric flow rate of approximately 47 liters per hour (approximately 1,140 liters per day) was calculated for groundwater flowing into the trench. The entire 1,140 liters per day of water flowing into the trench was assumed to flow into the open excavation and downward into the A-Sand Zone (Case 5 assumes the Young Bay Mud barrier was completely removed by excavation and there is a direct connection between the utility trench effluent and the A-Sand Zone). Figure 4-13 shows the conceptual model used to evaluate the migration of contamination due to the presence of an open excavation. Figure 4-18 shows the calculations used to determine the theoretical volumetric flow rate of groundwater entering the A-Sand Zone as a result of an open excavation.

Using the 100 ppb starting concentration for total VOCs in perched groundwater (from previous studies discussed under Case 1 above), and the calculated volumetric flow rate of 1,140 liters per day, the resulting mass loading rate of total VOC contamination to the A-Sand Zone is 0.114 grams per day.

Using the Summers equation and the calculated mass loading rate of 0.114 grams per day, the resulting level of total VOCs dissolved in groundwater in the A-Sand Zone is 99 ppb. It was assumed the mass of contamination evenly distributes throughout a mixing zone of 12 feet (3.8 m) deep (one half the thickness of the A-Sand Zone) by 12 feet (3.8 m) wide. The level calculated by the Summers equation represents the maximum groundwater concentration directly under an excavation. Actual levels of groundwater contamination in areas downgradient of the source will be much lower. Table 4-1 shows the values used and the results of this calculation.

4.3 ANALYTICAL COMPUTER MODELING

The preceding subsections provide estimates of levels of dissolved phase chemical concentration directly beneath source areas for the five conceptual cases. The calculations were based on a simple dilution concept. The purpose of performing the analytical computer modeling is to simulate the transport of contamination in the saturated portion of the A-Sand Zone in areas downgradient and away from the respective source areas. Output from both the dilution equation and the analytical computer model should be considered when assessing the results of this evaluation and forming conclusions concerning contaminant transport at SFIA.

The computer code used to develop the analytical model is AT123D (Yeh, 1981). AT123D is a generalized analytical, transient, one-, two-, and three-dimensional code for estimating the transport of dissolved phase contamination in the saturated zone. The code operates with a uniform, one-dimensional, steady state groundwater flow field. The saturated zone properties are homogeneous, isotropic, and of uniform geometry. Terms are included in the model input to simulate the effects of dispersion (in three dimensions), diffusion, adsorption, and first order decay.

The AT123D model code has been independently verified and validated by the USEPA, and is accepted for use in contaminant migration studies by numerous State agencies.

Application of the AT123D model was performed in two steps: case specific modeling and chemical specific modeling. The duration of each simulation was limited to 1000 years. Initially, model runs were conducted using case specific chemical release rates, chemical application areas, and chemical release duration. The chemical release rates used for each case in the AT123D model are identical to those developed for use in the dilution equation. All other input parameters were held constant among the five conceptual case simulations. The chemical used in these simulations was a conservative generic compound exhibiting no retardation or decay. The results of each of these five case simulations were compared to establish the worst case scenario (the conceptual case resulting in the greatest levels of dissolved contamination).

Once the worst conceptual case scenario was established, further chemical specific AT123D modeling was performed for a list of thirteen indicator chemicals.

The following describes the model input parameters and the results of the case specific and chemical specific AT123D modeling.

4.3.1 Case Specific Modeling

Aquifer parameters for the case specific AT123D models are based on data collected in previous investigations performed at SFIA (B&McD 1994, 1995c). Table 4-2 lists the input values used for the aquifer parameters for all five conceptual cases. The source parameters (chemical release rates, chemical release duration, and chemical application areas) varied by case and are listed in Table 4-3. The chemical specific distribution coefficient and decay constant were set to zero.

The case models were run with the input parameters discussed above for a duration of 1,000 years. The resulting levels of contamination were plotted against time at four specific migration distances (potential receptors located at 500, 750, 1,000, and 1,250 feet) directly downgradient of each respective source area on the centerline of the dissolved chemical plume. Figures 4-19 through 4-23 are plots of dissolved chemical concentration in groundwater versus time for each of the five conceptual cases at the four migration distances. Table 4-4 shows the resulting peak chemical concentrations for the five conceptual cases at the four migration distances. Table 4-4 shows that the resulting Case 1 (Natural Features) chemical concentrations are on the order of 3 to 6 ppb while the results of the remaining four cases are insignificant at levels of less than 1 ppb. Note that the results given here are conservative in that the effects of retardation or chemical decay were not considered in the models.

The results of the case specific AT123D modeling indicate that Case 1 (infilled tidal channel) yields the highest levels of contamination and poses the greatest theoretical risk to groundwater quality in the A-Sand Zone. Based on the results of the case specific AT123D modeling, further AT123D modeling on a chemical specific basis was performed on the Case 1 scenario only.

4.3.2 Chemical Specific Modeling

Aquifer parameter input values for the chemical specific AT123D model are based on data collected during previous investigations performed at SFIA (B&McD 1994, 1995c) and are identical to those used in the case specific modeling. Table 4-2 lists the aquifer input values used for the Case 1 model. The source parameters (chemical release rate, chemical release duration, and chemical application area) for Case 1 are listed in Table 4-3. The chemical specific constants for the thirteen indicator chemicals are listed in Tables 4-2 and 4-5 (references given with tables).

The Case 1 AT123D model was run for each of the indicator chemicals using the input parameters discussed above. The AT123D model calculates the indicator chemical concentrations at various time steps at four specific migration distances (potential receptors located at 500, 750, 1,000, and 1,250 feet) directly downgradient of the source area on the centerline of the dissolved chemical plume. Table 4-6 lists the peak chemical concentrations calculated by the Case 1 AT123D model for each of the indicator chemicals at each of the four migration distances. The chemicals with the highest concentration levels after 1,000 years of simulated contaminant transport are chloroform (0.13 ppb at 500 feet), 1,2-dichloroethene (0.14 ppb at 500 feet), and vinyl chloride (0.088 ppb at 500 feet). The levels of contamination calculated by the computer model for the remaining chemicals are insignificant, and many are well below currently achievable analytical laboratory detection or quantification limits. Figure 4-24 is a plot of maximum (peak) groundwater concentration with respect to distance (from source area) for chloroform, 1,2-dichloroethene, and vinyl chloride.

Additional Case 1 AT123D modeling was performed using various initial concentrations of 1,2-dichloroethene (the chemical yielding the greatest levels of contamination for Case 1) ranging from 10 to 10,000 ppb in the A-Sand Zone directly beneath the source area. This was done to develop a relationship between initial chemical concentration in the source area and resulting chemical concentrations at the four migration distances. The peak groundwater concentrations of 1,2-dichloroethene at the four migration distances for various source input concentrations are shown in Table 4-7. Figure 4-25 is a plot of maximum (peak) groundwater concentration with respect to distance (from source area) for various initial source groundwater concentrations of 1,2-dichloroethene.

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5.0 SUMMARY AND CONCLUSIONS

The evaluation of potential contaminant migration down through the Young Bay Mud and into the A-Sand Zone consisted of the following tasks:

- Preparation of a Bay Mud thickness map, a historic tidal stream channel map, and six geologic profiles

- Estimation of the potential rate of infiltration and mass transfer of contamination from the A-Fill Zone, through the Young Bay Mud, and into the A-Sand Zone for five conceptual case models

- Development of analytical computer models to evaluate the hypothetical migration of contaminants within the A-Sand Zone

All of the conceptual case models were developed using conservative assumptions. This resulted in the generation of idealized models of contaminant migration with conditions that are worse (with respect to migration rates and distances) than any actually encountered in the numerous investigations performed at SFIA. The purpose of the evaluation was to establish that even under worse case conditions, the impact to water quality in the A-Sand Zone would be minimal.

The following sections discuss the results of the evaluation.

5.1 BAY MUD THICKNESS AND CONTINUITY

Young Bay Mud deposits in excess of 5 feet prevail over the vast majority of the SFIA area. However, three small areas of relatively thin (2 to 4 feet) Young Bay Mud deposits were identified. The first area is the bedrock high which is located at the north end of United Airlines' MOC (Discharger Area XVI). The second area is located at the former Pan Am facility

(Discharger Area I), and the third area is located along the east side of U.S. Highway 101 and west of the north storm water retention basin (Discharger Area XXI).

Review of the six geologic profiles and the Bay Mud thickness map indicates that excessive scouring of the Young Bay Mud did not occur within the former tidal stream channels and the thickness of the Young Bay Mud beneath the stream channels does not appear to have been reduced significantly. Materials deposited within the extent of the tidal stream channels above the Young Bay Mud are not distinguishable from the A-Zone fill. Continuous deposits of clean sand or other highly permeable materials which may provide corridors for groundwater and contaminant movement were not observed in the borings reviewed.

5.2 CASE 1 - NATURAL FEATURES

Analysis of the Case 1 conceptual model indicates a total volume of contaminated groundwater flowing into the A-Sand Zone of approximately 14 liters per hour (approximately 334 liters per day). Based on this and an initial concentration of 100 ppb, the mass loading rate of total VOC contamination to the A-Sand Zone is 0.0334 grams per day. This loading rate could occur over a long period of time since the infilled tidal channel is theoretically a natural and permanent subsurface feature.

The Summers equation and the mass loading rate discussed above were used to calculate a total estimated dissolved VOC level in the A-Sand Zone of 96 ppb.

It should be reiterated that these modeling results assume a large portion of the Young Bay Mud was removed by tidal channel development and was subsequently replaced by highly permeable sand deposits. This is a conservative and highly idealized case which has been modeled to demonstrate that significant scouring of the Young Bay Mud would only minimally impact the water quality of the A-Sand Zone.

5.3 CASE 2 - INTACT PILES

A negative impact to lower water bearing units is highly unlikely due to the downward movement of contaminated materials during pile driving activities.

Liquefaction of the dense sand material in the A-Sand Zone during pile driving activities or earthquakes is considered minimal.

Analysis of the Case 2 conceptual model and an equation for gravity flow through an open borehole, indicates a volumetric flow rate of contaminated groundwater flowing into the A-Sand Zone of approximately 4 liters per hour per pre-drilled borehole.

Using the 100 ppb starting concentration for total VOCs in perched groundwater and the calculated total volumetric flow rate of 241 liters per day, the resulting mass loading rate of total VOC contamination to the A-Sand Zone is 0.024 grams per day.

Using the Summers equation and the calculated mass loading rate of 0.024 grams per day, the resulting level of total VOCs dissolved in groundwater in the A-Sand Zone is 95 ppb.

5.4 CASE 3 - DEGRADED PILES

Analysis of the Case 3 conceptual model indicates a rate of contaminated groundwater entering the A-Sand Zone per degraded pile of approximately 0.0015 liters per hour (approximately 0.036 liters per day). Using the 100 ppb starting concentration for total VOCs in perched groundwater and the calculated volumetric flow rate of 0.036 liters per day, the resulting mass loading rate of total VOC contamination to the A-Sand Zone is 3.6×10^{-06} grams per day.

Using the Summers equation and the calculated mass loading rate of 3.6×10^{-06} grams per day, the resulting level of total VOCs dissolved in groundwater in the A-Sand Zone is 0.3 ppb.

5.5 CASE 4 - BORINGS

Analysis of the Case 4 conceptual model resulted in a rate of contaminated groundwater entering the A-Sand Zone per boring of approximately 0.0379 liters per hour (approximately 0.91 liters per day).

Using the 100 ppb starting concentration for total VOCs in perched groundwater and the calculated volumetric flow rate of 0.910 liters per day, the resulting mass loading rate of total VOC contamination to the A-Sand Zone is 9.1×10^{-05} grams per day.

Using the Summers equation and the calculated mass loading rate of 9.1×10^{-05} grams per day, the resulting level of total VOCs dissolved in groundwater in the A-Sand Zone was 6.8 ppb.

5.6 CASE 5 - EXCAVATIONS

Analysis of Case 5 conceptual model using an equation for gravity flow to a trench, a volumetric flow rate of approximately 47 liters per hour (approximately 1,140 liters per day) was calculated for groundwater flowing into the trench.

Using the 100 ppb starting concentration for total VOCs in perched groundwater and the calculated volumetric flow rate of 1,140 liters per day, the resulting mass loading rate of total VOC contamination to the A-Sand Zone is 0.114 grams per day.

Using the Summers equation and the calculated mass loading rate of 0.114 grams per day, the resulting level of total VOCs dissolved in groundwater in the A-Sand Zone is 99 ppb. This would be an essentially transient condition.

5.7 ANALYTICAL COMPUTER MODELING

Modeling the migration of a generic chemical for 1,000 years produced chemical concentrations for the Case 1 Scenario on the order of 3 to 6 ppb. The concentrations calculated for the remaining four cases are insignificant (concentration levels less than 1 ppb).

Case 1 yielded the highest estimated levels of contamination and poses the greatest theoretical risk to groundwater quality in the A-Sand Zone. Further AT123D modeling on a chemical specific basis was performed on the Case 1 scenario only.

The Case 1 AT123D model was run for each of the indicator chemicals. The chemicals with the highest concentration levels after 1,000 years of simulated contaminant transport were chloroform (0.130 ppb at 500 feet), 1,2-dichloroethene (0.140 ppb at 500 feet), and vinyl chloride (0.088 ppb at 500 feet). The levels of contamination calculated by the computer model for the remaining indicator chemicals were insignificant, and many of the calculated concentrations were well below currently achievable analytical laboratory detection or quantification limits.

Additional Case 1 AT123D computer modeling was performed using various initial concentrations of 1,2-dichloroethene (the chemical yielding the greatest levels of contamination for Case 1). The results of 1,000 years of simulated contaminant transport indicate that initial concentrations of 1,2-dichloroethene as high as 10,000 ppb in the shallow groundwater would not generate A-Sand Zone groundwater concentrations exceeding 1 ppb at distances greater than 1,000 feet. Site Cleanup Order 95-136 sets a maximum limit of 157 ppb for 1,2-DCE in groundwater in MMZ 2, and 3.2 ppb in the Ecological Protection Zones.

The conclusion of this modeling is that the Order 95-136 cleanup levels for VOCs in shallow groundwater are protective of the deeper aquifer at SFIA.

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6.0 REFERENCES

Bailey, E.H., Irwin, W.P, and Jones, D.L., 1964. *Franciscan and Related Rocks and Their Significance in the Geology of Western California.* Bulletin 183, California Division of Mines and Geology.

Burns & McDonnell Waste Consultants, Inc. (B&McD), 1994. *Additional Site Investigation and Remediation of the Former Pan Am Plot 1 Site (UST Area), San Francisco International Airport, San Francisco, California.*

Burns & McDonnell Waste Consultants, Inc. (B&McD), 1995a. *Task 1B - Bay Mud Evaluation Workplan at the San Francisco International Airport, San Mateo County.*

Burns & McDonnell Waste Consultants, Inc. (B&McD), 1995b. *Task 3 - Recommended Cleanup Objectives at the San Francisco International Airport, San Mateo County. (Draft Report)*

Burns & McDonnell Waste Consultants, Inc. (B&McD), 1995c. *Task 1A - Preliminary Bay Mud Evaluation at the San Francisco International Airport, San Mateo County.*

Burns & McDonnell Waste Consultants, Inc., (B&McD) 1995d. *Phase II Subsurface Investigation, Sites C, D, and E, Plots 4, 5, and 6, San Francisco International Airport, San Mateo County.*

California Regional Water Quality Control Board (RWQCB), San Francisco Bay Region, 1995. *Order 95-018 Site Cleanup Requirements for: City and County of San Francisco and San Francisco International Airport Tenants.*

California Regional Water Quality Control Board (RWQCB), San Francisco Bay Region, 1995. *Order 95-136 Site Cleanup Requirements for: City and County of San Francisco and San Francisco International Airport Tenants.*

Dames & Moore (D&M), 1991. *Geotechnical Investigation Final Report - San Francisco International Airport.*

Dames & Moore (D&M), 1993. *Supplemental Geotechnical Investigation, Master Plan Projects, San Francisco International Airport.*

Departments of the Army, the Navy, and the Air Force, November 1983. *Dewatering and Groundwater Control.* (Navy NAVFAC P-418).

Goldman, Harold B., 1969. *Geologic & Engineering Aspects of San Francisco Bay Fill.* California Division of Mines and Geology. Special Report No. 97.

Helley, E.J., Lajoie, K.R., Spangle, W.E., and Blair, M.L., 1979. *Flatland Deposits of the San Francisco Bay Region, California: Their Geology and Engineering Properties and Their Importance to Comprehensive Planning.* U.S. Geological Survey Professional Paper 943.

Holmes, L.C., 1914. *Reconnaissance Soil Survey of the San Francisco Bay Region, California.* United States Department of Agriculture Field Operative of the Bureau of Soils.

Jennings, C.W. and Burnett, J.L., 1977. *Geologic Map of California, San Francisco Sheet.* California Division of Mines and Geology.

Kostecki, Paul T. and Calabrese, Edward J., editors, 1991. *Hydrocarbon Contaminated Soils and Groundwater, Analysis - Fate - Environmental and Public Health Effects - Remediation.* Volume 2. Lewis Publishers.

McCulley, Frick, & Gilman, Inc. (MF&G), 1993. *Additional Soil and Groundwater Investigation Report, Avis Rent A Car System, Inc., San Francisco International Airport, San Mateo County, California.*

Rogers, J.D. and Figuers, S.H., 1992. *Late Quaternary Stratigraphy of the East Bay Region.* Proceedings of the Second Conference on Earthquake Hazards in the Eastern San Francisco Bay Area. California Division of Mines and Geology. Publication No. 113.

Rutherford & Chekene Consulting Engineers (RCCE), 1980. *Soils Investigation and Foundation Report, Air Cargo Facility for Japan Airlines, San Francisco International Airport, San Francisco, California.*

Summers, K.S., Gerhini and C. Chen, Tetra Tech Inc., 1980. *Methodology to Evaluate the Potential for Groundwater Contamination from Geothermal Fluid Release. EPA-540/2-89-057.*

United States Geological Survey (USGS), 1899. *San Mateo 15-minute Topographic Quadrangle.*

United States Geological Survey (USGS), 1994. *Geologic Map of the Montara Mountain and San Mateo 7.5 minute Quadrangles.* United States Geological Survey.

Versar-Sierra EnviroGroup (VSE), 1995. *Work Plan - Regional Water Control Board Site Cleanup Requirements Order, Task 1B: Evaluation of Risk to the Westside Basin, San Francisco International Airport, San Francisco, California.*

Yeh, G.T., 1981. *AT123D: Analytical One-, Two-, and Three-Dimensional Simulation of Waste Transport in the Aquifer System.* Oak Ridge National Laboratory, Oak Ridge, Tennessee.

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TABLES

Table 2-1
Physical Soil Properties
Bay Mud - Airport Wide

Discharger Area (Site)	Boring	Depth	Percent Moisture	PL	LL	PI	USCS Class.	Dry Wt. (pcf)	Void Ratio	Spec. Grav.	K (cm/sec)	TOC (mg/kg)
Burns & McDonnell, 1995												
VII (Plots 4, 5, 6)	C-19	9.5 - 12	32.9	25	42	17	CL	69			6E-08	2900
VII (Plots 4, 5, 6)	D-22	9 - 11.5	25.6	24	32	8	ML	71			7E-08	91
VII (Plots 4, 5, 6)	MW-34	9.5 - 12	52.2	41	85	44	MH	57			4E-07	4000
VII (Plots 4, 5, 6)	MW-37	9 - 11.5	68.4	38	77	39	MH	60			4E-07	4500
Burns & McDonnell, 1994												
I (Plot1)	B28	10-10.5	61.0	34	79	45	CH	61.0				
I (Plot1)	B28	11-13.5	76.2	44	87	43	MH	56.0				6500
I (Plot1)	B29A	12.5-13	87.1									13000
I (Plot1)	B29A	13.5-16	71.0	54	93	39	MH	56.0	1.993	2.97	4E-07	
I (Plot1)	B30	10-10.5	106.5	49	88	39	MH	44.0				
I (Plot1)	B30	13.5-16	21.1					108.0	0.586	2.61	2E-07	
I (Plot1)	B30	16.5-17	26.2									1800
I (Plot1)	B31	11-13.5	85.5	47	83	36	MH	52.0				1500
I (Plot1)	B32	11.5-12	86.0									15000
I (Plot1)	B32	12.5-15	73.9	41	80	39	MH	55.3	2.049	2.58	1E-07	
Trans Pacific Geotechnical Consultants, Inc., 1994												
I (Plot1)	3	10.0	60.0					52.0				
I (Plot1)	6	10.0	91.0					49.0				
Youngdahl & Associates, 1994												
I (Plot1)	1	10.0	56.0	29	71	42	CH	65.8				
I (Plot1)	1	14.5	47.0	29	71	42	CH	89.6				
I (Plot1)	1	20.0	20.0	29	71	42	CH	115.8				
I (Plot1)	2	15.0	73.5					54.1				
Dames and Moore, 1992												
VII (Plots 4, 5, 6)	B1	16.0	83.4	40.5	92.8	52.3	MH	52.1				
VII (Plots 4, 5, 6)	B1	20.0	89.7									
VII (Plots 4, 5, 6)	B1	25.0	79.2					53.2				
VII (Plots 4, 5, 6)	B1	30.0	77.9	43.5	104.3	60.8	MH	53.4				
VII (Plots 4, 5, 6)	B2	15.5	93.4					47.6				
VII (Plots 4, 5, 6)	B2	20.0	88.4	40.8	98.2	57.4	CH	48.8				
VII (Plots 4, 5, 6)	B2	24.0	81.7									
VII (Plots 4, 5, 6)	B2	28.0	63.7	40.2	84.6	44.4	MH	60.8				
VII (Plots 4, 5, 6)	B2	32.0	74.4					55.7				

Table 2-1 (Continued)
Physical Soil Properties
Bay Mud - Airport Wide

Discharger Area (Site)	Boring	Depth	Percent Moisture	PL	LL	PI	USCS Class.	Dry Wt. (pcf)	Void Ratio	Spec. Grav.	K (cm/sec)	TOC (mg/kg)
Dames and Moore, 1992 (continued)												
VII (Plots 4, 5, 6)	B2	36.0	62.0					62.5				
VII (Plots 4, 5, 6)	B3	16.0	80.3	41.1	95.7	54.6	MH	52.4				
VII (Plots 4, 5, 6)	B3	20.0	88.2									
VII (Plots 4, 5, 6)	B3	24.0	68.4					57.7				
VII (Plots 4, 5, 6)	B3	28.0	73.9					55.9				
VII (Plots 4, 5, 6)	B3	32.0	78.6	40.6	93.8	53.2	MH	53.7				
VII (Plots 4, 5, 6)	B3	36.0	69.8					58.2				
Dames and Moore, 1991												
(Plot 41)	1	15.0	72.0					58.0				
(Plot 41)	1	20.0	67.0					60.0				
(Plot 41)	1	25.0	70.0					57.0				
(Plot 41)	1	30.0	78.0					55.0				
(Plot 41)	1	35.0	69.0					59.0				
(Plot 41)	1	45.0	74.0					56.0				
XVI (MOC)	1	11.0	103.0					44.0				
XVI (MOC)	1	15.0	93.0					47.0				
XVI (MOC)	1	20.0	88.0					50.0				
XVI (MOC)	2	10.0	106.0					43.0				
XVI (MOC)	3	15.0	86.0					51.0				
(Plot 41)	2	13.0	87.0					51.0				
(Plot 41)	2	20.0	78.0	36.0	80.0	44.0	CH	54.0				
(Plot 41)	2	30.0	89.0					49.0				
(Plot 41)	2	40.0	90.0					49.0				
(Plot 41)	2	60.0	72.0					57.0				
(Plot 41)	3	30.0	82.0					53.0				
V (Rental Car Sites)	4	10.0	59.0					62.0				
V (Rental Car Sites)	4	15.0	89.0					49.0				
V (Rental Car Sites)	4	25.0	89.2					57.0				
V (Rental Car Sites)	4	35.0	76.0					55.0				
V (Rental Car Sites)	4	45.0	81.0					52.0				
VII (Plots 4, 5, 6)	5	9.0	74.0					56.0				
VII (Plots 4, 5, 6)	5	15.0	91.4	44.7	110	65.3	MH	48.2				
VII (Plots 4, 5, 6)	5	24.0	78.0					55.0				

Table 2-1 (Continued)
Physical Soil Properties
Bay Mud - Airport Wide

Discharger Area (Site)	Boring	Depth	Percent Moisture	PL	LL	PI	USCS Class.	Dry Wt. (pcf)	Void Ratio	Spec. Grav.	K (cm/sec)	TOC (mg/kg)
Dames and Moore, 1991 (continued)												
(Rental Car Sites)	6	16.0	84.0	45.8	106.5	60.7	MH	50.5				
(Rental Car Sites)	6	25.5	92.4					48.0				
(Rental Car Sites)	6	35.0	72.0					57.0				
I (Plot 1)	7	11.0	93.0					48.0				
I (Plot 1)	7	20.0	71.0					57.0				
VIII (South Terminal)	8	14.0	87.0					50.0				
VIII (South Terminal)	8	20.0	77.5	40.0	106.0	66.0	CH	53.5				
VIII (South Terminal)	8	30.0	66.7					57.0				
VIII (South Terminal)	8	40.0	52.0					70.0				
VIII (South Terminal)	9	13.0	92.0					46.0				
VIII (South Terminal)	9	23.0	32.0					89.0				
II (Plot 3)	10	10.0	74.0					56.0				
II (Plot 3)	10	23.0	105.0					43.0				
II (Plot 3)	10	25.0	71.0					57.0				
II (Plot 3)	10	32.0	108.0					42.0				
I (Plot 1)	11	10.0	66.0					61.0				
I (Plot 1)	11	15.0	84.0					51.0				
(Rental Car Sites)	12	13.0	93.0					48.0				
(Rental Car Sites)	12	20.0	83.6	40.0	98.5	58.5	CH	51.0				
(Rental Car Sites)	13	15.0	94.0					48.0				
(Rental Car Sites)	13	25.0	82.0					52.0				
(Rental Car Sites)	13	32.0	103.0					43.0				
(Rental Car Sites)	14	14.0	93.0					48.0				
(Rental Car Sites)	14	25.0	82.9					50.0				
(Rental Car Sites)	14	35.0	101.0					42.0				
(Rental Car Sites)	14	43.0	65.0					61.0				
VII (Plots 4, 5, 6)	15	10.0	92.0					48.0				
VII (Plots 4, 5, 6)	15	20.0	96.0					46.0				
Southwest of VII	16	11.0	91.0					48.0				
Southwest of VII	16	20.0	75.0					55.0				
Southwest of VII	16	35.0	79.0					52.0				
(Plot 2)	17	14.0	88.0					49.0				
(Plot 2)	17	20.0	76.0					54.0				

Table 2-1 (Continued)
Physical Soil Properties
Bay Mud - Airport Wide

Discharger Area (Site)	Boring	Depth	Percent Moisture	PL	LL	PI	USCS Class.	Dry Wt. (pcf)	Void Ratio	Spec. Grav.	K (cm/sec)	TOC (mg/kg)
Dames and Moore, 1991 (continued)												
I (Plot 1)	18	14.0	61.0					62.0				
II (Plot 3)	19	11.0	87.0					49.0				
II (Plot 3)	19	15.0	88.0					48.0				
VII (Plots 4, 5, 6)	20	8.0	61.0					62.0				
VII (Plots 4, 5, 6)	20	13.0	86.0					49.0				
VII (Plots 4, 5, 6)	20	15.0	95.0					46.0				
VII (Plots 4, 5, 6)	21	15.0	71.0					55.0				
VII (Plots 4, 5, 6)	22	11.0	72.0					55.0				
VII (Plots 4, 5, 6)	22	15.0	92.0					48.0				
(Plot 41)	23	20.0	58.0					61.0				
(Plot 41)	24	22.0	54.0					68.0				
(Plot 41)	24	27.0	79.0					54.0				
(Plot 41)	26	13.0	62.0					63.0				
(Plot 41)	27	13.0	79.0					53.0				
Trans Pacific Geotechnical Consultants / Dames and Moore, 1991												
VIII (South Terminal)	10	10.0	74.0					56.0				
VIII (South Terminal)	10	13.0	105.0					43.0				
VIII (South Terminal)	10	25.0	71.0					57.0				
VIII (South Terminal)	10	32.5	108.0					42.0				
I (Plot 1)	19	11.5	87.0					49.0				
I (Plot 1)	19	15.0	88.0					48.0				
AGS, 1987												
XIII (Plot 40)	PD-1	20	60					64				
XIII (Plot 40)	PD-1	31	66					63				
XIII (Plot 40)	PD-3	21	63					63				
XIII (Plot 40)	PD-3	51	70					58				
XIII (Plot 40)	PD-5	30	61					65				
XIII (Plot 40)	PD-5	50	74					57				
Dames and Moore, 1984												
XVI (MOC)	1	3	16					116				

Table 2-1 (Continued)
Physical Soil Properties
Bay Mud - Airport Wide

Discharger Area (Site)	Boring	Depth	Percent Moisture	PL	LL	PI	USCS Class.	Dry Wt. (pcf)	Void Ratio	Spec. Grav.	K (cm/sec)	TOC (mg/kg)
Associated Geotechnical Engineers, 1980												
(Fire House No. 1)	EB-1	9	93.0					47.0				
(Fire House No. 1)	EB-1	15	92.0					54.0				
(Fire House No. 1)	EB-1	20	88.0					50.0				
Rutherford & Chekene, 1980												
XVIII (JAL Air Cargo)	4	24.8	85.5	31.5	76.8	45.3	CH	51.5	2.29	2.71		
XVIII (JAL Air Cargo)	5	24.0	89.7	32.4	73.7	41.3	CH	50.3	2.35	2.71		
XVIII (JAL Air Cargo)	6	29.8	92.4	28.6	74.8	46.2	CH	48.1	2.39	2.71		
XVIII (JAL Air Cargo)	8	16.0	91.6	34.9	86.8	51.9	CH	45.3	2.40	2.71		
XVIII (JAL Air Cargo)	6	25.8	89.7	29.6	77.4	47.8	CH	49.8	2.51	2.71		
XVIII (JAL Air Cargo)	3	25.5	94.9	27.1	72.1	45.0	CH	48.3	2.50	2.71		
XVIII (JAL Air Cargo)	23	30.0	63.0	44.5	81.5	37.0	MH	58.6	1.89	2.71		
XVIII (JAL Air Cargo)	25	25.0	79.0	34.0	75.0	41.0	CH	51.7	2.27	2.71		
Rutherford & Chekene, 1979												
XVIII (Plot 50)	2	30.5	80.2					51.0				
XVIII (Plot 50)	3	13.5	81.9					46.0				
XVIII (Plot 50)	3	18.5	84.5					47.4				
XVIII (Plot 50)	3	23.5	78.8					49.9				
XVIII (Plot 50)	3	28.5	78.8					55.0				
XVIII (Plot 50)	3	33.5	89.4					45.1				
XVIII (Plot 50)	24	24.0	68.0					57.0				
Dames and Moore, 1977												
VII (Plots 4, 5, 6)	1	8	23					55				
VII (Plots 4, 5, 6)	1	13	80					51				
VII (Plots 4, 5, 6)	1	18	91					47				
VII (Plots 4, 5, 6)	1	23	64					60				
VII (Plots 4, 5, 6)	1	29	28					51				
VII (Plots 4, 5, 6)	2	10	85					50				
VII (Plots 4, 5, 6)	2	20	89					49				
Dames and Moore, 1975												
VII (Plots 4, 5, 6)	1	14	95	52	113	61	MH	48				
VII (Plots 4, 5, 6)	1	22	71					57				
VII (Plots 4, 5, 6)	2	13	84					51				
VII (Plots 4, 5, 6)	2	18	97					46				

Table 2-1 (Continued)
Physical Soil Properties
Bay Mud - Airport Wide

Discharger Area (Site)	Boring	Depth	Percent Moisture	PL	LL	PI	USCS Class.	Dry Wt. (pcf)	Void Ratio	Spec. Grav.	K (cm/sec)	TOC (mg/kg)
Lowney-Haldveer Associates, 1974												
(Plot 20)	1	13	87									
(Plot 20)	1	18	82	37	72	35	MH					
(Plot 20)	1	23	90									
(Plot 20)	1	28	79									
(Plot 20)	1	33	101									
(Plot 20)	2	18	78	37	75	38	MH	50				
(Plot 20)	2	23	74									
(Plot 20)	2	33	73									
Cooper-Clark & Associates, 1970												
(Bank of America)	2	8.5	59.2					61.0				
(Bank of America)	2	12.0	78.7					51.0				
(Bank of America)	2	16.5	96.8					45.0				
(Bank of America)	2	21.5	27.9					96.0				
(Bank of America)	5	8.5	24.7					89.0				
(Bank of America)	5	11.5	85.5					50.0				
(Bank of America)	5	15.5	96.9					45.0				
(Bank of America)	5	20.5	94.3					47.0				
Harding, Miller, Lawson, & Associates, 1969												
(Sewage Treatment Facilities)	1	8	68.8					57				
(Sewage Treatment Facilities)	2	24	81.4					51				
(Sewage Treatment Facilities)	3	17	80.8					49				
(Sewage Treatment Facilities)	4	30	55.3					66				
(Sewage Treatment Facilities)	5	12	100.3					44				
(Sewage Treatment Facilities)	5	28	80.5					53				
(Sewage Treatment Facilities)	6	13	97.1					45				
(Sewage Treatment Facilities)	7	14	98.5					47				
(Sewage Treatment Facilities)	10	22	58.2					59				
(Sewage Treatment Facilities)	12	33	61.8					63				
Lee & Praszker, 1969												
VIII (South Terminal)	G2	11	98.6					46.1	2.54			
VIII (South Terminal)	G2	24	94.3					46.8	2.49			
VIII (South Terminal)	G2	32	92.0					48.1	2.39			
VIII (South Terminal)	G2	42	92.8					45.9	2.56			

Table 2-1 (Continued)
Physical Soil Properties
Bay Mud - Airport Wide

Discharger Area (Site)	Boring	Depth	Percent Moisture	PL	LL	PI	USCS Class.	Dry Wt. (pcf)	Void Ratio	Spec. Grav.	K (cm/sec)	TOC (mg/kg)
Lee & Praszker, 1969 (continued)												
VIII (South Terminal)	G3	11	95.4					46.9	2.52			
VIII (South Terminal)	G3	16	70.2					55.9	1.95			
VIII (South Terminal)	G3	31	78.2					53.9	2.06			
VIII (South Terminal)	G3	44	95.1					46.3	2.57			
IX (North Terminal	G6	11	86.8					50.6	2.23			
IX (North Terminal	G6	21	90.5					48.6	2.36			
(International Terminal)	11	25	83.2					50.8	2.21			
(International Terminal)	13	21	74.9					55.4	1.95			
(International Terminal)	13	31	87.0					48.9	2.34			
IX (Vault Area)	24	11	105.0					43.6	2.77			
IX (Vault Area)	24	21	94.5					46.7	2.51			
Dames and Moore, 1968												
XVI (MOC)	3	24	87					49				
Lee & Praszker, 1968												
VIII (South Terminal)	2	20	157.2					30.4	4.50			
(Rental Car Sites)	2	12	68.3					59.3	1.82			
(Rental Car Sites)	2	25	90.0					49.1	2.41			
(Rental Car Sites)	3	19	78.8					54.7	2.04			
(Rental Car Sites)	4	10	100.0					45.3	2.67			
(Rental Car Sites)	4	20	103.1					44.2	2.74			
(International Terminal)	12	20	91.2					49.3	2.44			
IX (North Terminal	21	8	79.5					53.3	2.11			
IX (North Terminal	21	15	94.1					47.4	2.50			
IX (North Terminal	21	22	83.5					52.1	2.22			
IX (North Terminal	22	15	90.4					48.8	2.33			
IX (North Terminal	22	21	92.6					48.0	2.41			
Cooper-Clark & Associates, 1967												
(Plot 12)	2	7.5	67.7	70.0	116.2	46.2	MH	57.0				
(Plot 12)	2	10.5	87.7	57.8	100.8	43.0	MH	50.0				
(Plot 12)	2	15.0	20.2	17.5	32.4	14.9	CL	108.0				
(Plot 12)	3	9.0	90.6	39.2	117.3	78.1	CH					
(Plot 12)	3	11.5	26.5					101.0				
(Plot 12)	5	10.5	21.0					107.0				

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Table 2-1 (Continued)
Physical Soil Properties
Bay Mud - Airport Wide

Discharger Area (Site)	Boring	Depth	Percent Moisture	PL	LL	PI	USCS Class.	Dry Wt. (pcf)	Void Ratio	Spec. Grav.	K (cm/sec)	TOC (mg/kg)
Cooper-Clark & Associates, 1967 (continued)												
(Plot 12)	5	21.5	21.8					104.0				
(Plot 12)	6	5.5	40.1	36.6	83.0	46.4	CH	74.0				
(Plot 12)	8	5.5	45.5	36.1	78.9	42.8	MH	71.0				
(Plot 12)	8	9.5	83.1	34.8	94.0	59.2	CH	51.0				
(Plot 12)	9	3.0	39.8					67.0				
(Plot 12)	9	5.5	61.4					58.0				
(Plot 12)	9	9.0	86.7					50.0				
(Plot 12)	10	12.0	25.9					95.0				
(Plot 12)	11	6.5	36.4					72.0				
Cooper-Clark & Associates, 1966												
I (Plot 1)	1	10.5	85.9					49.0				
I (Plot 1)	5	15.5	97.1					45.0				
Woodward-Clyde-Sherard & Associates, 1966												
XII (Plots 7, 8, 10)	1	7.0	61.0					63.0				
XII (Plots 7, 8, 10)	1	12.0	107.0					42.0				
Dames and Moore, 1962												
I (Plot 1)	11	9	74					55				
I (Plot 1)	11	15	140					35				
Dames and Moore, 1960												
IX (Vault Area)	A	10	108.0					45				
IX (Vault Area)	A	18	105.0					46				
IX (Vault Area)	A	24	106.0					46				
VIII (South Terminal)	1	19	114.7					43				
VIII (South Terminal)	1	30	94.8					49				
VIII (South Terminal)	1	46	72.0					56				
VIII (South Terminal)	1	54	64.5					61				
VIII (South Terminal)	2	15	94.9					49				
VIII (South Terminal)	2	35	84.5					52				
VIII (South Terminal)	17	25	145.0					34				
VIII (South Terminal)	17	40	74.0					56				

Table 2-1 (Continued)
Physical Soil Properties
Bay Mud - Airport Wide

Discharger Area (Site)	Boring	Depth	Percent Moisture	PL	LL	PI	USCS Class.	Dry Wt. (pcf)	Void Ratio	Spec. Grav.	K (cm/sec)	TOC (mg/kg)
Dames and Moore, 1948												
IX (North Terminal)	6	22	100.8					45.2				
IX (North Terminal)	8	5	95.4					44.8				
IX (North Terminal)	8	22	89.8					48.1				
(International Terminal)	10	11	105.3					43.4				
(International Terminal)	10	16	85.2					49.8				
	Average		78.7	38.5	84.1	45.5		54.9	2.34	2.71	2E-07	5477
	Maximum		157.2	70.0	117.3	78.1		116.0	4.50	2.97	4E-07	15000
	Minimum		16.0	17.5	32.0	8.0		30.4	0.59	2.58	6E-08	91

PL - Plastic Limit (%)
LL - Liquid Limit (%)
PI - Plasticity Index (%)
TOC - Total Organic Carbon
pcf - pound per cubic foot

Table 4-1
Estimated Levels of Groundwater Contamination in A-Sand Zone Based on Dilution of Infiltration from A-Fill Zone
Bay Mud Evaluation - SFIA

CASE	Infiltration (L/hr)	Conc. (µg/L)	Qp (m^3/day)	M1 (g/day)	Qa (m^3/day)	Cgw (µg/L)
1	13.9	100	3.34E-01	3.34E-02	1.25E-02	96
2	80.4	100	2.41E-01	2.41E-02	1.25E-02	95
3	1.48E-03	100	3.55E-05	3.55E-06	1.25E-02	0.28
4	3.79E-02	100	9.10E-04	9.10E-05	1.25E-02	6.8
5	47.3	100	1.14E+00	1.14E-01	1.25E-02	99

NOTES:

- Infiltration = Volumetric flow rate of infiltration into the A-Sand zone. From Figures 4-14 through 4-18
- Conc. = Aqueous-phase concentration of infiltration into A-Sand zone.
- Qp = Volumetric flow rate of infiltration into the A-Sand zone.
- M1 = Mass loading rate to A-Sand zone.
- Qa = Volumetric flow rate of groundwater in A-Sand zone.

  Where: Qa = kIA

  k = 1E-4 cm/sec = 8.64E-2 m/day

  i = 0.01

  A = b*w = 3.8 m * 3.8 m (Assume mixing zone b = ½ of the average thickness of the A-Sand or 3.8 meters. Assume width w = b).

  Qa = 0.0864 * 0.01 * 3.8 * 3.8

  Qa = 1.25E-02 m^3/day
- Cgw = Contaminant concentration of groundwater in A-Sand zone.

  Cgw = (M1/(Qp+Qa))

- Reference: Summers, K.S., Gherini and C. Chen, Tetra Tech Inc., Methodology to Evaluate the Potential for Groundwater Contamination from Geothermal Fluid Release, EPA-600/7-80-117, 1980.

Table 4-2
AT123D Input Parameters
Bay Mud Evaluation - SFIA

Param. Type	Parameter	Value	Units	Reference
Source	Chemical Source Type	Continuous	---	---
	Discharge Time of Chemical Source	Variable by Case[1]	days	---
	Chemical Release Rate	Variable by Case[1]	Kg / hour	---
	Initial Volume for Release	Variable by Case[1]	cubic meters	---
Aquifer	Aquifer Width	Infinite	meter	B&McD95
	Aquifer Depth	7.5	meter	B&McD95
	Porosity	0.30	Unitless	B&McD94
	Hydraulic Conductivity	0.0036	meter / hour	B&McD94
	Hydraulic Gradient	0.01	Unitless	B&McD94
	Bulk Density of Soil	1860	Kg / cubic meter	B&McD94
	Longitudinal Dispersivity	10	meter	AT123D
	Lateral Dispersivity	1	meter	AT123D
	Vertical Dispersivity	1	meter	AT123D
Chemical*	Apparent Diffusion Coefficient	3.6 E-6	sq. meter / hour	WRR
	Distribution Coefficient	Variable by Chemical[2]	cubic meter/ Kg	SPHEM
	Decay Constant	Variable by Chemical[2]	1 / hour	EDR

Notes:

* - Applicable only for chemical specific modeling

[1] - See Table 4-3 for further information.

[2] - See Table 4-4 for further information.

AT123D - AT123D Operations Manual, G.T. Yeh, March 1981.

B&McD94 - "Additional Site Investigation and Remediation of the Former PAN AM Plot 1 Site (UST Area) - San Francisco International Airport", Burns and McDonnell Waste Consultants, March 1994.

B&McD95 - "Task 1A - Preliminary Bay Mud Evaluation at the San Francisco International Airport, San Mateo County", Burns and McDonnell Waste Consultants, February, 1995.

EDR - "Handbook of Environmental Degradation Rates", Howard et.al., 1991.

FE - "Foundation Engineering", Peck et. al., 1974.

PCH - "Physical and Chemical Hydrogeology", Domenico and Schwartz, 1990.

SPHEM - Superfund Public Health and Evaluation Manual, Environmental Protection Agency, October 1986.

WRR - "An Advection-Diffusion Concept for Solute Transport in Heterogeneous Unconsolidated Geological Deposits", Gillham et al, Water Resources Research, March 1984.

Table 4-3
Case Specific AT123D Input Parameters
Bay Mud Evaluation - SFIA

Case	Chemical Release Rate (Kg / hour)	Chemical Release Duration (years)	Length, Width, and Thickness of Initial Application Area (meters)
1	1.39E-06	10	20 x 64 x 7.5
2	1.01E-06	0.33	10 x 10 x 7.5
3	1.48 E-10	10	2 x 2 x 7.5
4	3.79 E-9	10	2 x 2 x 7.5
5	4.73E-06	.0274 (10 Days)	10 x 10 x 7.5

Notes:

- Cases 1 through 5 are described In Figures 4-14 through 4-18, respectively.

Table 4-4
Case Specific AT123D Results
Bay Mud Evaluation - SFIA

Case	Case Description	500 ft. Peak Groundwater Conc. (ppb)	750 ft. Peak Groundwater Conc. (ppb)	1000 ft. Peak Groundwater Conc. (ppb)	1250 ft. Peak Groundwater Conc. (ppb)
1	Tidal Channel	6.12	4.91	4.22	3.76
2	Newly Emplaced Piles	0.481	0.387	0.334	0.298
3	Degraded Piles	0.005	0.004	0.004	0.003
4	Improperly Plugged Boreholes	0.139	0.113	0.098	0.087
5	Open Excavation	0.188	0.151	0.130	0.116

Notes:

- Results for the five cases shown above are for a conservative (non-dispersive, non-diffusive), non-degrading, generic chemical.

Table 4-5
Chemical Specific AT123D Input Parameters
Bay Mud Evaluation - SFIA

Chemical	CAS Number	Organic Carbon Partitioning Coef., Koc (mL/g)	Kd (mL / g)	Distribution Coefficient, Kd m^3/Kg	Retardation Factor, R	Decay Constant k (1/hour)
Benzene	71-43-2	83	0.83	8.30E-04	6.1	4.01E-06
Chloroform	67-66-3	31	0.31	3.10E-04	2.9	1.60E-06
1,2-dichloroethane	107-06-2	14	0.14	1.40E-04	1.9	8.02E-06
1,1-dichloroethene	75-35-4	65	0.65	6.50E-04	5.0	2.19E-05
1,2-dichloroethene	540-59-0	49	0.49	4.90E-04	4.0	1.00E-06
Ethylbenzene	100-41-4	1100	11.00	1.10E-02	69	1.27E-05
Methylene chloride	75-09-2	8.8	0.088	8.80E-05	1.5	5.16E-05
Tetrachloroethene	127-18-4	364	3.64	3.64E-03	24	4.01E-06
Toluene	108-88-3	300	3.00	3.00E-03	20	1.03E-04
1,1,2-Trichloroethane	79-00-5	56	0.56	5.60E-04	4.5	3.96E-06
Trichlorethene	79-01-6	126	1.26	1.26E-03	8.8	1.75E-06
Vinyl chloride	75-01-4	57	0.57	5.70E-04	4.5	1.00E-06
Xylenes	1330-20-7	240	2.40	2.40E-03	16	8.02E-06

Notes:

- All Organic Carbon Partitioning Coefficient (Koc) values were obtained from the Superfund Public Health Evaluation Manual, Environmental Protection Agency, October 1986.
- Decay Constant (k) values were obtained by multiplying 0.1 by the decay constant values in "Handbook of Environmental Degradation Rates", Howard et. al., 1991.
- In calculating the Distribution Coefficient (Kd), the fraction of organic carbon was assumed to be 0.01.

Table 4-6
Chemical Specific AT123D Results
Bay Mud Evaluation - SFIA

Chemical	500 ft. Peak Groundwater Conc. (ppb)	750 ft. Peak Groundwater Conc. (ppb)	1000 ft. Peak Groundwater Conc. (ppb)	1250 ft. Peak Groundwater Conc. (ppb)
Benzene	3.63E-06	1.18E-09	4.57E-13	1.83E-16
Chloroform	1.30E-01	9.87E-03	8.75E-04	8.02E-05
1,2 - Dichloroethane	6.25E-04	1.94E-06	6.93E-07	2.56E-11
1,1 - Dichloroethene	3.92E-15	8.72E-24	9.84E-33	5.30E-43
1,2 - Dichloroethene	1.40E-01	1.46E-02	1.68E-03	1.99E-04
Ethylbenzene	1.10E-56	0.00E+00	0.00E+00	0.00E+00
Methylene Chloride	4.49E-12	3.09E-19	2.68E-26	7.06E-34
Tetrachloroethene	1.61E-14	1.92E-22	0.00E+00	0.00E+00
Toluene	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1,1,2-Trichloroethane	7.84E-05	1.20E-07	2.21E-10	4.15E-13
Trichloroethene	1.09E-04	3.02E-07	9.62E-10	1.18E-12
Vinyl Chloride	8.75E-02	7.44E-03	6.97E-04	6.76E-05
Xylene	6.25E-17	2.46E-26	1.69E-36	0.00E+00

Notes:

- The chemicals indicated were modeled using the Case 1 scenario and the specific distribution coefficients and decay constants as shown on Table 4-4.
- Shading indicates chemical concentrations in groundwater plotted in Figure 4-24

Table 4-7
Case 1 - AT123D Results for
Various Concentrations of 1,2-Dichloroethene
Bay Mud Evaluation - SFIA

Initial Source Concentration (ppb)	500 ft. Peak Groundwater Conc. (ppb)	750 ft. Peak Groundwater Conc. (ppb)	1000 ft. Peak Groundwater Conc. (ppb)	1250 ft. Peak Groundwater Conc. (ppb)
10	1.40E-02	1.46E-03	1.68E-04	1.99E-05
100	1.40E-01	1.46E-02	1.68E-03	1.99E-04
1,000	1.40E+00	1.46E-01	1.68E-02	1.99E-03
10,000	1.40E+01	1.46E+00	1.68E-01	1.99E-02

Notes:

- The peak groundwater concentrations indicated above are for 1, 2-Dichloroethene with the specific input parameters shown on Tables 4-2 through 4-4.

FIGURES

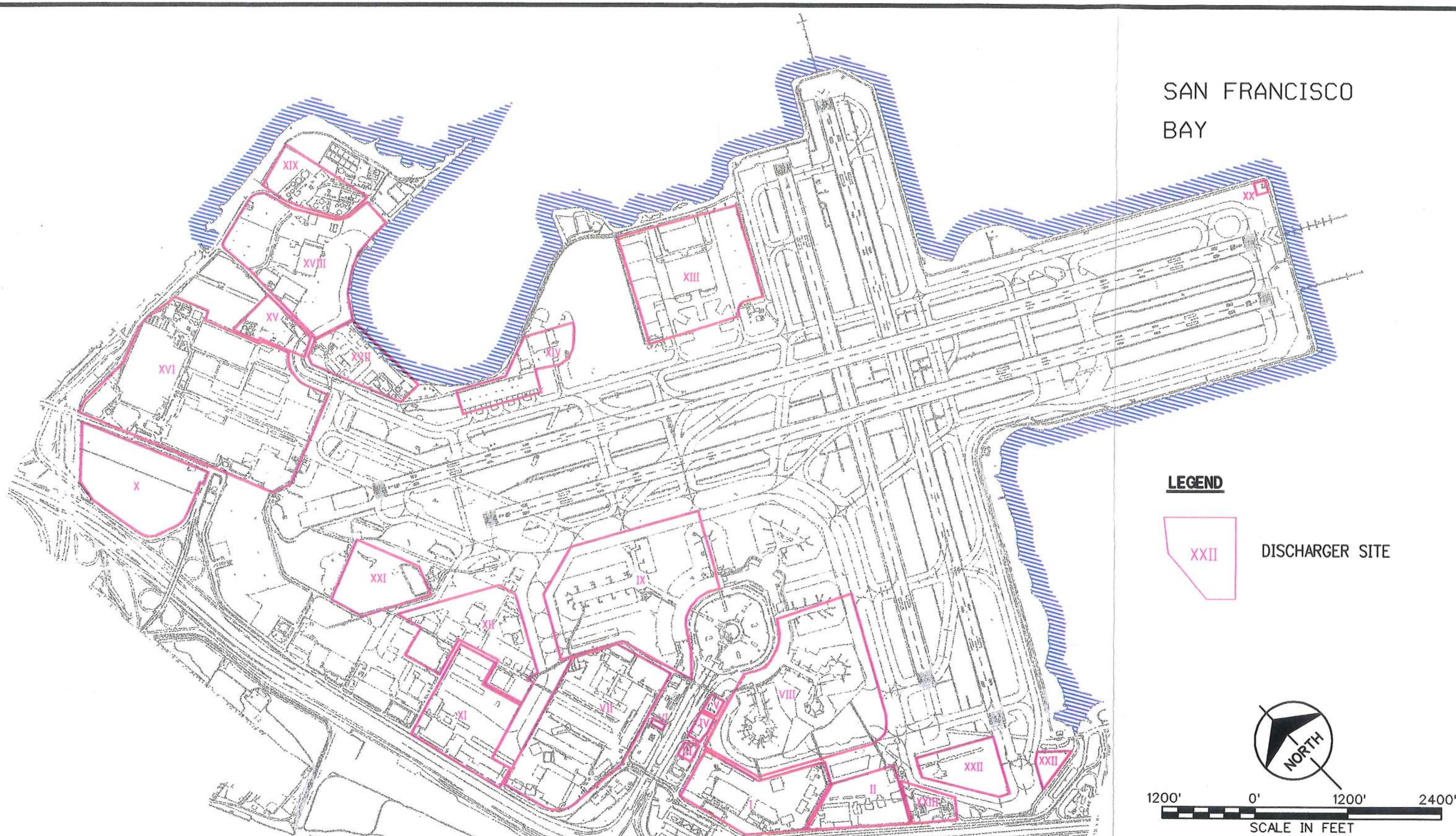

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Figure 1-1

SAN FRANCISCO INTERNATIONAL AIRPORT AND RWQRB DISCHARGER SITES

SANFG284.D 31-MAY-95 13:50/DBR

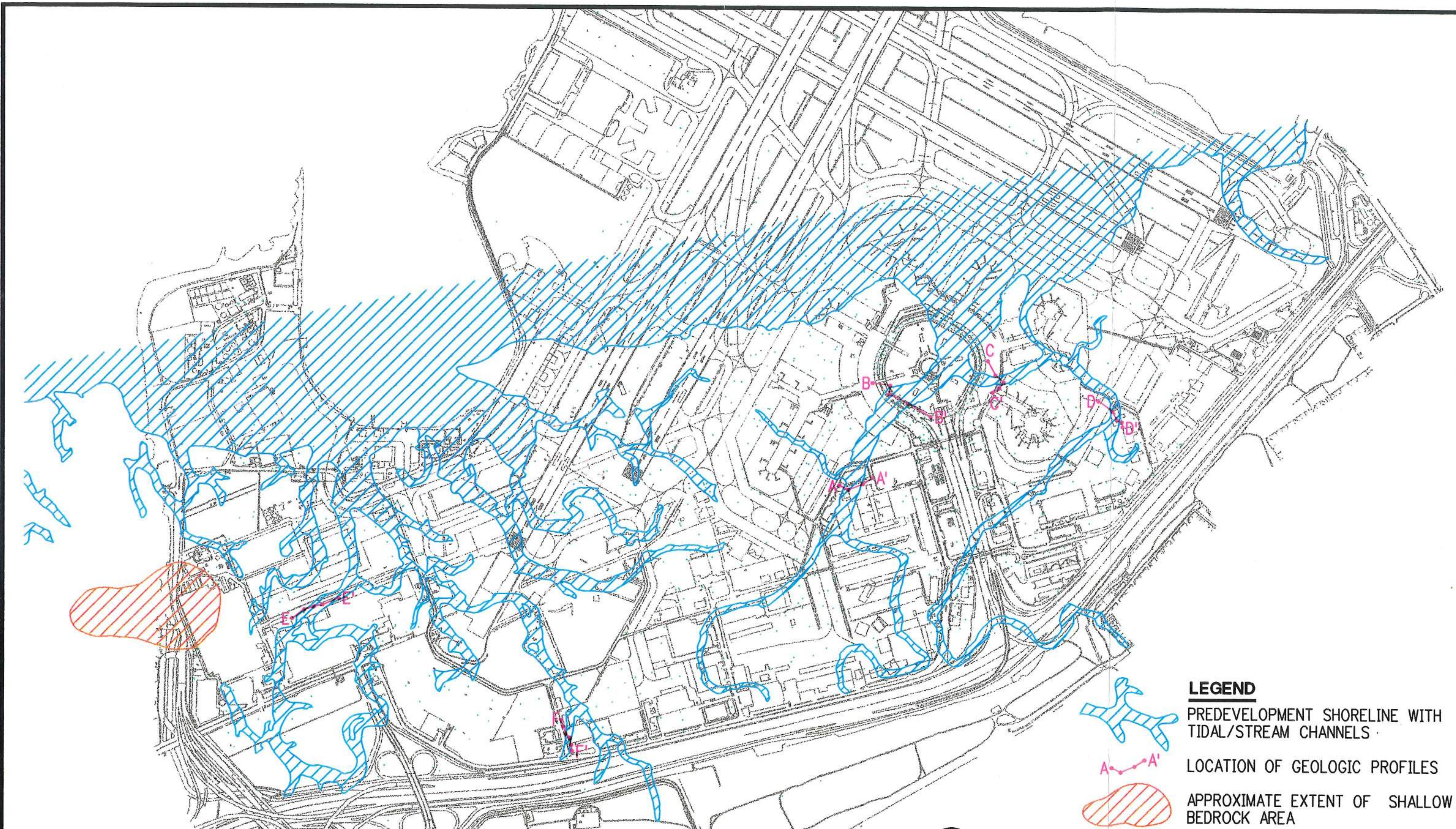

Figure 4-1

PREDEVELOPMENT TIDAL/STREAM CHANNELS BAY MUD EVALUATION - SFIA

LEGEND

UNIFIED SOIL CLASSIFICATION SYSTEM

MAJOR DIVISIONS			LETTER SYMBOL	DESCRIPTION
COARSE-GRAINED SOILS MORE THAN 50% LARGER THAN NO. 200 SIEVE SIZE	GRAVEL AND GRAVELLY SOILS	CLEAN GRAVELS LITTLE OR NO FINES	GW	WELL-GRADED GRAVEL, GRAVEL-SAND MIXTURE
			GP	POORLY-GRADED GRAVEL, GRAVEL-SAND MIXTURE
		GRAVEL WITH FINES APPRECIABLE FINES	GM	SILTY GRAVEL, GRAVEL-SAND-SILT MIXTURE
			GC	CLAYEY-GRAVEL, GRAVEL-SAND-CLAY MIXTURE
	SAND AND SANDY SOILS	CLEAN SANDS LITTLE OR NO FINES	SW	WELL-GRADED SAND, GRAVELLY SAND
			SP	POORLY-GRADED SAND, GRAVELLY SAND
		SANDS WITH FINES APPRECIABLE FINES	SM	SILTY SAND, SAND-SILT MIXTURE
			SC	CLAYEY SAND, SAND-CLAY MIXTURE
FINE-GRAINED SOILS MORE THAN 50% SMALLER THAN NO. 200 SIEVE SIZE	SILTS AND CLAYS	LIQUID LIMIT LESS THAN 50	ML	SILT, CLAYEY SILT, SILTY OR CLAYEY VERY FINE SAND, SLIGHT PLASTICITY
			CL	CLAY, SANDY CLAY, SILTY CLAY, LOW TO MEDIUM PLASTICITY
			OL	ORGANIC SILTS OR SILTY CLAYS OF LOW PLASTICITY
	SILTS AND CLAYS	LIQUID LIMIT MORE THAN 50	MH	SILT, FINE SANDY OR SILTY SOIL WITH HIGH PLASTICITY
			CH	CLAY, HIGH PLASTICITY
			OH	ORGANIC CLAY OF MEDIUM TO HIGH PLASTICITY
HIGHLY ORGANIC SOILS			PT	PEAT, HUMUS, SWAMP SOIL

- PAVEMENT
- A-FILL ZONE
- CLAY (YOUNGER BAY MUD)
- SAND
- PEAT
- SILTS OR CLAYS (OLDER BAY MUD)

NOTE:

APPENDIX A PROVIDES BORING LOGS FOR GEOLOGIC PROFILES.

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Figure 4-2

GEOLOGIC PROFILE LEGEND

BAY MUD EVALUATION - SFIA

SANFG282.DGN/31-MAY-95 15:52/DBR

SANFG280.DGN/31-MAY-95 16:02/DBR
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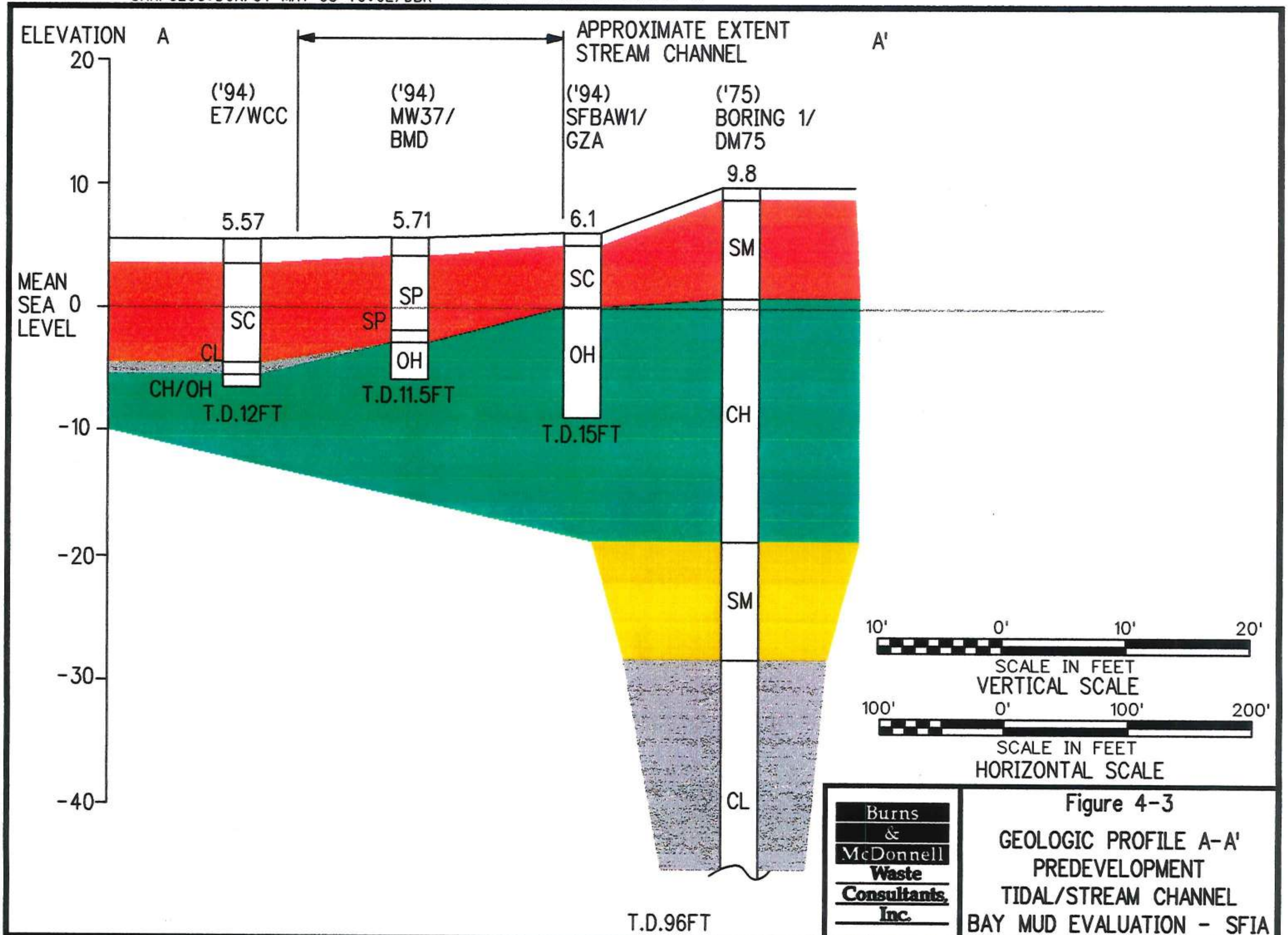

Figure 4-3
GEOLOGIC PROFILE A-A'
PREDEVELOPMENT
TIDAL/STREAM CHANNEL
BAY MUD EVALUATION - SFIA

SANFG281.DGN/31-MAY-95 16:05/DBR

SANFG281.DGN,OF=12
,BDR2DCV:WCIBDR04.DGN,OF=61

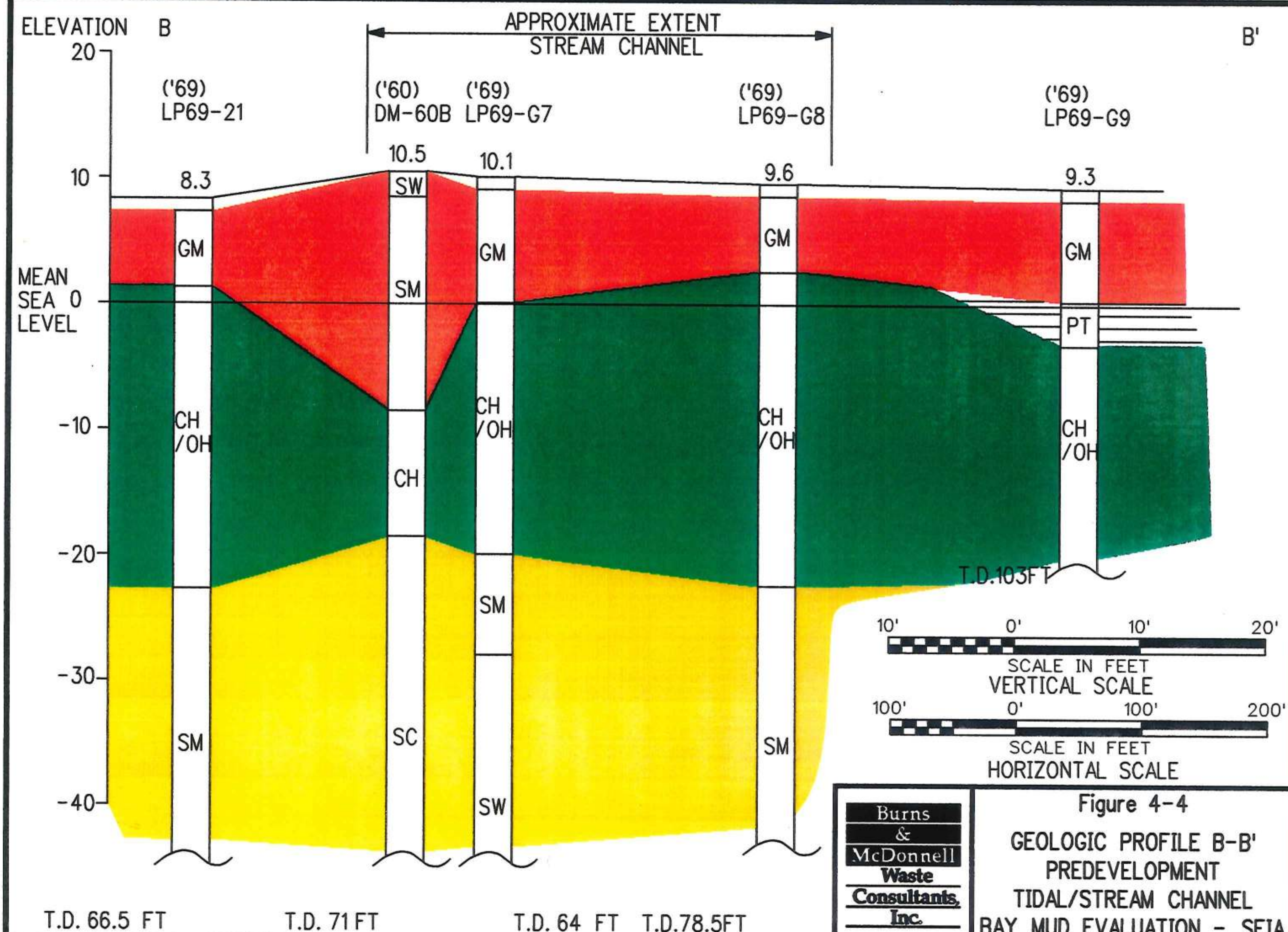

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Figure 4-4

GEOLOGIC PROFILE B-B'
PREDEVELOPMENT
TIDAL/STREAM CHANNEL
BAY MUD EVALUATION - SFIA

SANFG278.DGN/31-MAY-95 16:09/DBR

SANFG278.DGN,OF=12
,BDR2DCV:WCIBDR04.DGN,OF=61

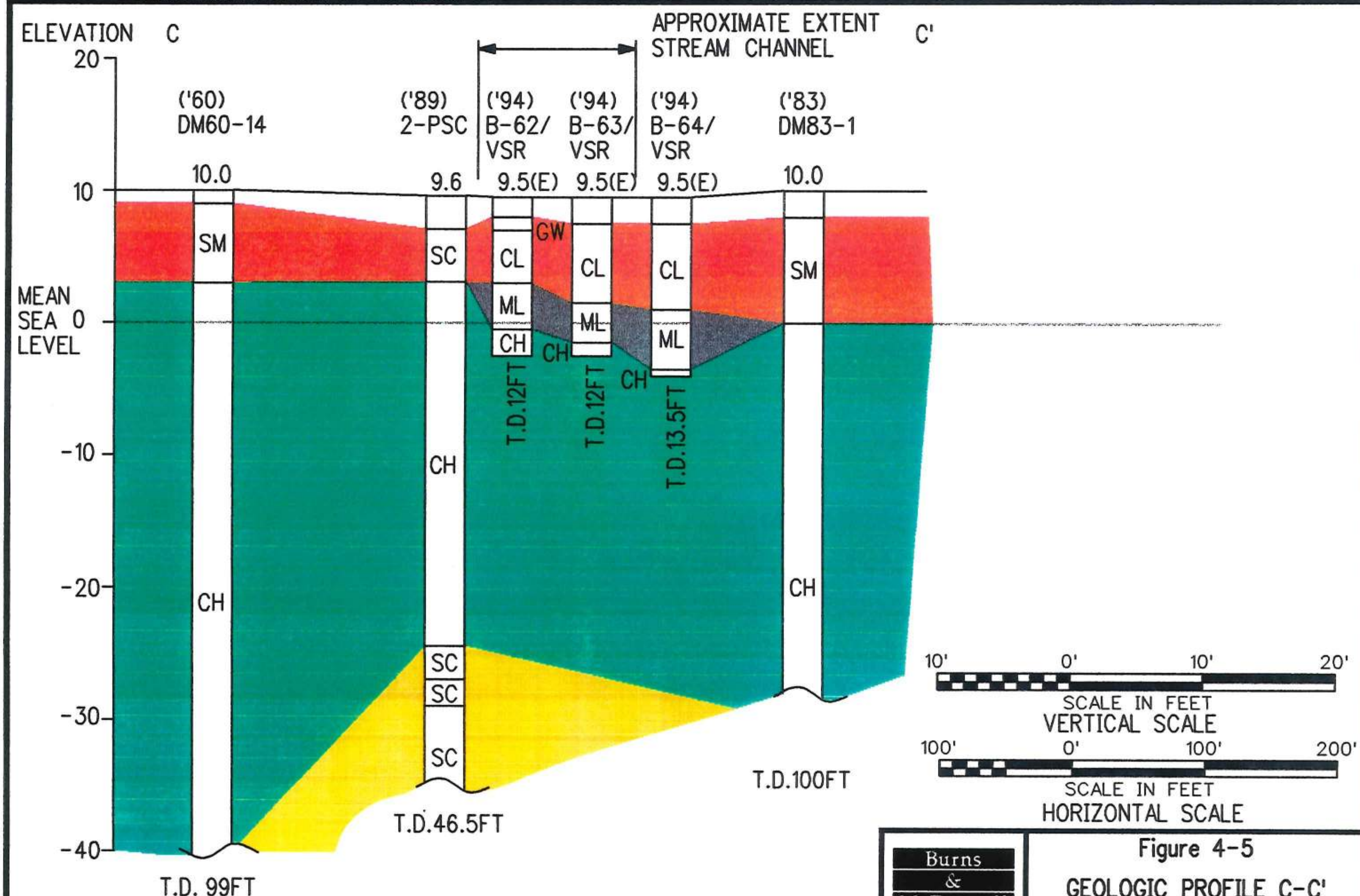

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Figure 4-5

GEOLOGIC PROFILE C-C'
PREDEVELOPMENT
TIDAL/STREAM CHANNEL
BAY MUD EVALUATION - SFIA

SANFG279.DGN/31-MAY-95 16:12/DBR

SANFG279.DGN,OF=12
,BDR2DCV:WCIBDR04.DGN,OF=61

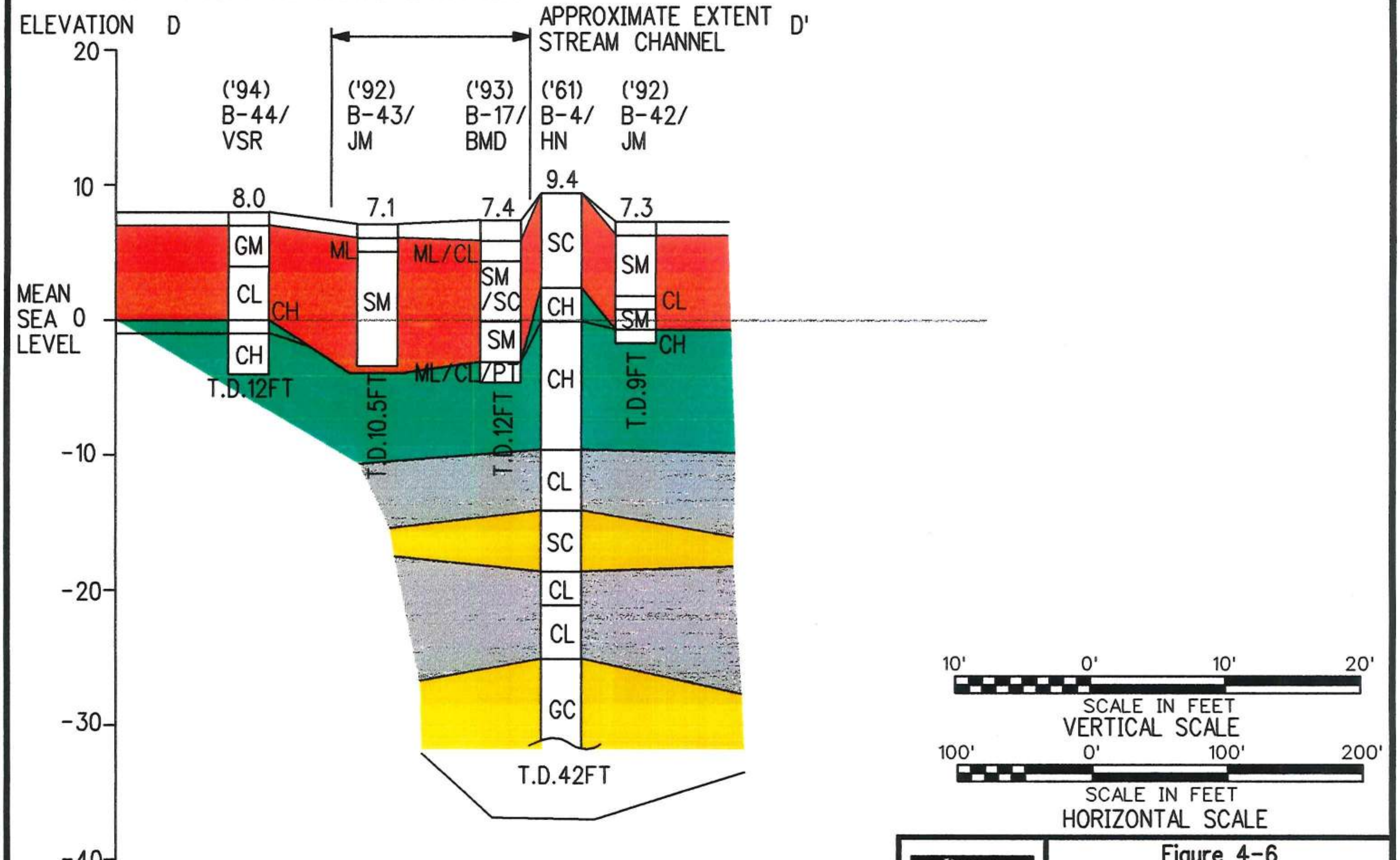

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Figure 4-6

GEOLOGIC PROFILE D-D'
PREDEVELOPMENT
TIDAL/STREAM CHANNEL
BAY MUD EVALUATION - SFIA

SANFG276.DGN/31-MAY-95 16:16/DBR
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,BDR2DCV:WCIBDR04.DGN,OF=61

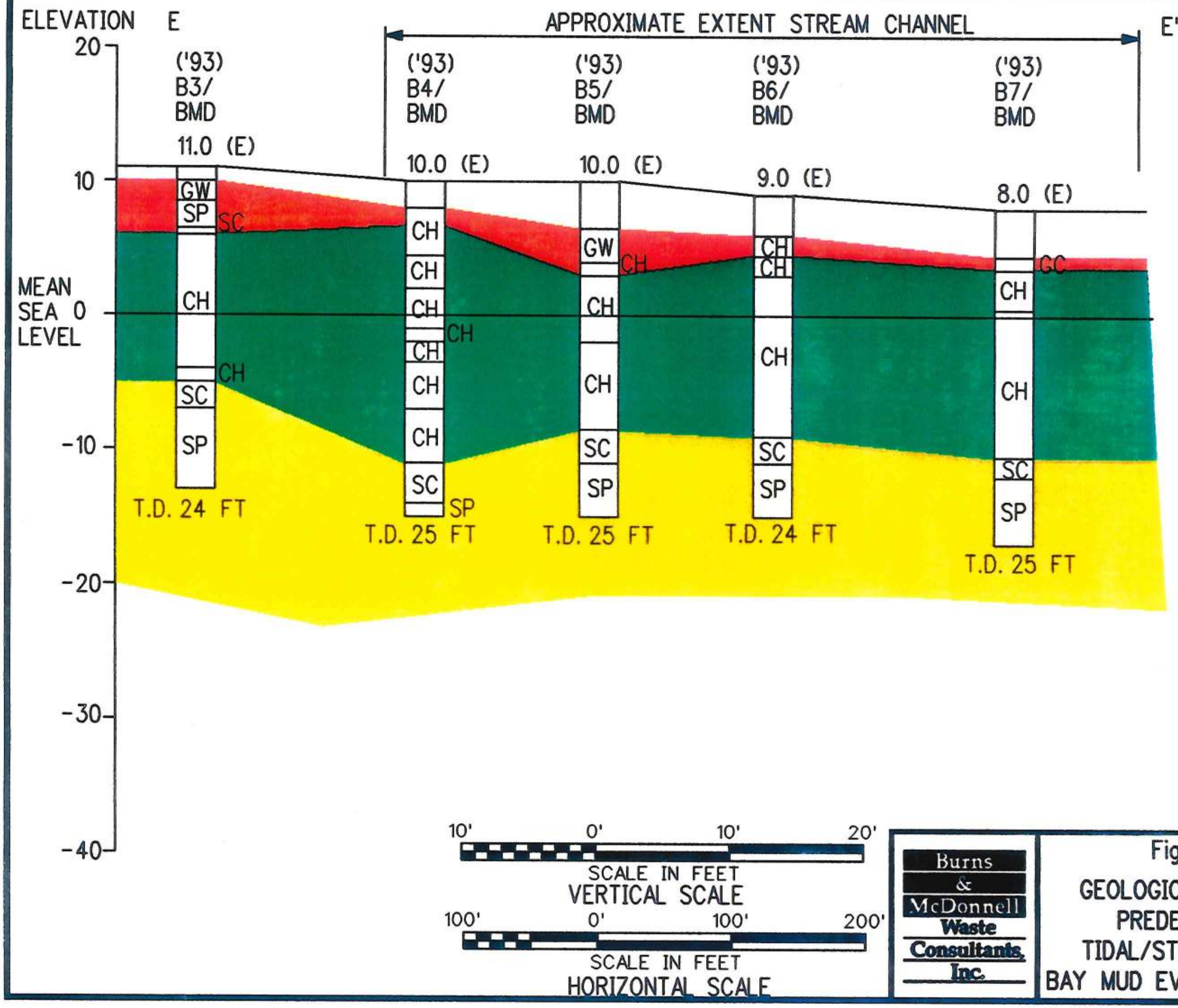

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Figure 4-7

GEOLOGIC PROFILE E-E'
PREDEVELOPMENT
TIDAL/STREAM CHANNEL
BAY MUD EVALUATION - SFIA

.BDR2DCV:WCIBDR .GN.OF=61

SANFG277.DGN/31-MAY-95 16:20/DBR

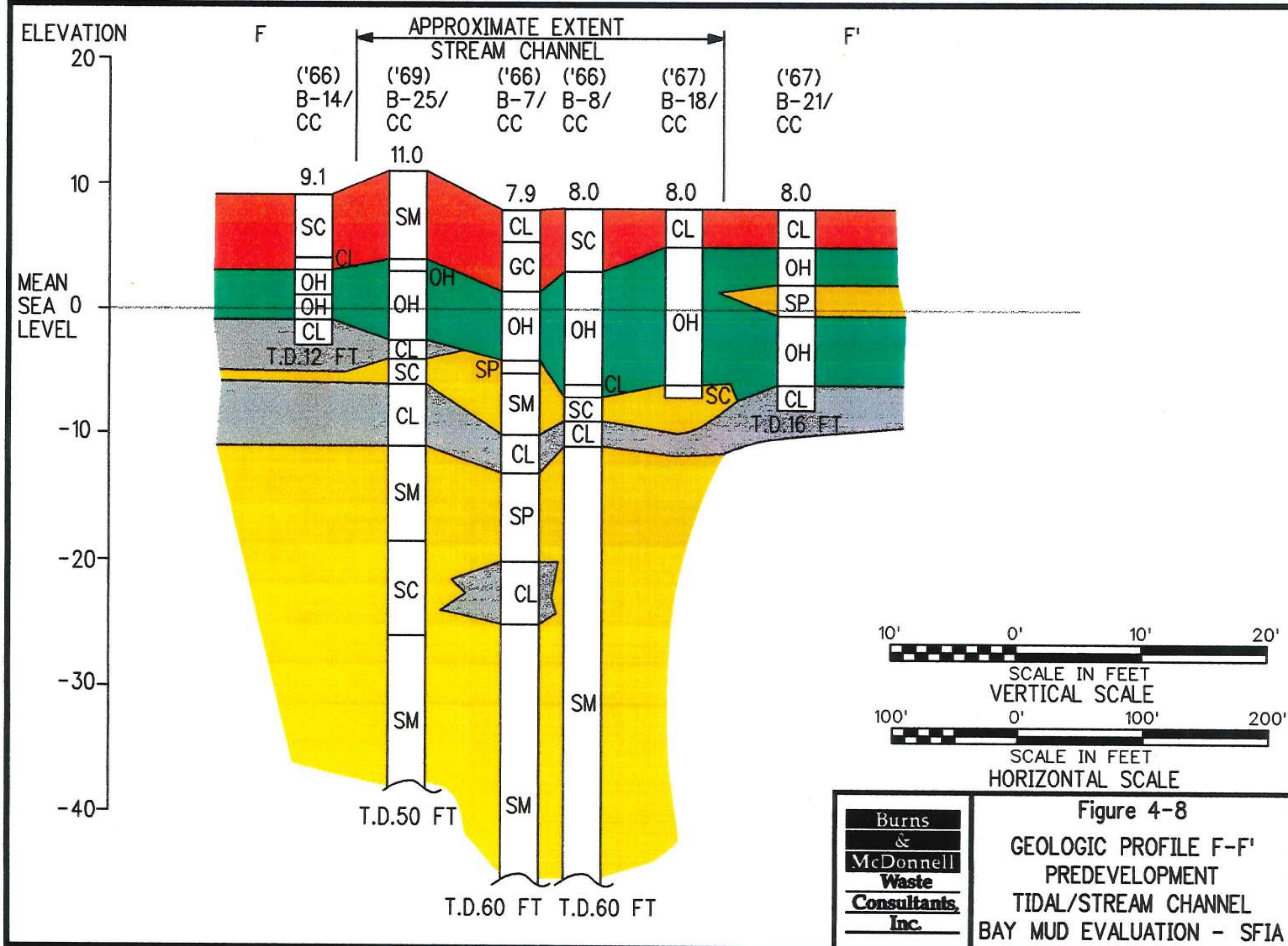
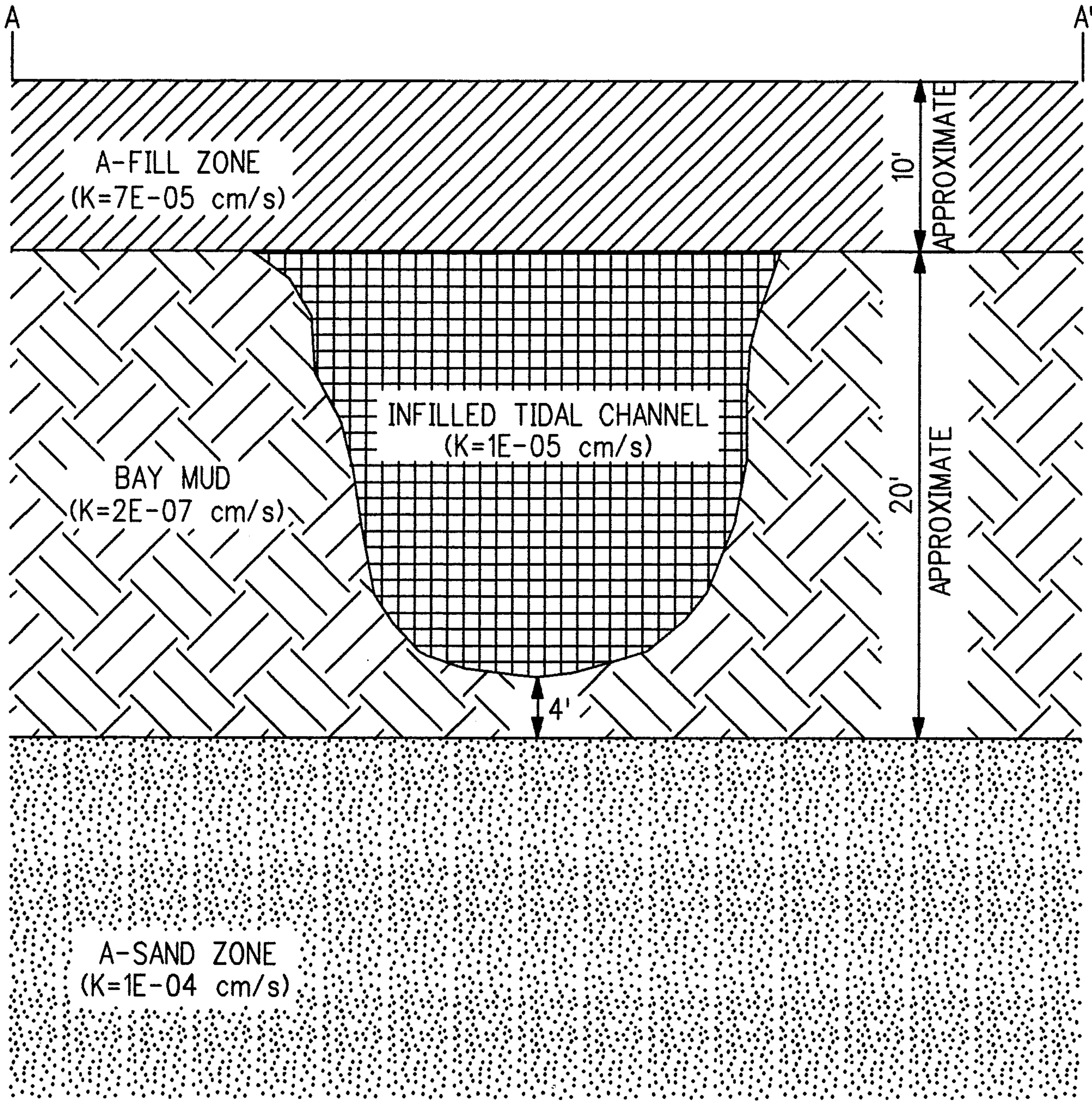


Figure 4-8

GEOLOGIC PROFILE F-F'
PREDEVELOPMENT
TIDAL/STREAM CHANNEL
BAY MUD EVALUATION - SFIA



SANFG271.DGN,OF=NONE
.BDR2DCV:WCIBDR03.DGN
S, 271.DGN/2-NOV-95 09:29/CJW

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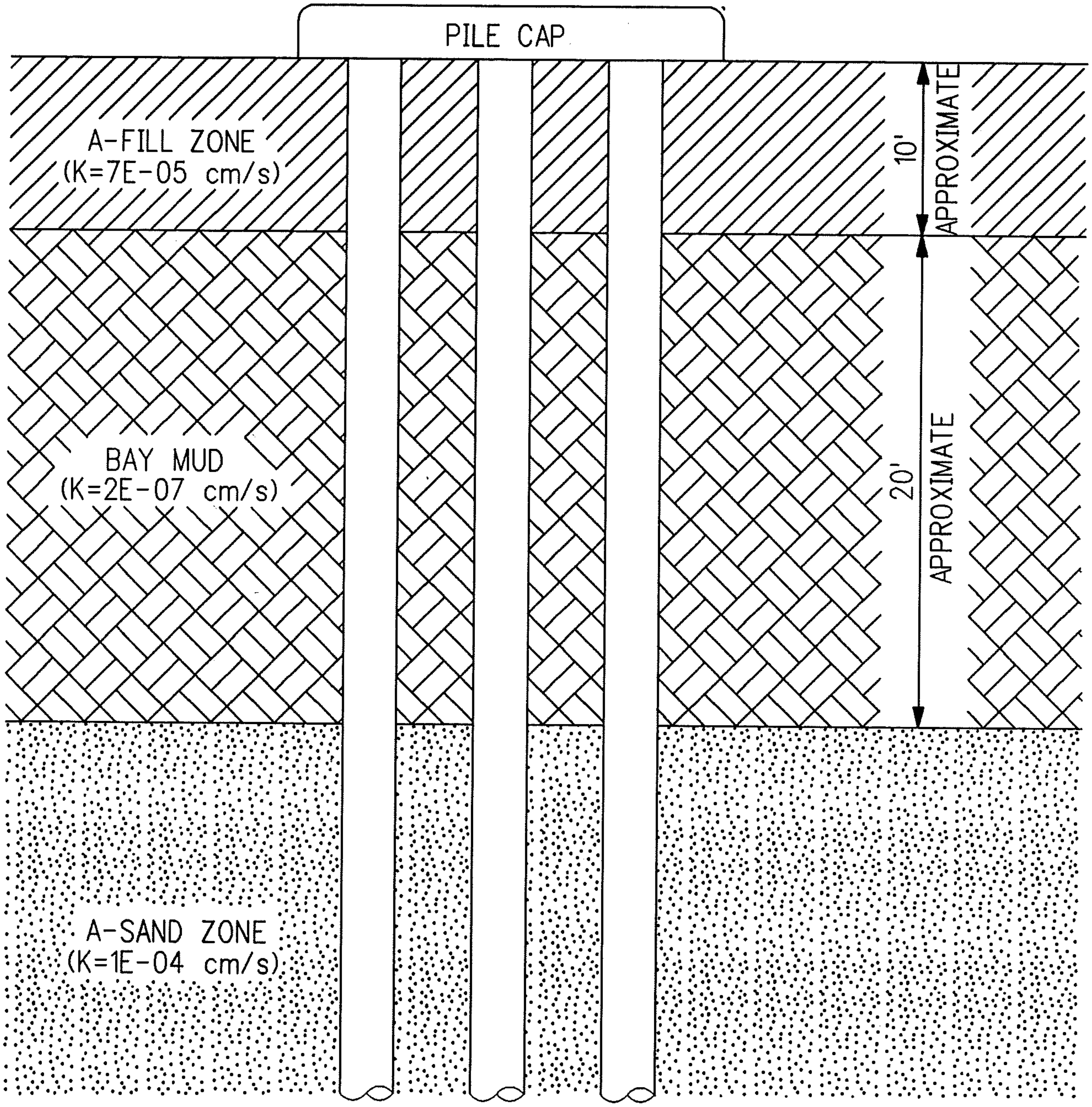
Figure 4-9

CASE 1 - TIDAL CHANNEL CONCEPTUAL MODEL
BAY MUD EVALUATION - SFIA



PRE-CAST CONCRETE PILINGS

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Figure 4-10

CASE 2 -
NEWLY EMPLACED PILES
CONCEPTUAL MODEL
BAY MUD EVALUATION - SFIA

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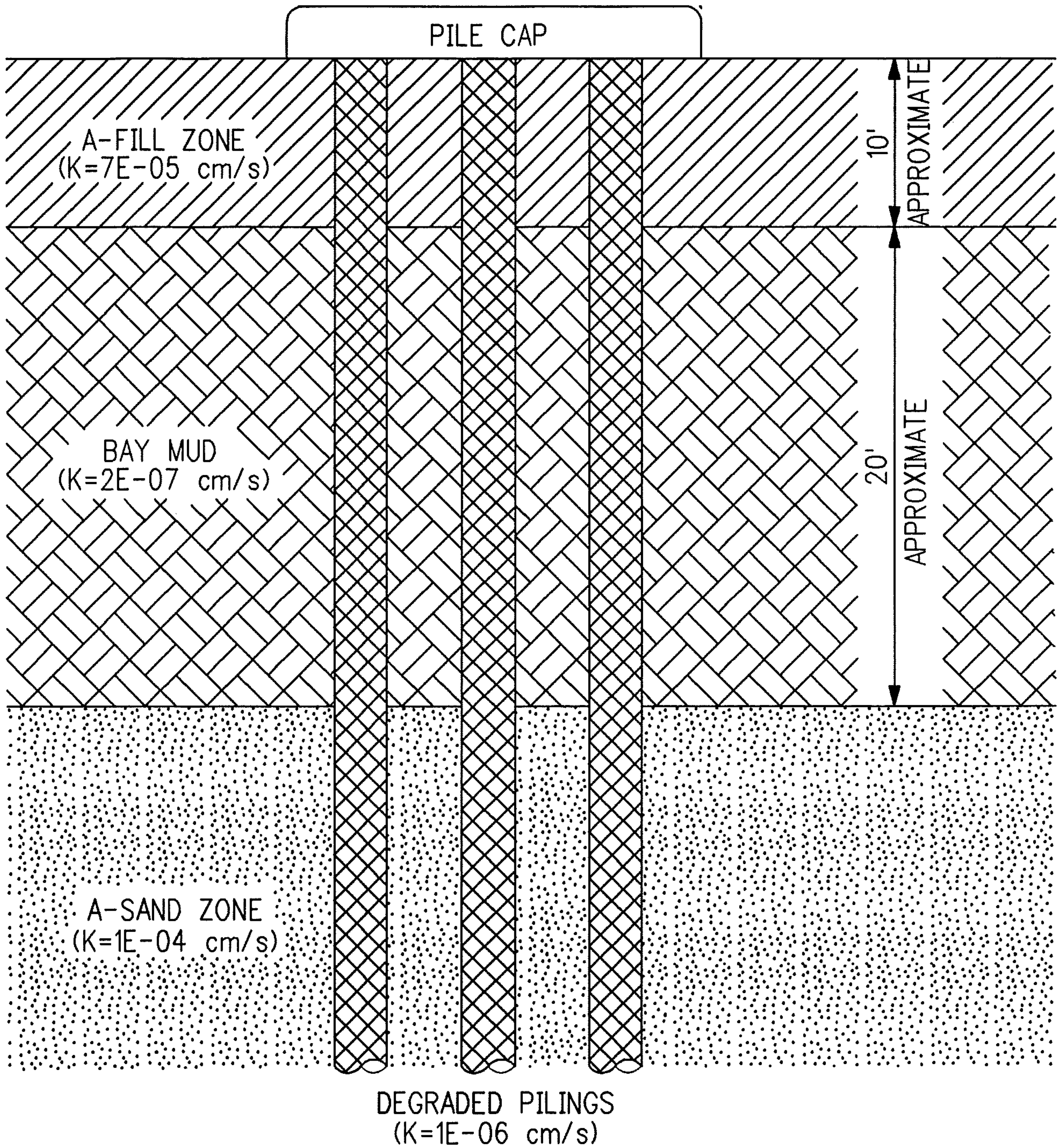
SANFG231.DGN,OF=NONE
,BDR2DCV:WCIBDR03.DGN 61



SANFG272.DGN/1-JUN-95 12:37/DBR

SANFG272.DGN,UF=NONE,BDR2DCV:WCIBDR03.DGN,

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Figure 4-11

CASE 3 - DEGRADED PILE CONCEPTUAL MODEL

BAY MUD EVALUATION - SFIA

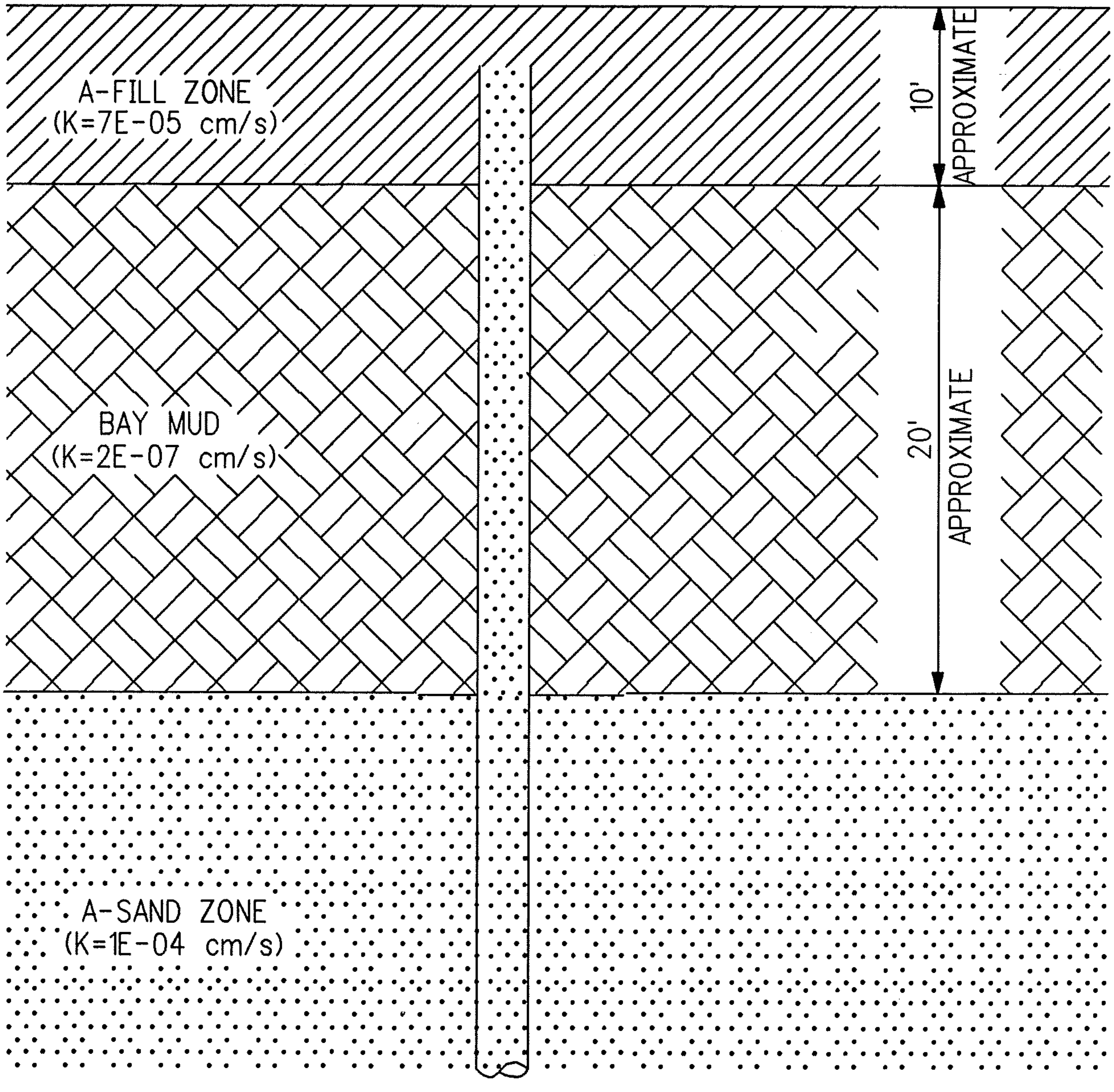

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Figure 4-12

CASE 4 - IMPROPERLY ABANDONED BOREHOLE CONCEPTUAL MODEL
BAY MUD EVALUATION - SFIA

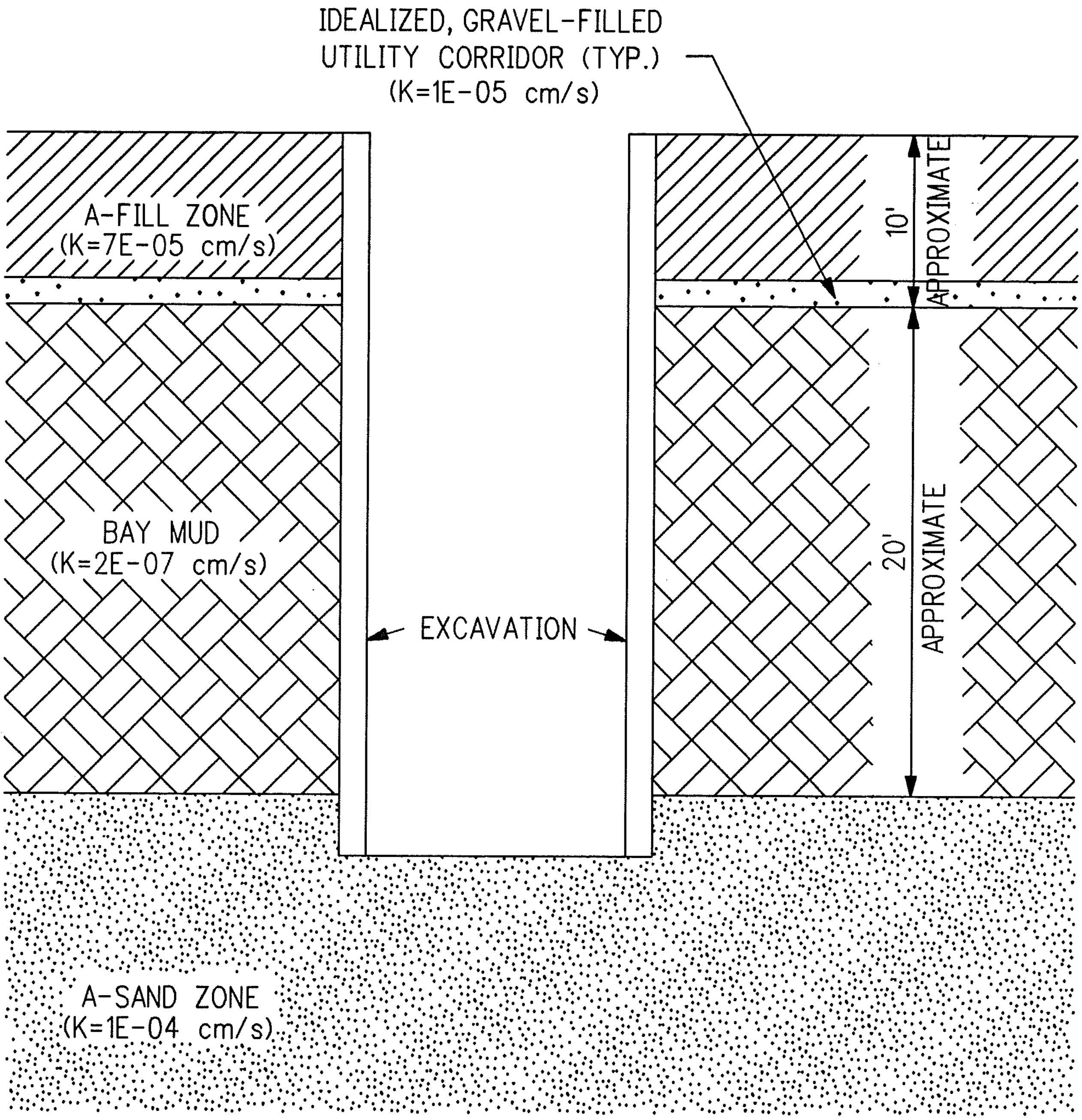

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Figure 4-13

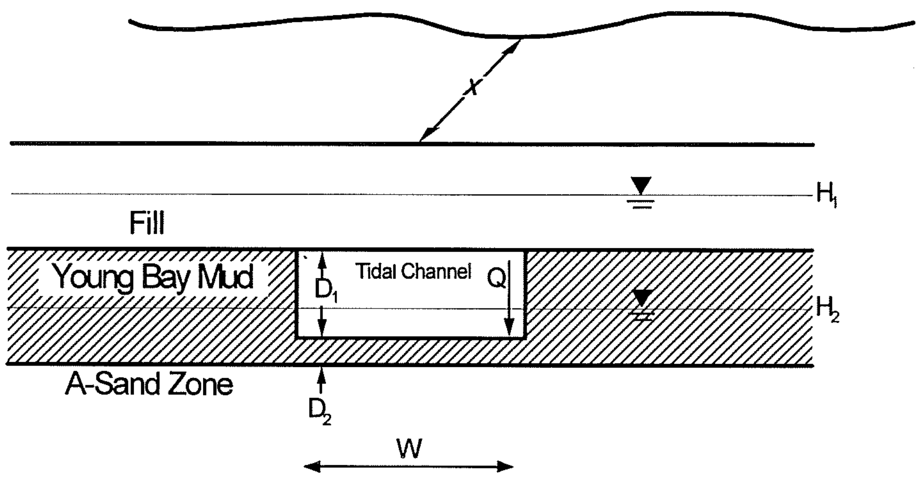
CASE 5 - OPEN EXCAVATION CONCEPTUAL MODEL
BAY MUD EVALUATION - SFIA

SANFG233.DGN,OF=NONE ,BDR2DCV:WCIBDR03.DGN,

SANFG233.DGN/1-JUN-95 14:58/DBR

CASE 1

Calculation of the Migration of a Contaminant Due to a Tidal Channel



Cross-Section of a Tidal Channel

Note: Diagram is not to scale.

Assumptions:

Width of Tidal Channel (W) = 6,400 cm
Length of Tidal Channel Intersecting A-Sand (X) = 2,000 cm
Difference between Heads, H_1 and H_2 (Δ H) = 6.5 ft = 198 cm
Heads H_1 and H_2 apply to Fill zone and A-Sand zone respectively.
D_1 = Tidal Channel Thickness = 16 ft = 488 cm
D_2 = Bay Mud Thickness @ Base of Channel = 4 ft = 122 cm
Combined Thickness of D_1 and D_2 = 20 ft = 610 cm
Hydraulic Conductivity of Tidal Channel (K_1) = 1E-5 cm/s
Hydraulic Conductivity of Bay Mud (K_2) = 2E-7 cm/sec

1. Calculation for the effective Hydraulic Conductivity (Tidal Channel + Bay Mud) =

$$\frac{D}{D_1/K_1 + D_2/K_2} = 9.26E\text{-}7 \text{ cm/sec}$$

where $D = D_1 + D_2$ = 20 ft = 610 cm

2. Calculation of the gradient (i) through the tidal channel:
Gradient (i) = (Δ H) / D = 198 cm / 610 cm = .325

3. Calculation of the volumetric flow rate (Q) through the tidal channel:
Flow Rate (Q) = (Effective Conductivity) (i) (W) (X) =
= (9.26e-7 cm/sec) (.325) (6,400 cm) (2,000 cm)
= 3.9 cm^3 /sec = 13.9 L/hour

Burns & McDonnell Waste Consultants, Inc.	Figure 4-14 CASE 1 - TIDAL CHANNEL CALCULATIONS BAY MUD EVALUATION - SFIA

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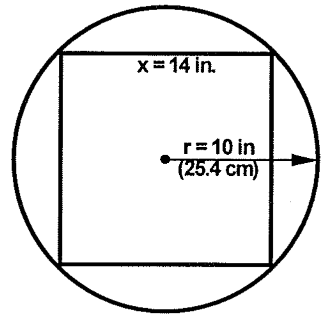
CASE 2

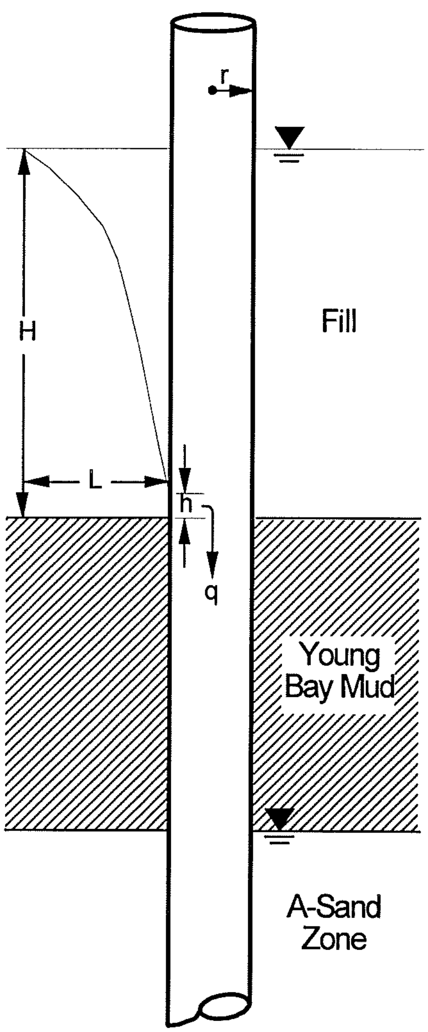
Calculation of the Migration of a Contaminant Due to Newly Emplaced Piles

Assumptions:

Width of a Square Pile (x) = 14 in = 35.6 cm
Hydraulic Conductivity of the Fill (K) = 7 E-5 cm / sec
Distance from the Borehole to Zero Drawdown (L) = 100 cm
Saturated Thickness of the Fill (H) = 150 cm
Seepage Face of Borehole (h) = 50 cm
Amount of Time the Drilled Borehole Will Remain Open (t) = 3 hours
Pile Placement Area (20 piles) (A) = 1,000 cm by 1,000 cm



Map View - Borehole and Pile



Cross-Section of Borehole

1. Calculation of the borehole radius (r):

   Radius of Borehole (r) = $(0.5)(2x^2)^{0.5} = (0.5)[2\,(14)^2]^{0.5}$
   Radius of Borehole (r) = 10 in = 25.4 cm

2. Calculation of the volumetric flow rate (q) from the fill to the borehole: (Assuming entire q flows into the A-Sand Zone at the same rate, and no water flows from the Young Bay Mud) (Equation was taken from "Dewatering and Groundwater Control", a publication of the Dept. of Army, Navy, and Air Force, p. 4-2)

   Flow Rate (q) = $(K)(2\pi r)(H^2 - h^2) / (2L) = (7\ E\text{-}5)(\pi)(25.4)[(150)^2 - (50)^2] / (100)$
   Flow Rate (q) = 1.12 cm^3/ sec = 4.02 L / hour (NOTE: Q is per pile)

3. Caculation of the volumetric flow rate (Q) of contaminated water flowing from the fill down into the A-Sand Zone assuming 20 piles are installed per day and the drilled borehole for each pile remains open for 3 hours:

   Flow Rate (Q) = q(no. of piles per day) = (4.02)(20)
   Flow Rate (Q) = 80.4 L/hour (or 241 L/day assuming the pre-drilled boreholes remain open for 3 hours).

Note: Both diagrams are not to scale.

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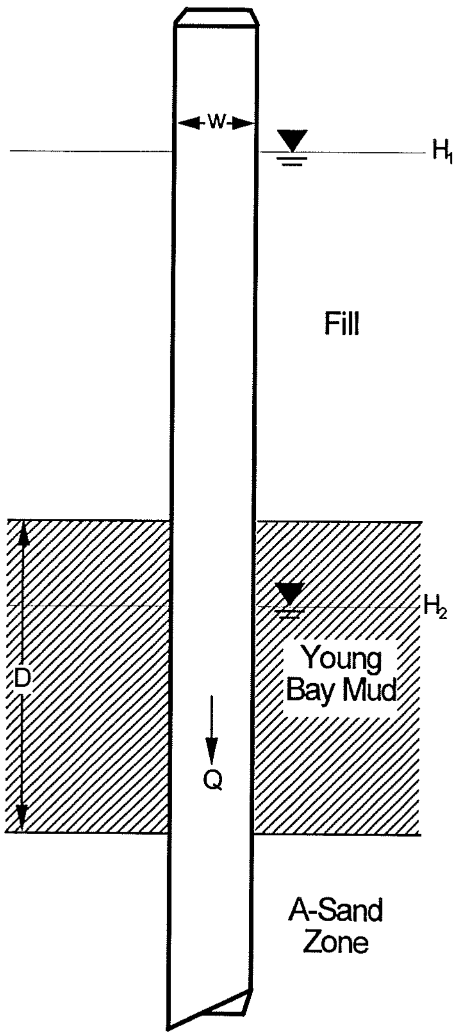
Figure 4-15
CASE 2 - NEWLY EMPLACED PILES CALCULATIONS
BAY MUD EVALUATION - SFIA

CASE 3

Calculation of the Migration of a Contaminant Due to a Degraded Pile



Cross-Section of Borehole

Note: Diagram is not to scale.

Assumptions:

Width of the Pile (w) = 14 in = 35.6 cm
Hydraulic Conductivity of the Pile (K) = 1 E-6 cm / sec
Thickness of Young Bay Mud (D) = 20 ft = 610 cm
Difference between Heads, H_1 and H_2 (Δ H) = 6.5 ft = 198 cm

1. Calculation of the gradient (i) through the pile:

   Gradient (i) = (Δ H) / (D) = 198 / 610
   Gradient (i) = 0.325

2. Calculation of the volumetric flow rate (Q) through the pile:

   Flow Rate (Q) = $(K)(i)(w)^2$ = $(1\text{ E-6})(0.325)(35.6)^2$
   Flow Rate (Q) = 4.11 E-4 cm^3 / sec = 1.48 E-3 L / hour

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Figure 4-16
CASE 3 - DEGRADED PILE CALCULATIONS
BAY MUD EVALUATION - SFIA

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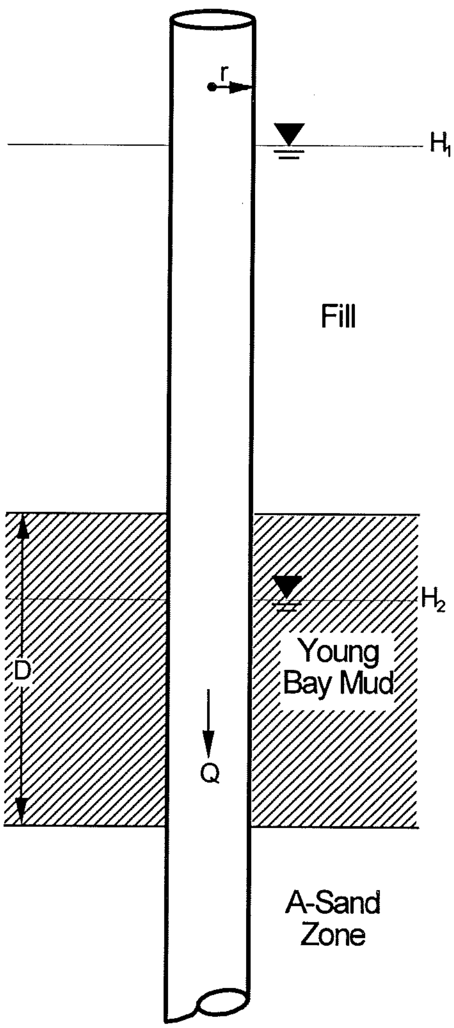
CASE 4

Calculation of the Migration of a Contaminant Due to Improperly Plugged Boreholes



Cross-Section of Borehole

Note: Diagram is not to scale.

Assumptions:

Radius of the Borehole (r) = 4 in = 10.2 cm
Hydraulic Conductivity of the Borehole (K) = 1 E-4 cm / sec
Thickness of Young Bay Mud (D) = 20 ft = 610 cm
Difference between Heads, H_1 and H_2 (Δ H) = 6.5 ft = 198 cm
Heads H_1 and H_2 apply to the Fill zone and A-Sand zone respectively.

1. Calculation of the area (Ab) of the borehole:

   Area of Borehole (Ab) $= \pi r^2 = \pi (10.2)^2 = 324 \text{ cm}^2$

2. Calculation of the gradient (i) through the borehole:

   Gradient (i) = (ΔH) / (D) = 198 / 610
   Gradient (i) = 0.325

3. Calculation of the volumetric flow rate (Q) through the borehole:

   Flow Rate (Q) = (K)(i)(Ab) = (1 E-4)(0.325)(324)
   Flow Rate (Q) = 1.05 E-2 cm^3/ sec = 3.79 E-2 L / hour

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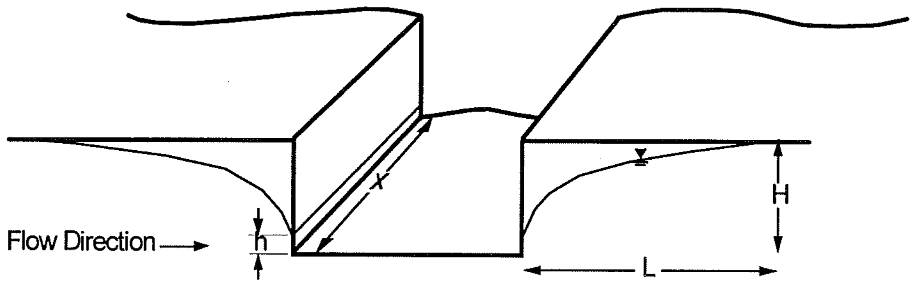
Figure 4-17
CASE 4 - IMPROPERLY ABANDONED BOREHOLE CALCULATIONS
BAY MUD EVALUATION - SFIA

CASE 5

Calculation of the Migration of a Contaminant Due to an Open Excavation



Cross-Section of a Portion of the Trench

Note: Diagram is not to scale.

Assumptions:

Hydraulic Conductivity of the Fill (K) = 7 E-5 cm / sec
Length of the Trench Section (X) = 100 m (10,000 cm)
Distance from the Trench to Zero Drawdown (L) = 100 cm
Saturated Thickness of the Fill (H) = 50 cm
Seepage Face in the Trench (h) = 25 cm

1. Calculation of the volumetric flow rate (Q) from the fill to the trench section:
   (From "Dewatering and Groundwater Control", a publication of the Department of Army, Navy, and Air Force, p 4-5)

   Flow Rate (Q) = $(K)(X)(H^2 - h^2) / (L)$ = $(7\text{ E-}5)(10{,}000)[(50)^2 - (25)^2] / (100)$
   Flow Rate (Q) = 13.1 cm^3 / sec = 47.3 L / hour

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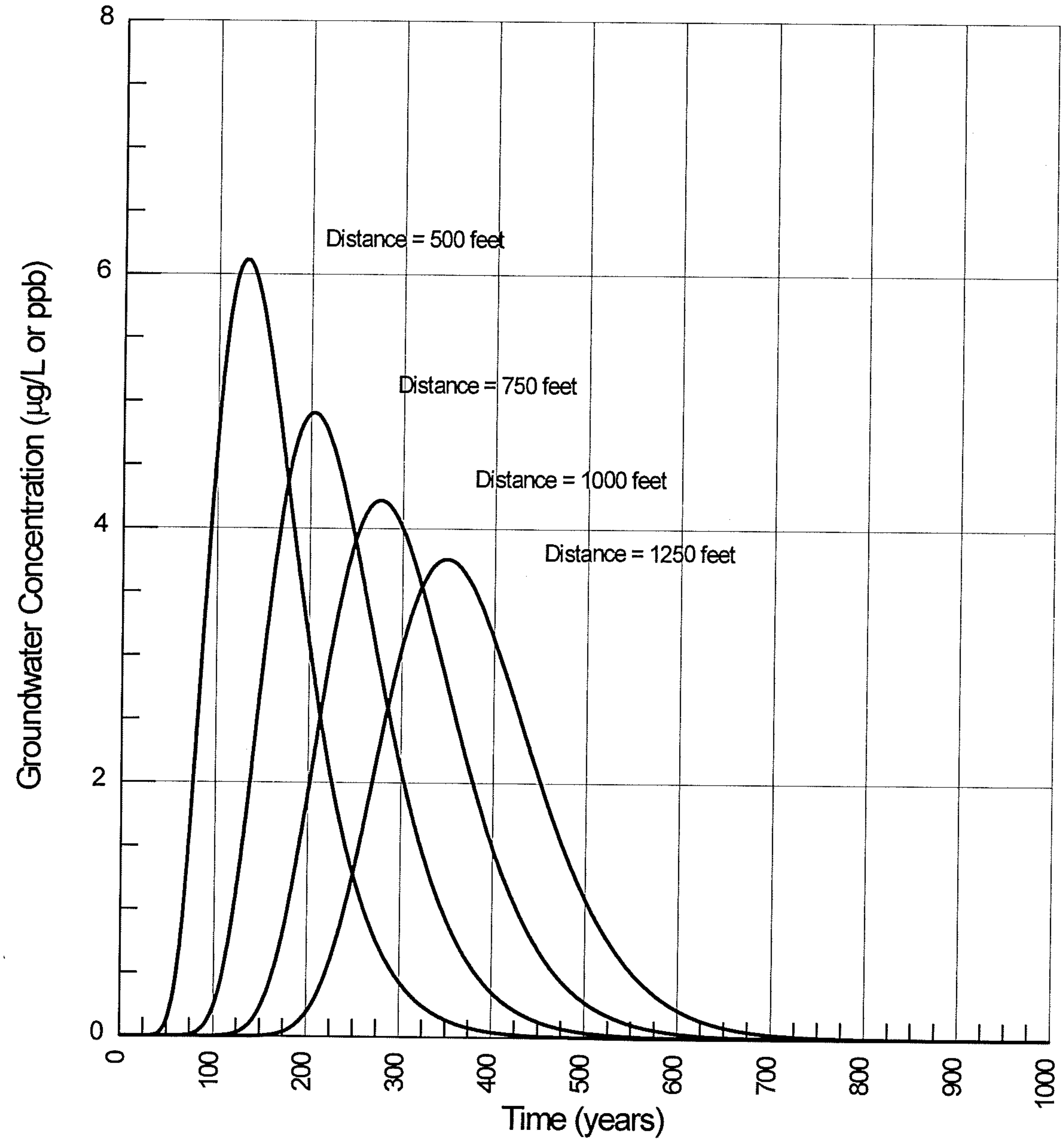
Figure 4-18
CASE 5 - OPEN EXCAVATION CALCULATIONS
BAY MUD EVALUATION - SFIA

k:\united\sfo\412014\model\general\hmi\trench.grf



NOTE: The curves shown above indicate dissolved levels of contamination at potential receptor locations for various travel times.

The distances shown indicate the distance to potential receptors located directly down gradient of the source area.

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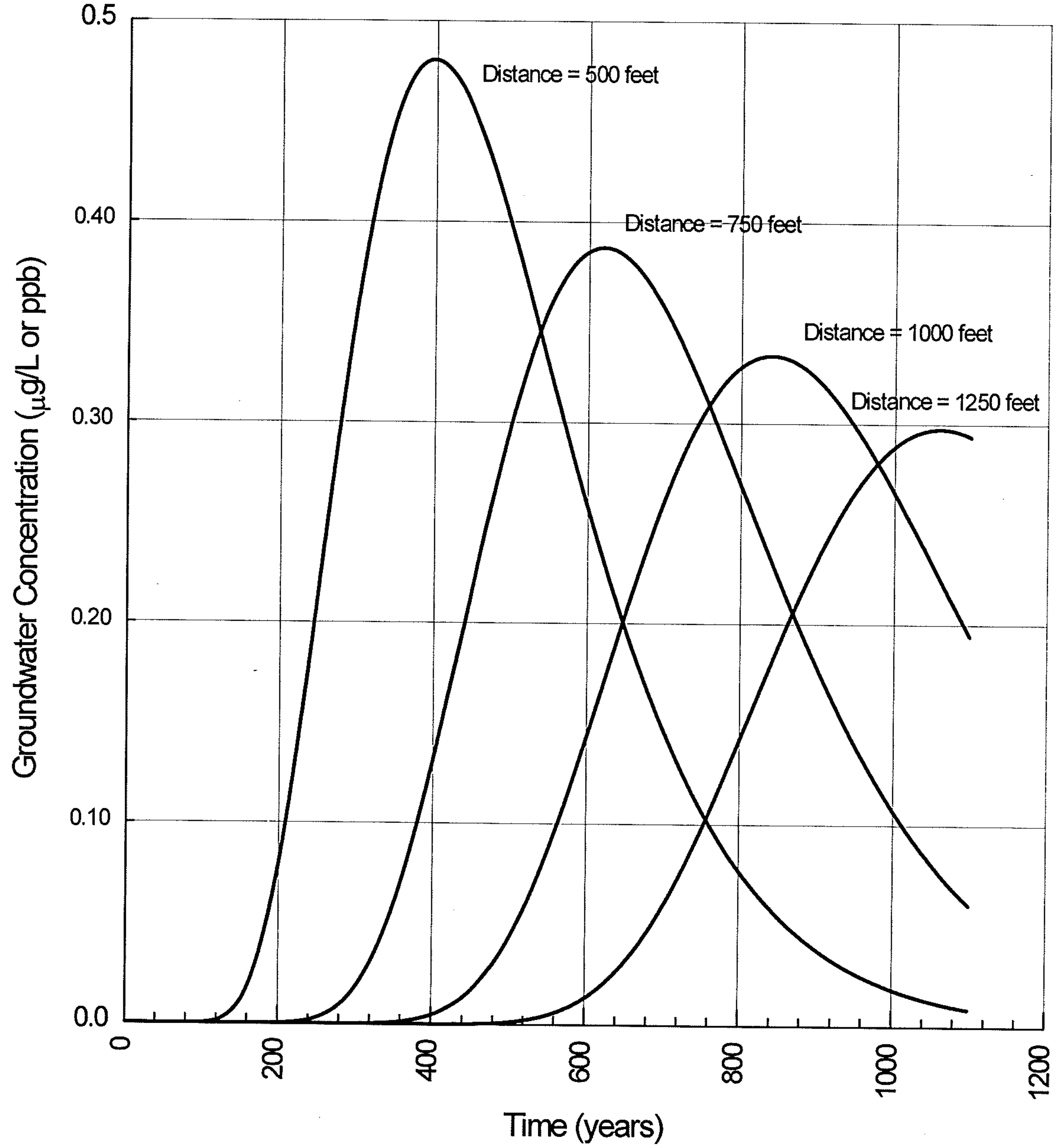
Figure 4-19
CASE 1 - TIDAL CHANNEL MIGRATION
BAY MUD EVALUATION - SFIA

k:\united\sfo\412014\model\at123d\case1\case1a2.grf



NOTE: The curves shown above indicate dissolved levels of contamination at potential receptor locations for various travel times.

The distances shown indicate the distance to potential receptors located directly down gradient of the source area.

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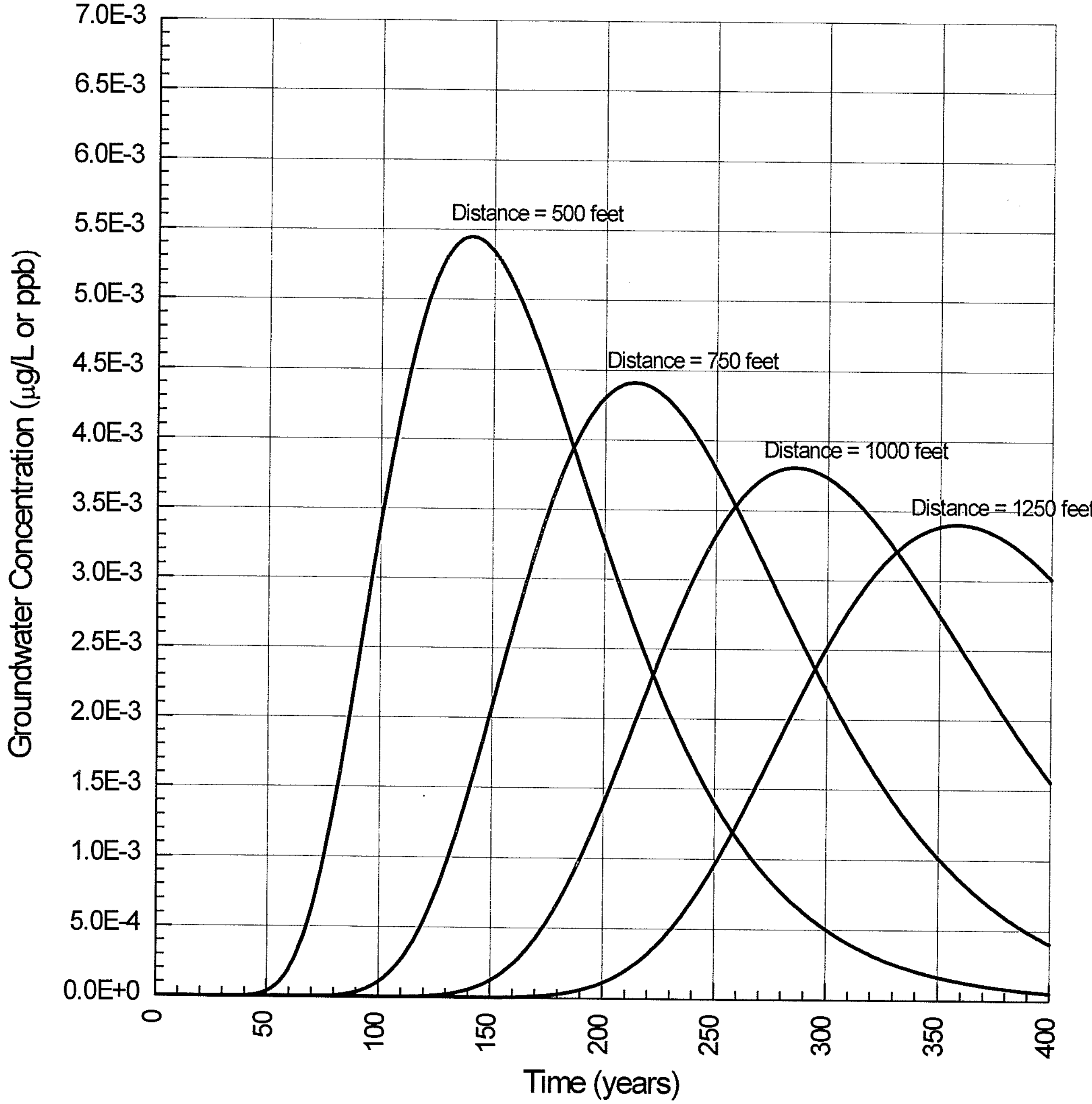
Figure 4-20
CASE 2 - NEWLY EMPLACED PILES MIGRATION
BAY MUD EVALUATION - SFIA

k:\united\sfo\412014\model\at123d\case2\case2a2.grf



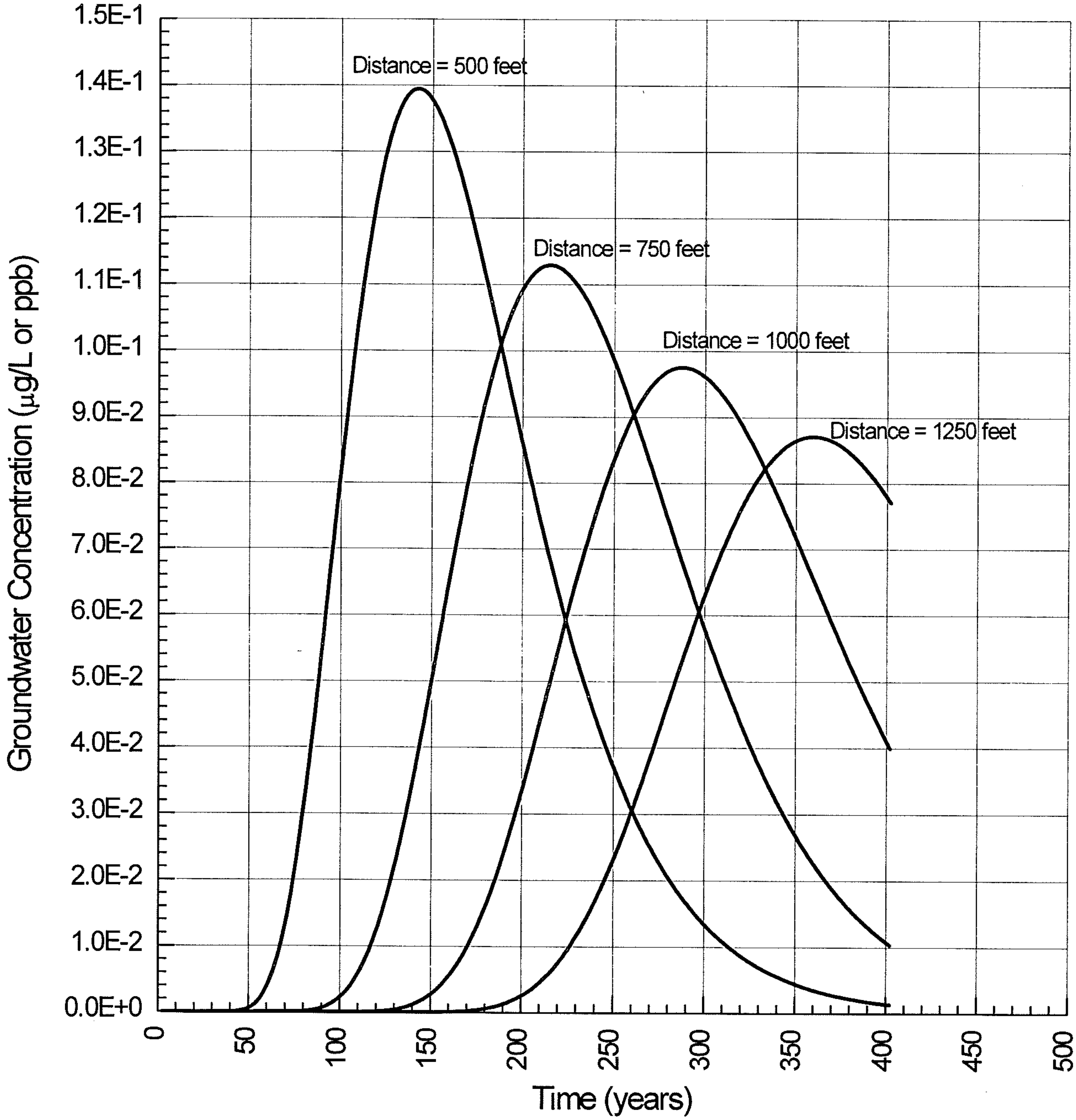
NOTE: The curves shown above indicate dissolved levels of contamination at potential receptor locations for various travel times.

The distances shown indicate the distance to potential receptors located directly down gradient of the source area.

Burns & McDonnell Waste Consultants, Inc.

Figure 4-21
CASE 3 - DEGRADED PILE MIGRATION
BAY MUD EVALUATION - SFIA

k:\united\sfo\412014\model\at123d\case3\case3a.grf



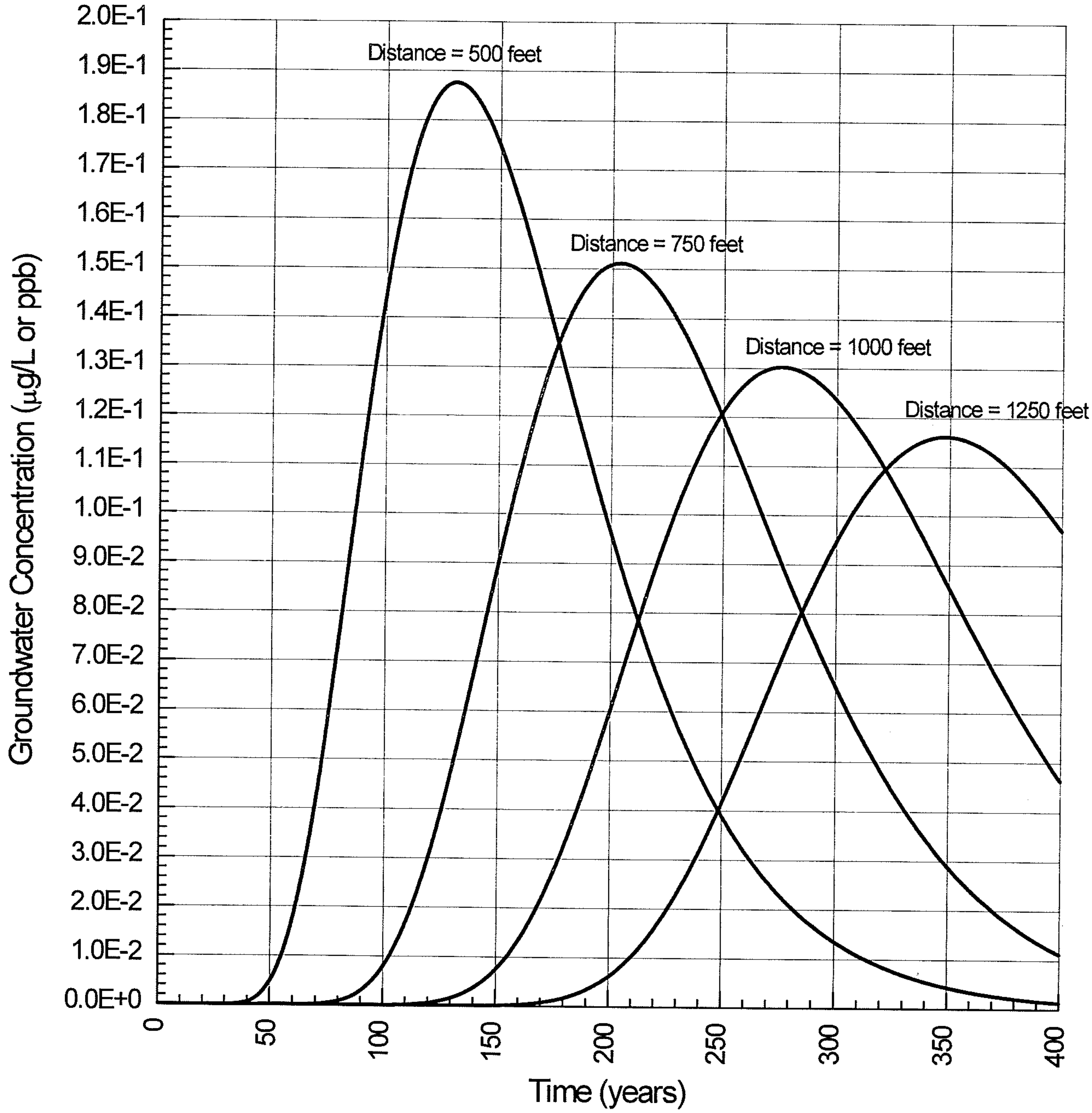
NOTE: The curves shown above indicate dissolved levels of contamination at potential receptor locations for various travel times.

The distances shown indicate the distance to potential receptors located directly down gradient of the source area.

Burns & McDonnell Waste Consultants, Inc.

Figure 4-22
CASE 4 - IMPROPERLY ABANDONED BOREHOLE MIGRATION
BAY MUD EVALUATION - SFIA

k:\united\sfo\412014\model\at123d\case4\case4a.grf

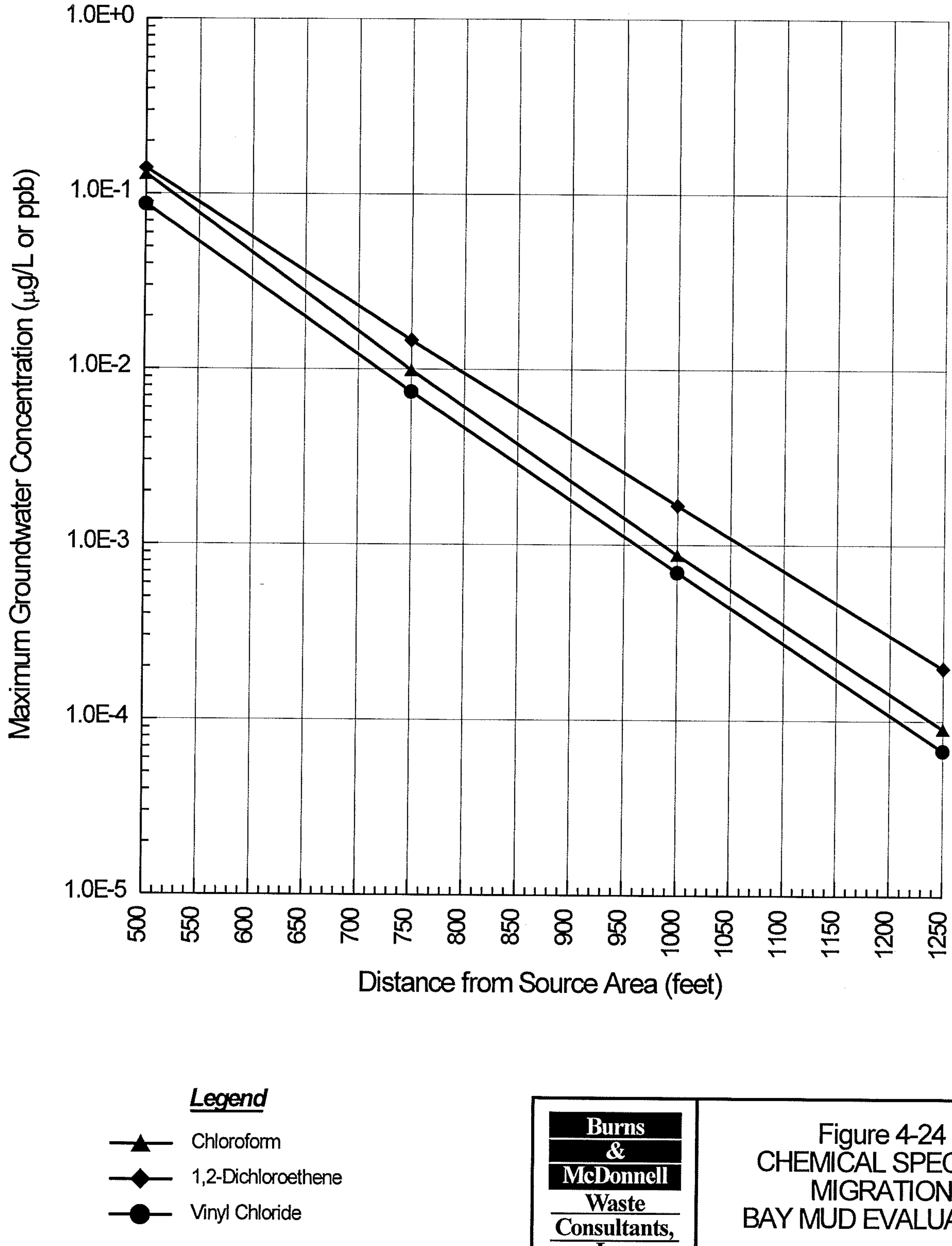


NOTE: The curves shown above indicate dissolved levels of contamination at potential receptor locations for various travel times.

The distances shown indicate the distance to potential receptors located directly down gradient of the source area.

Burns & McDonnell Waste Consultants, Inc.	Figure 4-23 CASE 5 - OPEN EXCAVATION MIGRATION BAY MUD EVALUATION - SFIA

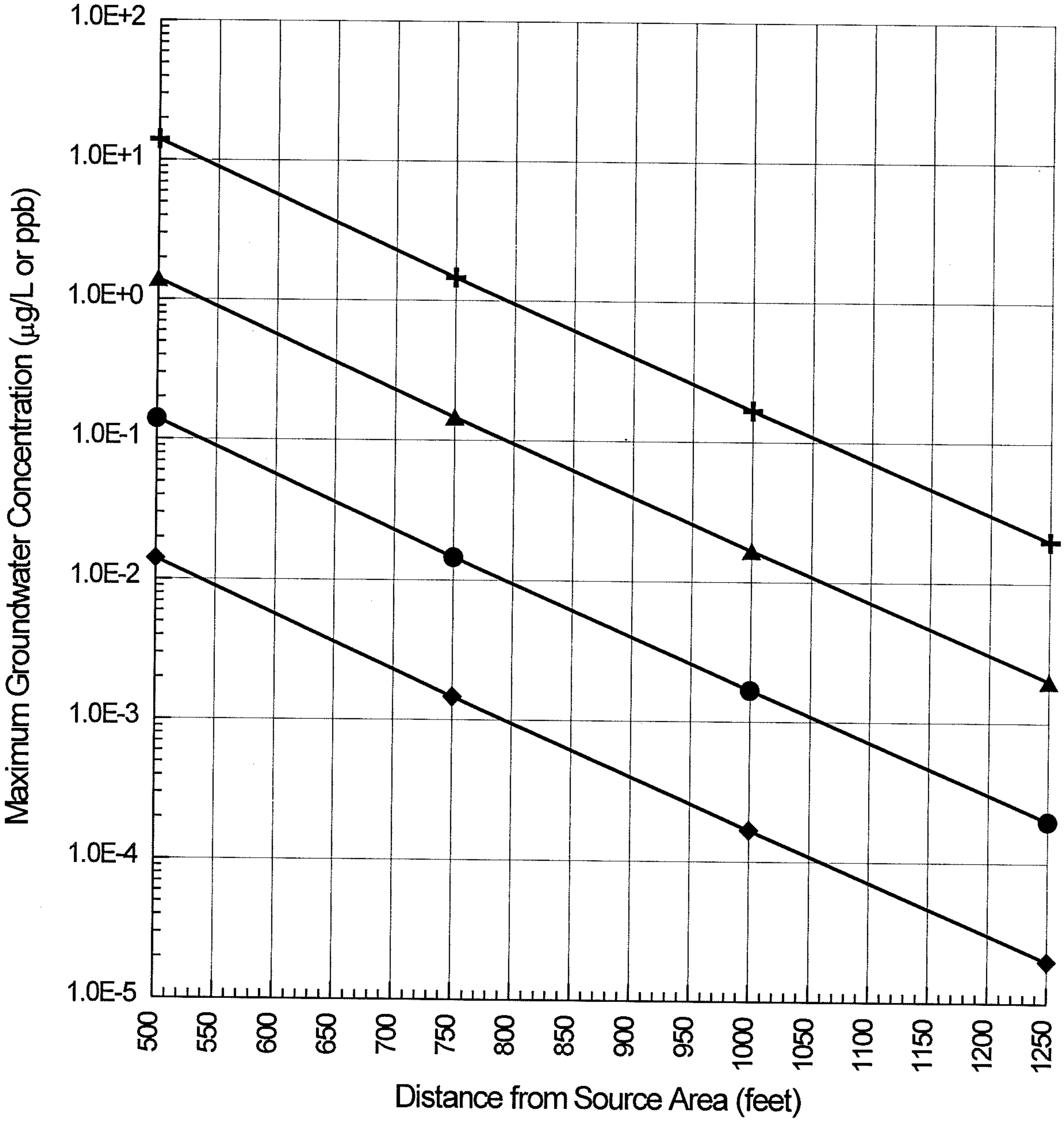
k:\united\sfo\412014\model\at123d\case5\case5a.grf



Burns & McDonnell Waste Consultants, Inc.

Figure 4-24
CHEMICAL SPECIFIC
MIGRATION
BAY MUD EVALUATION

k:\united\sfo\412014\model\at123d\case1\chem\max2.grf



Legend

- + 10,000 µg/L (ppb) Initial Groundwater Concentration
- ▲ 1000 µg/L (ppb) Initial Groundwater Concentration
- ● 100 µg/L (ppb) Initial Groundwater Concentration
- ◆ 10 µg/L (ppb) Initial Groundwater Concentration

Burns & McDonnell Waste Consultants, Inc.

Figure 4-25
CASE 1 - MIGRATION
1,2-DICHLOROETHENE
BAY MUD EVALUATION

k:\united\sfo\412014\model\at123d\case1\12dce\12dcemx2.grf

APPENDIX B
Geotechnical Memorandum

Burns & McDonnell

Memorandum

Date: April 3, 1995

From: Craig Buhr
Ali Abdel-Haq

To: Paul Niebergall

Re: UALRP
San Francisco Airport
94-023-4-120-14

As per our meeting on March 21, 1995, this memo provides a discussion from a geotechnical standpoint, of potential for cross contamination to the underlying strata below the bay mud, as a result of the proposed pile driving at the airport.

Our opinions and conclusion in this regard are based on information obtained from the following sources:

1. A review of geotechnical reports by Trans Pacific Geotechnical Consultant -Dames & Moore (1991, 1992), Rutherford & Chekene (1980), and an environmental report by Burns & McDonnell (1995).

2. Telephone conversations with Mr. David Keefer at the U.S.G.S and Ms. Sena Huse at Santa Clara Water District. The minutes of the telephone conversations are attached herewith.

3. An extensive research in available literature on topics related to driven piles in multi-layered soils, liquefaction due to pile driving, and potential for liquefaction due to future earthquake events. The attached reference list includes some of these references.

BACKGROUND

It is our understanding that the San Francisco Airport has proposed facilities expansion and modifications which consist of at least 10 major construction projects with an anticipation of a extensive pile installation process (4000 driven piles), that will be utilized to support additional proposed developments at the San Francisco International Airport. The immediately proposed additions include an International Terminal Building, Boarding Area G, and Ground Transportation Center, which are addressed at this time in the memo for possible cross contamination as a result of pile installation. Based upon a review of the geotechnical investigation report prepared by Trans Pacific-Dames & Moore, materials encountered at the site consist of fill overlying Young Bay Mud (YBM). Below, interfingered sand and clay layers were encountered. These layers consist of predominantly medium dense to dense clayey to gravelly sand, underlain by Older Bay Mud (OBM). The OBM is typically underlain by interbedded layers of dense sand and stiff clay, down to bedrock. A summary of the generalized soil profile is provided in Table 1.

TABLE 1
GENERALIZE SOIL PROFILE THICKNESS

	INTERNATIONAL TERMINAL	BOARDING AREA G	GROUND TRANSPORTATION CENTER
Fill	7'-20'	7'-10'	9'-13'
YBM	33'-46'	15'-35'	18'-43'
Sand & Clay	4'-19'	20'-35	down to bedrock*
OBM	5'-32'	16'	
Dense sand & stiff clay	20'-33'	2'-60'	

*This layer of dense sand and stiff clay extends to bedrock at over 100 ft depth, except at approximately 60 ft below existing grade where an OBM layer with an average thickness of about 10 ft thick was encountered in the west side of this site.

The upper fill layer consists of predominantly clayey, silty-sand to sandy gravel with occasional sandy, silty-clay. We understand that regions within this upper fill have documented some level of contamination, and it is believed that the YBM currently provides a barrier that prevents downward migration of contaminants.

As a result of proposed pile installation for the facilities which will penetrate the YBM barrier as indicated and recommended in the Dames and Moore geotechnical report, environmental concerns have been expressed for possible cross-contamination. Such concerns have stemmed from concerns that the pile driving may provide an avenue for contamination to pass through to lower more permeable soils or aquifers by, several means including:

1. Contaminated soils either sticking to driven piles or being displaced through the YBM and into the permeable soils.

2. Formation of localized liquefaction induced sand boils resulting from high intensity dynamic vibration during pile driving. These may constitute a "tunnel" or pathway around the pile perimeter through the bay mud which would allow for cross-contamination.

3. Formation of progressive fissuring from prior and successive earthquake events that may be filled with permeable sands. The formation of these fissures over progressive events may permit interconnection through the YBM providing a pathway for cross-contamination. Also the formation of sand boils from lower sandy layers due to liquefaction of the lower formation under earthquake events could produce sufficient pressures to break through the relatively thick bay mud layer.

4. Formation of a zone, thin but of sufficient thickness, between driven piles and the surrounding YBM soils consisting of granular soils from the fill or upper permeable layers that would provide a passage for contaminates to pass through. If available from pile installation, such zones may become a preferred pathway for subsequent boils to form due to liquefaction of underlying materials during a future seismic event.

DISCUSSION

The expressed environmental concerns were evaluated from a geotechnical standpoint, taking into consideration site specific geotechnical conditions, available geological mapping, and case histories available in literature. A detailed discussion of each of the above concerns is provided below.

1. Contaminated Soil Advancing with Pile Driving

The proposed pile type to be driven according to Dames & Moore's report is a precast-prestressed concrete pile.

Two potential regions along the pile could contribute to the possible advancement of contaminated soil from upper predominately granular fill and soils. First, soil may build up under the tip of the pile as a conical wedge during driving. Several references describe this wedge that can develop, (Vesic 1977).

The second mode of advancement would be for soil to adhere to the pile and pull along the side of the pile downward. Based upon literature, there does not appear to be a likelihood for this to occur. Meyerhof (1959) and Robinsky and Morrison (1964) have shown the extent of vertical displacement of soils and densification due to driving below and along the sides of the driven pile.

Robinsky and Morrison utilized carefully conducted model-pile tests in sand in which the displacement and compaction around the piles was studied by means of radiography techniques. They also showed that the process of sand displacement and compaction below the tip is followed by sand movements adjacent to the pile sides. The pattern of vertical displacement by the authors is displayed in Figure 1 which indicates that these vertical displacements in sands are generally limited to 2 X diameter or width of pile tip. Therefore transferring downward sandy soils, typical of the predominate fill and contaminated soils, should not exceed a penetration depth into the bay mud of more than 2 X the pile tip width, well less than the thickness observed for the bay mud.

An end bearing soil wedge typically develops downward as the pile tip is advanced, as shown in Figure 2. Such a wedge is small considering the small cross sectional area of the pile, approximately 0.5 cubic foot in volume for a 14-inch square pile. The driven wedge may gradually be replaced by newly penetrated materials as driving continues and therefore could be spread over penetration depth.

When the pile enters the bay mud interface, it will encounter a predominantly cohesive, soft clay-like material. Clays tend to adhere or stick to the sides of piles over time. During initial driving the clays are exposed to increased pore pressures which reduce their effective strength or adhesion capability. Studies conducted upon piles installed through soft clays over stiff clays have exhibited a very thin zone, less than 1/2-inch thick, that may remain in contact with the pile side (Tomlinson 1970). This zone will develop a similar displacement pattern curling down along the side of the pile as a continuous clay plug. It has been shown by load test studies that the pore pressures dissipate with time and the clay's strength and adhesion to the pile increase (a term referred to as thixotropy). At such time the clay develops a bond to the pile and a restriction to flow characteristics.

2. <u>Formation of Localized Sand Boils Resulting from Pile Driving</u>

When piles are advanced into the ground, the driving energy is released through the pile to the ground. This typically causes a localized increase of pore water pressure in saturated clays or sands. The intensity of released energy has been shown to be higher closer to the pile tip, and should diminish (attenuate) as the distance away from the pile increases. Similarly, excess pore water pressure is expected to be the highest closest to the tip and sides of the pile, and should diminish away from the pile. Therefore, site liquefaction during driving piles has a localized impact zone very close to the pile tip. In sands, the energy quickly dissipates, and the localized zone cannot readily break through the thicker bay mud layer. Furthermore, in sites where interfingered layers of sand and clay are present, pore water tends to dissipate horizontally along sandy layer/lens rather than crossing clayey impermeable soils along a vertical pathway. In such cases, sand boils are less likely to occur.

Sand boils formation due to liquefaction during driving piles does not appear to be a wide spread phenomenon. We reviewed several references that discuss driven pile installation and influence on adjacent properties. Research presented to the 1982 GeoPile Conference (Wood 1982) studied 10 case histories of pile installations in the San Francisco area and their effect upon adjacent structures. Six sites from the 10 studied exhibit soil profiles similar to the San Francisco Airport area. Liquefaction related problems and/or sand boils during pile installations were not observed or reported in these case histories.

An indicator pile installed at the San Francisco International Airport by the joint association of Trans Pacific Geotechnical Consultants, Inc. and Dames & Moore was load tested (Dames & Moore 1992). Several end bearing and/or friction piles (precast concrete similar to those proposed for construction) were driven at the three sites. Again, based upon the document provided from this study by Dames & Moore sand boils or fissures were not observed or noted during or after pile installation.

3. Liquefaction Potential at the Site

Geotechnical data shows that the general vicinity of the airport is susceptible to liquefaction potential and sand boil. However, U.S.G.S data indicates the airport's general area to be within a low to high potential for liquefaction, depending on the local prevailing site specific geotechnical conditions (Youd 1987, Mitchell 1990).

Liquefaction potential at the site was evaluated by the project geotechnical consultant, Dames and Moore & Trans Pacific Geotechnical Consultant, Inc. Based on the obtained geotechnical data, "it is not anticipated liquefaction to occur at the site because the sand layers are predominantly medium dense to dense silty clayey sands," (Dames and Moore 1991).

Since liquefaction potential is considered low for the site, no liquefaction manifestation in the form of sand boils or fissures is expected during future design earthquake events.

4. Gap Formation Between The Pile And Surrounding Soils

The proposed driven piles at the site are designed as end bearing and/or skin friction piles. To mobilize the frictional resistance the pile has to have contact with the surrounding soils. Dynamic monitoring results of the indicator pile test program indicated that "the tested piles achieved capacity estimates that readily exceed design requirements at final penetration," (Dames & Moore 1992).

The driving force generates excess pore water pressure temporarily which tends to dissipate after driving is completed (thixotropy). Dissipation of excess pore water pressure normally leads to tighter grip of soils on the pile sides. Therefore, based on the available geotechnical data including the pile field test results, it appears that separation between the driven pile and the surrounding soils is not likely to occur and if it occurs, it should be random and limited to local areas, and should not be continuous to form a drainage path. Furthermore, no sand boils travelling along the pile-soil interface is expected to develop since the site is considered to have low liquefaction potential.

Attachments: Reference Sheet
Minutes of telephone conversations
Figure 1
Figure 2

REFERENCES

1. Alexander Vesic (1977). Design of Pile Foundations, National Cooperative Highway Research Program, Synthesis of Highway Practice, Transportation Research Board, NCHRP Synthesis 42.

2. Burn & McDonnell (1995). Task 1A-Preliminary Bay Mud Evaluation at The San Francisco International Airport, San Mateo County, California. Project Name: UALRP, Project No.: 94-023-4-120-13. Dated: February 15.

3. Meyerhof, G.G. (1959). "Compaction of Sands and Bearing Capacity of Piles." Journal of Soil Mechanics and Foundation Engineering, ASCE, vol. 85: SMG: 1-29.

4. Mitchell J.K, Masood T., Kayen R.E, and Seed R.B (1990), Soil Conditions and Earthquake Hazard Mitigation at The Marina District of San Francisco. A Report to The Mayor of The City of San Francisco.

5. Robinsky, E.I. & Morrison, C.E. (1964). "Sand Displacement and compaction Around Model Friction Piles." Canadian Geotechnical Journal, vol. 1, no. :81.

6. Rutherford & Chekene Consulting Engineers (1980). Soil Investigation and Foundation Report, Air Cargo Facility for Japan Air Lines, San Francisco International Airport, California. # 7930S. Dated: October 28.

7. Tomlinson M.J, (1971). Some Effects of Pile Driving on Skin Friction, Behavior of Piles, Proceeding of The Conference Organized By The Institution of Civil Engineers in London, 15-17 September 1970.

8. Trans Pacific Geotechnical Consultant, Inc. - Dames & Moore, (1991). Geotechnical Investigation, Final Report. San Francisco International Airport. Dated: June 28.

9. Trans Pacific Geotechnical Consultant, Inc. - Dames & Moore, (1992). Geotechnical Engineering Services, Indicator Pile Program, Master Plan Project, San Francisco International Airport. TPGC Job No.: 1388-001, D&M Job No.:185-224-003.

10. Wood W.C and Theissen J.R, (1982). Variations in Adjacent Structures Due to Pile Driving, 1982 GeoPile Conference, San Francisco, California.

11. Youd L.T and Perkins J.B, (1987). Map Showing Liquefaction Susceptibility of San Mateo County, California. U.S.G.S, Map 1-1257-6.

Telephone Call Memo

Date: March 23, 1995 Time: 1:30 AM / PM

Person: Called/Calling Sena Huse Phone No. (408)927-0710

Representing: Santa Clara Water District Info. Acct. 9161

Project Name: UALRP (United) Project No.: 94-023-4-120-14

Contract Name: Contract No.:

RE: Conference Call with Dave Stous - Craig Buhr - Ali Abdel-Haq "Concerns Regarding Cross-Contamination, S.F.A."

Sena first indicated that she works for Santa Clara Water District and the Airport is under the jurisdiction of San Mateo County, who has the final authority. She is only advising on the matter from experience.

- Sena indicated that deep groundwater is drinking water and is not connected to the marine water. Deep groundwater has no salts.
- She said we need to search and identify Old Water Supply Wells (1900 or earlier) before the airport construction.
- She stated that liquefaction is a potential in the area and fissures from lateral spreading will be filled with sand. - After several earthquakes, different deposits may form.

To help in this matter she recommended reviewing the following resources:

a) U.S.G.S. Publication No. 993 (out of print now) by Leslie Youd & Sena Huse.

b) U.S.G.S. Map "Historic Mapping of San Francisco Bay" U.S.G.S. OFR 71-216.

Note: This map is 7 1/2 min Topo Map showing areas of fill and channel distribution.

- Flood Basin - "Non Marine Deposits". Sena said that a California non-saline bunch grass was growing in the area, with roots up to 27' deep (through clay deposits). The roots could entrap the contaminant. She said we need to carefully look for such roots when we drill on-site.

- Sena said that in her county, they request that all hollow piles be filled with concrete groute placed inside. She said that in case of non-hollow piles, sandboils can erupt around piles during an earthquake. However, but during the 1989 earthquake, she is not aware of any similar observation. If this happens under buildings, we can not see it.

She recommends we contact: Mike Bennett (U.S.G.S.) - (415) 329-4890

Robert Pyke (Tagon Software Engineering - (415)283-6765 (may change to 510)

- We asked Sena if she has observed liquefaction around piles previously? She said she personally observed earthquake effects in Guatemala and Argentina. She said she saw wells collapse "she said that is similar to piles".

- Sena thinks that liquefaction can occur down to 100 feet and she doesn't agree with Professor H. Seed in this area.

- We asked her about other references. She is not aware of any other references of sandboils around piles

- In the U.S.G.S. 993 paper, fissures observed in the Young Bay mud deposits. She said bay mud does not have much tension capability.

Other areas:
- Coyottee Creek
- 237 Freeway out to Bay Margin
- Flood deposits and estuary deposits

We can ask Mike Bennett at the U.S.G.S. (415)329-4890, who has done work on liquefaction in the San Francisco area.

- Sena said that she hasn't seen any reference which talks about liquefaction around piles.

- Cary Sea at Cal Tech did fissure mapping. Not particularly deep fissures observed.

250' long fissure with 3' to 5' connection fissures and

2" - 3" sandboil pipes, 30' - 40' long were noted

- Currently they have 27 Artesian Wells in Santa Clara County.

signed: ______________________ Page 2 of 2

Person Signing

PN/cgw385

Telephone Call Memo

Date: March 24, 1995 Time: 1:00 AM / PM

Person: Called/Calling David Keefer Phone No. (415)329-4893

Representing: U.S.G.S. "Menlo Park, California" Info. Acct. 9161

Project Name: UALRP (United) Project No.: 94-023-4-120-14

Contract Name: Contract No.:

RE: March 8, 1995, Telephone Memo, Sandboils around piles - San Juan Earthquake

David informed us that he'd never been to San Juan - Puerto Rico, but he did some work with Professor Leslie Youd in San Juan - Argentina. Their work in Argentina involved mapping earthquake damage and they studied four case histories of:

1) Lateral spreading of a block that oscillated back and forth
2) Crack that ripped foundations
3) Tower that was tilted and settled
4) Wire storage that tilted

3) and 4) are supported by concrete slab, not on piles.

David, together with Professor Youd published a paper with the findings of his visit to Argentina, in the Journal of Engineering, Geology, Volume 37, 1944, pp 211-233.

When asked if he saw liquefaction around piles, David said he has not seen it, only heard about it, and has not studied it. He also said he thinks it does happen.

David said that he has not done any work around the airport and he is not aware of anybody who has done that, but recommended to contact: "Bay Conservation and Development Commission" as they may have someone who has. The above organization is a government agency.

Signed: ______________________

Person Signing

PN/cgw384

Burns & McDonnell Waste Consultants, Inc.

CANADIAN GEOTECHNICAL JOURNAL

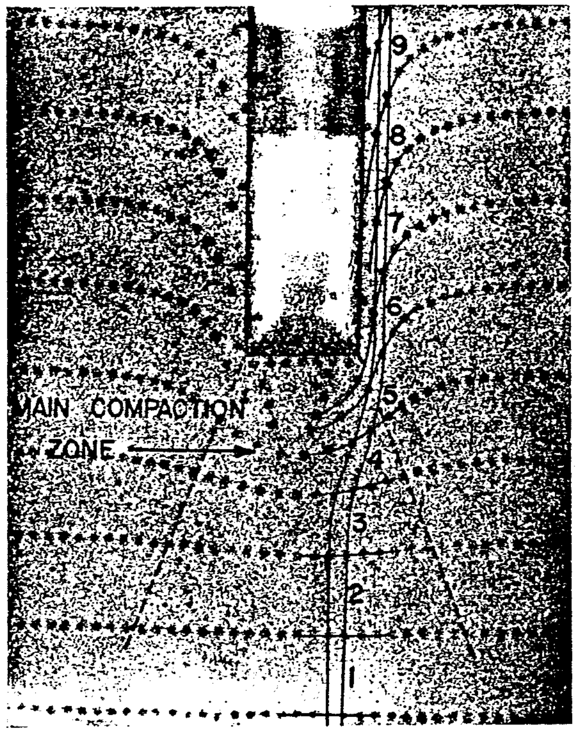


FIGURE 3. Radiograph of typical pile point showing main compaction zone and compaction–expansion sequence during driving

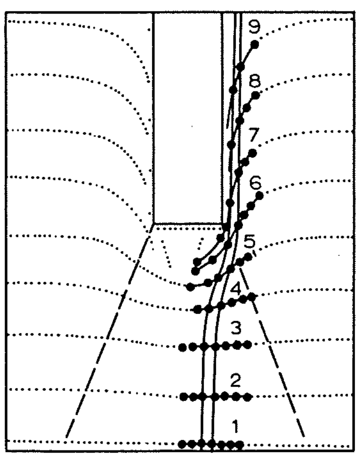


FIGURE 2.8 Displacements around driven pile in sand (after Robinsky and Morrison, 1964). (Reproduced by permission of the National Research Council of Canada from the Canadian Geotechnical Journal, Vol. 1, 1964, p. 81.)

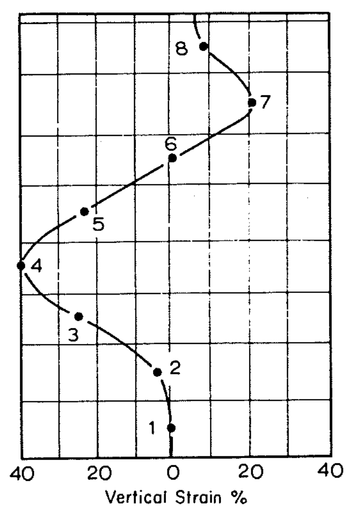


FIGURE 2.9 Strains around driven pile in sand (after Robinsky and Morrison, 1964). (Reproduced by permission of the National Research Council of Canada from the Canadian Geotechnical Journal, Vol. 1, 1964, p. 81.)

Burns & McDonnell Waste Consultants, Inc.

Figure 1

function of angle of shearing resistance (ϕ) and rigidity index (I_{rr}) of the soil can he found in Appendix A, which also contains a tahle of values of the hearing-capacity factors N_σ and N_q*.

A chart of N_σ-values is shown in Figure 10. If a comparison with N_q*-values given in conventional theories is made, it is important to keep in mind that these theories related q_u with vertical ground stress (q_v), which is related to the mean normal ground stress (σ_o) by Eq. 5. It follows from Eqs. 3, 5, and 6 that

$$N_q^* = \tfrac{1}{3}(1 + 2K_o)N_\sigma \qquad (7)$$

Thus, for the total range of K_o hetwcen 0.4 and, for example, 2.5, the "conventional" N_q* should be cnmpared with 0.6 to 2 N_σ. A review of experimental values of N_q* observed in different pile investigations is shown in Figure 11 and summarized in Tahle 3. The availahle evidence suggests that the N_q*-values for driven piles in ordinary quartz sands of alluvial and marine origin do not exceed those for shallow square footings. Thus, a good approximate formula for N_q* expressed in terms of ϕ alone is (*1*):

$$N_q^* = (1 + \tan\phi)e^{\tan\phi}\tan^2(45 + \phi/2) \qquad (8)$$

In applying this expression or chart in Fig. 10 it is essential to consider ϕ-angles corresponding to the stress level at failure in the vicinity of pile point. For medium-to-dense sands, these angles may be substantially lower than ϕ-angles determined from triaxial tests performed at conventional low pressures (*37*).

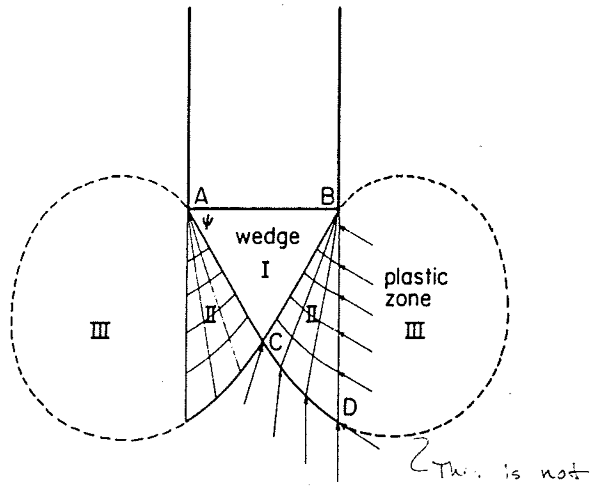


Figure 7. Assumed failure pattern under pile point.

It is also important to note that the N_q*-values for a homogeneous deposit of dense sand decrease quite drastically with depth, as both ϕ and I_{rr} decrease substantially with mean normal stress (*37*). For example, at 80 percent

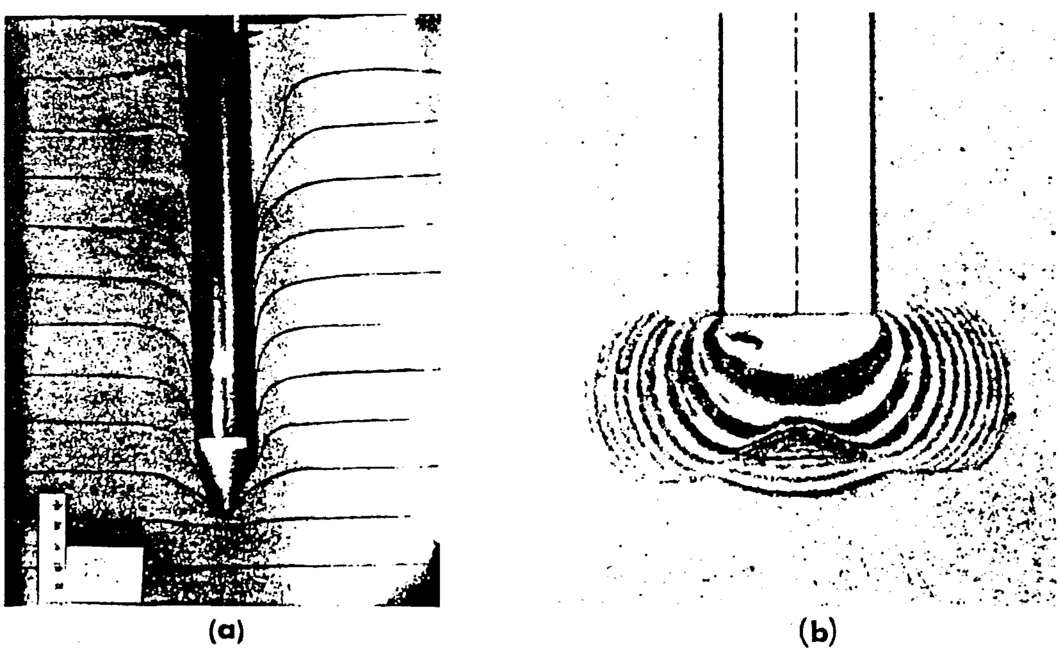


Figure 8. Failure patterns under pile point in dense sand (220, 34).

Burns & McDonnell Waste Consultants, Inc.

Figure 2

APPENDIX A
Boring Logs

(NOTE: This Appendix contains copies of the logs used to construct the geologic profiles shown in Figures 4-3 through 4-8. The logs are presented in order of appearance for each profile.)

GEOLOGIC PROFILE A - A'
(Figure 4-3)

Project: United Airlines **Project Location:** SFO (Plots 4, 5, and 6) **Project Number:** 931053NA	**Log of Boring E-7**

Date(s) Drilled: 3/25/94	Total Depth Drilled (feet): 12.0	Approx. Surface Elevation (feet): 5.57	Groundwater Level (feet): First 10	Completion	24 Hours
Logged by: O. Maurer	Checked by: [signature]	Diameter of Hole (inches): 3.25	Number of Samples	Disturbed: 0	Undisturbed: 1
Drilling Company: Access Soil Drilling		Drilling Method: Solid Stem Auger	Drill Rig Type: Minuteman		
Sampler Type: 2-inch I.D. Modified CA		Drill Bit Size: 3.25-inch	Type of Backfill: Neat Grout (1'-12')		
Comments: Asphalt patch (0-1')					

Depth, feet	Elevation, feet	SAMPLES: Depth bgs (feet)	SAMPLES: Blows	USCS Classification	Graphic Log	MATERIAL DESCRIPTION	HNu (ppm)	REMARKS
0						ASPHALT		Started drilling 0915
						GRAVEL/ROAD BASE		
				SC		CLAYEY SAND Brown (10YR 5/4), fine sand, trace gravel (blue), poorly sorted, low plasticity, slightly moist		
5		(5.5-6)	8 11 15			becomes dark brown (10YR 4/4), well sorted, roots	<1	0920
						becomes wet		
10			7 5 5			∇	<1	
				CL		SILTY CLAY Dark black (2.5Y N/2), stiff		
				CH/OH		BAY MUD Greenish and very dark gray (2.5Y N/3), high plasticity		1000
						TD @ 12 feet		Finished 1010 HNu readings of samples unless otherwise noted
15								
20								

Woodward-Clyde Consultants

Drilling Log

Project Name: UALRP	Project Number: 94-023-4-114-02	Boring Number: MW-37
Ground Elevation:	Location: Plots 4, 5 & 6 Site E, SE corner of Boiler Plant	Page 1 of 1
Air Monitoring Equipment: PID; OVM 580B ; CGI : MSA		Total Footage: 11.5'

Drilling Type	Hole Size	Overburden Footage	Bedrock Footage	No. Of Samples	No. Of Core Boxes
4¼ ID HSA	10"	11.5+	∅	2 to lab, 3 for Geotech.	∅

Drilling Company: Layne-Western	Driller (s): Rick Cooper, Craig Corrien
Drilling Rig: CME 75	Type of Sampler: California splitspoon, shelby tube
Date: 21 November 1994 To 21 November 1994	Field Observer (s): E Underkoffler, V. Farr

Depth (feet)	Description	Class	Blow Count	Recov.	Run/ Time	Sample Desig.	PID (ppm) BZ	PID (ppm) BH	PID (ppm) S	Remarks/ Water Levels
	ASPHALT			3.5"						Cored 11/18/94
	CONCRETE			6.5"						
1	GRAVEL Subbase	GP								
1–3.5	SAND, very fine, poorly graded, trace clay, medium density, damp, mod. yellowish brown (10YR 5/4)		N/A	27/30	1558 / 1600	SS-1	0.0	0.0	0.0 / 0.0	shelby tube MW-37-S-1
3.5–5		SP	6/7/13	15*/18	1612 / 1613	SS-2	0.0	0.0	0.0 / 0.0	*No recovery first splitspoon - tried again. Sample to lab MW-37-S-2
5–7.5			N/A	27/30	1620 / 1622	SS-3	0.0	0.0	0.0 / 0.0	shelby tube MW-37-S-3
7.5–8.5	SAND, very fine, poorly graded, trace clay, loose, moist, dark greenish gray (5GY 4/1)	SP	2/2/2	12/18	1632 / 1632	SS-4	0.0	0.0	0.0 / 0.0	Sample to lab MW-37-S-4
8.5–11.5	BAYMUD - CLAY, some organics, medium plasticity, soft, moist, grayish black (N2) and dark greenish gray (5GY 4/1)	OH	N/A	27/30	1639 / 1640	SS-5	0.0	0.0	0.0 / 0.0	shelby tube MW-37-S-5
11.5										T.D. 11.5' @ 1640 11/21/94
12										
13										
14										

BZ=Breathing Zone BH=Bore Hole S=Sample

GZA STRATIGRAPHIC LOG: B-1

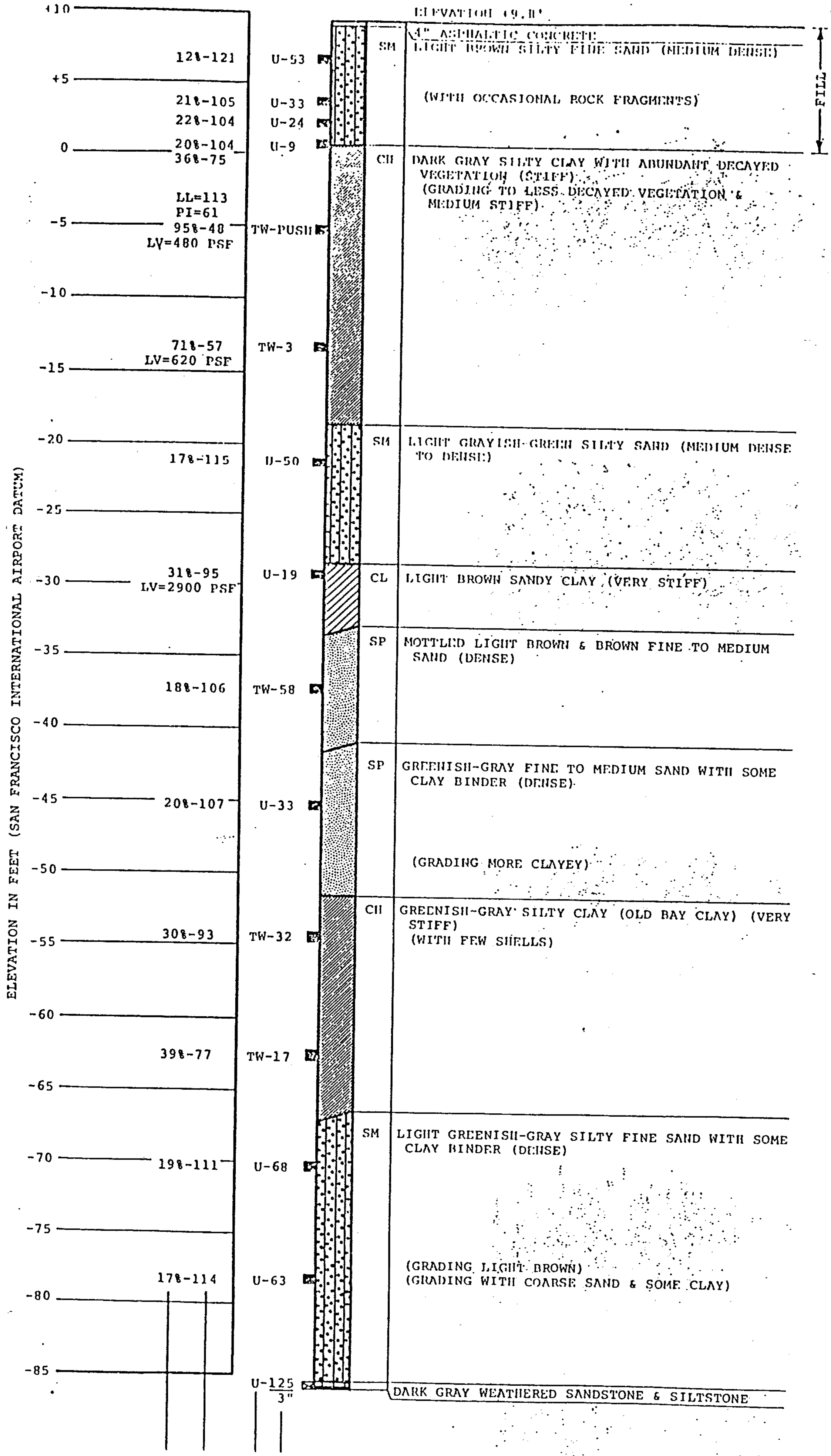
PROJECT LOC San Francisco, California   PROJECT NO 100489.11
START DATE 6 January, 1994   FINISH DATE 6 January, 1994
DRILLING COMPANY Maggiora Bros.   RIG TYPE Mobile B-51
DRILLING METHOD 3.25 inch (ID) Hollow Stem Auger   M.P. ELEVATION
DATUM   GROUNDWATER ELEVATION
FIELD GEOLOGIST A. Scott Grant   REVIEWED BY G. Michael Dennis, R.G.

Depth In Feet	PID	BLOWS/FT	TIME	SAMPLE TYPE	LITHOLOGIC DESCRIPTION	LITHOLOGIC LOG	WELL DIAGRAM
					12" of sandy gravels artificial fill (ABC)		
					CLAYEY SAND (SC): moderate yellowish brown (10YR5/4), moist, medium dense, no odor.		
	<1	29	1600				
5							
					SILTY CLAY (OH): dusky yellow green (5GY5/2), high plasticity, above plastic limit, soft, strong organic odor.		
	38	3	1605				
10							
					Initial groundwater encountered at 11 feet bgs.		
15							
					Boring terminated at 15 feet below ground surface (bgs).		
20							
25							
30							

NOTES:

BORING 1

DRILLED 7/16/75



GEOLOGIC PROFILE B - B'
(Figure 4-4)

Boring ... AAA/VVVVV

FILE NO L449a

LOG OF BORING 21

LP69-21 DIAGRAM 6

Page 21 of 27

JOB San Francisco International Airport DATE DRILLED 12/27/68 INSPECTOR F

CHECK JCP

Split and

G.S. ELEV 8.33 DRILLER J.N. Pitcher Co. RIG 1500 Failing SAMPLER Shelby Tub

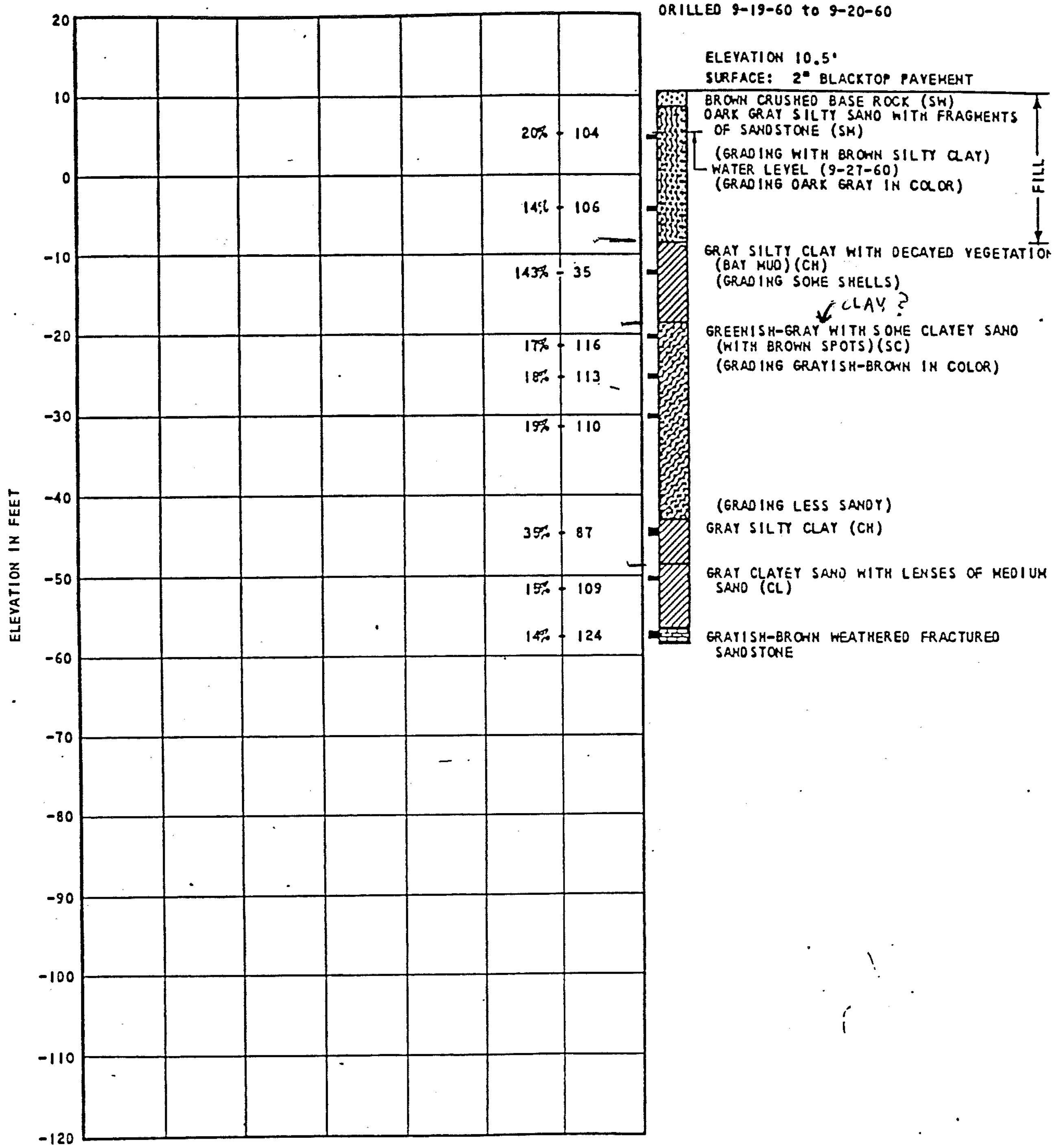
DEPTH FT	ELEV FT	LOG	SAMPLE	BLOWS/FT WT 325# DROP 18" 6"	1'	W. S. ELEV. / ELEV.	DESCRIPTION	DRY UNIT WEIGHT PCF	MOISTURE % DRY WT.	VOID RATIO e
0	+8.3									
	+7.4'			9	36		0'-10", asphalt concrete pavement and base rock	102.4	21.8	.64
	+1.8'			9	8	▼	10"-6½', rust brown silty sand with gravel	122.6	12.4	.37
10				1	1			53.3	79.5	2.11
				0	0		6½'-31', grey silty clays, organic shells, soft to firm	47.4	94.1	2.50
20				3	5½			52.1	83.5	2.22
30	-22.7			17	59		31'- 48', yellow-rust-brown, silty fine sand, cohesive, soft	119.3	14.9	.40
								108.9	21.6	.58
40				20	65		48-55½', Gray-buff silty fine sand, cohesive, soft.			
				15	55			103.9	23.6	.63
	-39.7									
50				8	35			101.4	25.2	.68
	-47.2			4	20		55½'-62½', medium grey sandy silty clay, soft.	92.7	31.5	.84
60	-54.2						62½'-66½', dark grey fractured shale weathered and fractured underlain by black shale, hard.	161	8.0	.04
	-58.2									
70										
80										
90										
100							Bottom of test boring is at 66½ ft. below ground surface at elevation -58.2ft. Water level is at 5 ft. below ground surface.			

Ref: L449A (1969)

Boring DM60-B

BORING B

DRILLED 9-19-60 to 9-20-60



LOG OF BORING

Ref: 185-025-03 (1960)

DAMES & MOORE
SOIL MECHANICS ENGINEERS

Boring LP69-G7

LOG OF BORING G7

FILE NO L449B

DIAGRAM 4-7

JOB San Francisco International Airport DATE DRILLED 2/6/69 INSPECTOR 2

CHECK JCP

G.S. ELEV 10.13' DRILLER J.N. Pitcher Co. RIG 1500 Failing SAMPLER Split and Shelby Tub.

DEPTH FT	ELEV FT	LOG	SAMPLE	BLOWS/FT WT 325# DROP 18" 6"	1'	W.S. ELEV.	DESCRIPTION	DRY UNIT WEIGHT PCF	MOISTURE % DRY WT.	VOID RATIO e
0	±10.1									
				11	30	▽	0-10', Asphalt pavement and base rock, underlain by grey silty sand with rock frags. fill	96.1	26.6	.73
10	+0.1'			4	7			96.0	25.6	.70
							10-30', Grey silty clay, soft, organic			
20				0	3		30-38', Green silty sand with small rock fragments, stiff	49.3	88.8	2.31
30	-19.9			15	53		38'-50', Tan-brown coarse to medium sand w/ rock frags., mottled w/ brown flecks	110.4	19.4	.50
	-27.9									
40				3	21		50-62', Green sand, clean, dense	112.6	18.0	.47
50	-39.9			10	58		62-64', Bedrock, sandstone, well fractured w/ clay seams	105.4	21.0	[illegible]8
60	-51.9									
	-53.9			80				121.6	15.2	.37
70										
80										
90										
100										
110										
120										
130							Bottom of test boring 64' below ground surface at elevation 53'10". Ground water level 7.25' below ground surface			
140										
150										

Ref: L449B (1968)

Boring LP69-G7

LOG OF BORING G7

FILE NO L449B

DIAGRAM 4-7

JOB San Francisco International Airport DATE DRILLED 2/6/69 INSPECTOR

CHECK JCP

G.S. ELEV 10.13' DRILLER J.N. Pitcher Co. RIG 1500 Failing SAMPLER Split and Shelby Tub

DEPTH FT	ELEV FT	LOG	SAMPLE	BLOWS/FT WT 325# DROP 18" 6"	1'	W. S. ELEV.	DESCRIPTION	DRY UNIT WEIGHT PCF	MOISTURE % DRY WT.	VOID RATIO e
0	+10.1						0-10', Asphalt pavement and base rock, underlain by grey silty sand with rock frags, fill			
				11	30	▽		96.1	26.6	.73
10	+0.1'			4	7			96.0	25.6	.70
							10-30', Grey silty clay, soft, organic			
20				0	3		30-38', Green silty sand with small rock fragments, stiff	49.3	88.8	2.31
30	-19.9			15	53		38'-50', Tan-brown coarse to medium sand w/ rock frags., mottled w/ brown flecks	110.4	19.4	.50
	-27.9									
40				3	21		50-62', Green sand, clean, dense	112.6	18.0	.47
50	-39.9			10	58		62-64', Bedrock, sandstone, well fractured w/ clay seams	105.4	21.0	[illegible]8
60	-51.9									
	-53.9			80				121.6	15.2	.37
70										
80										
90										
100										
110										
120										
130							Bottom of test boring 64' below ground surface at elevation 53'10". Ground water level 7.25' below ground surface			
140										
150										

Ref: L449B (1968)

Boring LP69-G8

LOG OF BORING G-8

FILE NO 1449B

DIAGRAM 4-8

JOB San Francisco International Airport — DATE DRILLED 2/5/69 — INSPECTOR JCP — CHECK JCP

G.S. ELEV 9.59' — DRILLER J.N. Pitcher Co. — RIG 1500 Failing — SAMPLER Split and Shelby Tube

BLOWS/FT: WT 325" DROP 18"

Strata

DEPTH FT	DESCRIPTION
0-7'	Asphalt pavement and base rock, underlain by green-grey silty sand w/ rock frags, fill
7-32'	Grey silty clay, soft, organic, UBM
32-56'	Brown-green silty fine sand, firm near 50'.
56-70'	Green silty clay, with brn. organic flecks, stiff
70-76'	Green clayey silty fine sand, w/ rock frags. stiff
76-78½'	Bedrock, tan-brown, sandstone, well fractured

Samples

ELEV FT	BLOWS/FT 6"	BLOWS/FT 1'	DRY UNIT WEIGHT PCF	MOISTURE % DRY WT.	VOID RATIO e
+9.6' (depth 0)					
+2.6'	2	5	91.1	33.0	.81
	0	0	48.4	90.2	2.37
	0	0.	46.8	95.7	2.49
-22.4	14	6"/32	109.6	18.5	.52
	5	19	108.6	20.4	.53
-46.4	11	47	94.5	33.5	.76
	8	25	80.6	41.7	1.05
-60.4					
-66.4	11	36	111.2	19.2	.49
-68.9	5"/1	25	134.3	9.4	.24

W. S. ELEV.: water level marked at approx. 10 ft depth.

Bottom of test boring 78½' below ground surface at elevation-68.9'.. Ground water level at 9.7' below ground surface.

Boring LP69-G9

LOG OF BORING G-9

FILE NO 1449B

DIAGRAM 4-9

JOB San Francisco International Airport DATE DRILLED 2/4/69 INSPECTOR
CHECK JCP

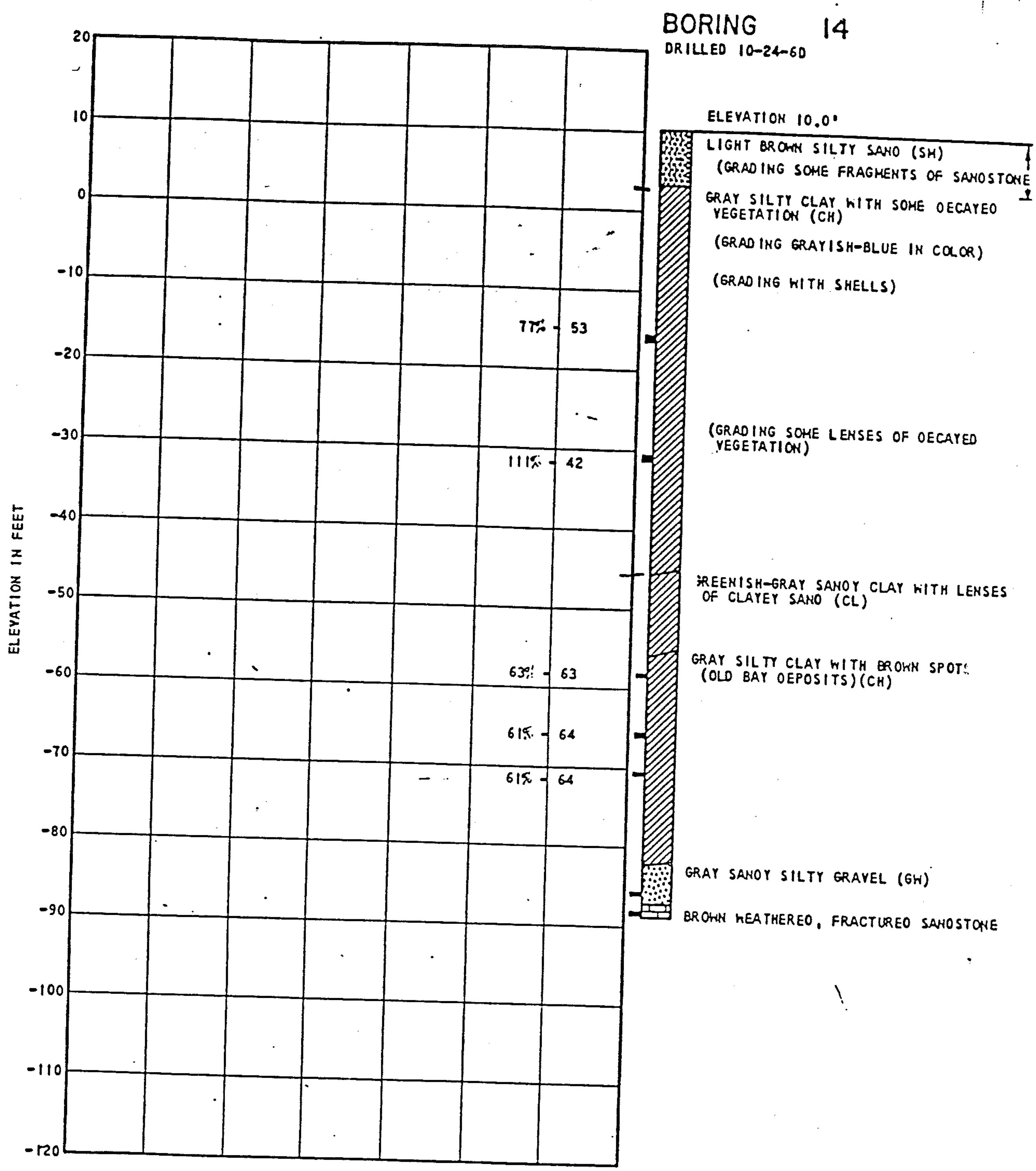
G.S. ELEV 9.25 DRILLER J.N. Pitcher Co. RIG 1500 Failing SAMPLER Split and Shelby Tube

DEPTH FT	ELEV FT	LOG	SAMPLE	BLOWS/FT WT 325# DROP 18" 6"	1'	W. S. ELEV. / ELEV.	DESCRIPTION	DRY UNIT WEIGHT PCF	MOISTURE % DRY WT.	VOID RATIO e
0	+9.3'									
	-.3'			7	22	▽	0-9', Asphalt pavement and base rock. underlain by grey silty sand w/rock frags, fill	108.8	20.1	.53
10				0	2		9'-53½', Grey-black silty clay soft, organic, overlain by a few feet of peat.	52.5	81.8	2.11
20				0	2			48.0	91.2	2.40
30				0	1			51.5	82.2	2.17
40				0	2			54.7	74.1	1.98
50	-42.2			5	14		53½-60', Green slightly silty sand, loose.	88.0	30.4	
60	-50.7			5	23		60-73', Tan silty sand w/ pea gravel, overlain by 3' of green sandy silty clay, w/s gravel	79.9	41.3	1.04
70	-63.7			4	17		73-92', Grey-green silty clay, stiff, plastic	79.4	41.9	1.09
80				3	11			68.2	55.2	1.39
90	-82.7			25	110		92-102', Brown silty sand w/pea gravel, very hard	111.1	19.4	.49
100	-92.7									
	-94.1			4"/100			102-103'4", Bedrock, black shale, well fractured	110.6	22.7	.50
110										
120										
130										
140										
150										

Bottom of test boring 103'4" below ground surface at elevation 94'1". Ground water level is at 6' below the ground surface.

GEOLOGIC PROFILE C - C'
(Figure 4-5)

Boring DM60-14



LOG OF BORING

Ref: 180-025-03 (1960)

DAMES & MOORE
SOIL MECHANICS ENGINEERS

Boring PSC-2

BORING LOCATION, ELEVATION, AND DATE DRILLED
See Site Plan, Plate 1
5/1/89

DRILLING METHOD
Truck Mounted 6 Inch Diameter Rotary Wash, Bentonite Drill Mud

SAMPLING METHOD
Shelby Tube ST, Mod.Cal. MC
320 lb. slip jars, 18" drop

BORING NUMBER 2

SHEET 1 OF _

SAMPLER TYPE	NUMBER OF BLOWS/FT	DRY DENSITY PCF	MOISTURE CONTENT % DRY WT	SAMPLE NUMBER	DEPTH IN FEET	U.S.C.S	DESCRIPTION
					0		6"asphalt over 6"concrete
					1		SUBGRADE
					2		
MC	30	-	10.0	1	3	SC	FILL CLAYEY SAND, yellow-brown, slightly moist, loose
					4		
MC	20	-	18.9	2	5		
					6		
					7	CH	YOUNGER BAY MUD SILTY CLAY, green-gray, wet, very soft, with decayed organics
					8		
MC	5	57	68.8	3	9		
					10		
					11		
					12		
ST	-	48	91.7	4	13		
					14		
					15		
					16		
					17		
					18		
					19		
					20		

LOG OF BORING

PSC ASSOCIATES INC.

Soils Foundation & Geological Engineers

GORDON H. CHONG & ASSOCIATES
CONTINENTAL AIRLINES, BOARDING AREA B,
SAN FRANCISCO INTERNATIONAL AIRPORT, CA

DATE: 5/89 | JOB NO: 89131.10

PLATE 9

PSC-2

BORING NUMBER 2

SHEET 2 OF 3

SAMPLER TYPE	NUMBER OF BLOWS/FT	DRY DENSITY PCF	MOISTURE CONTENT % DRY WT	SAMPLE NUMBER	DEPTH IN FEET	SOIL GRAPH	U.S.C.S	DESCRIPTION
					20		CH	
					21			YOUNGER BAY MUD SILTY CLAY, green-gray, wet, very soft, with decayed organics
					22			
ST	-			5	23			
					24			
					25			
					26			
					27			
					28			
					29			
					30			
MC	2			6	31			
					32			
					33			base bay mud
					34		SC	CLAYEY SAND, yellow-brown
					35			
					36			
					37		SC	CLAYEY SAND, gray-green, medium dense
MC	46			7	38			SAND and GRAVEL, loose
					39		SC	CLAYEY SAND, yellow-brown CLAYEY SAND, yellow-brown
					40			

LOG OF BORING

PSC ASSOCIATES INC.

Soils Foundation & Geological Engineers

GORDON H. CHONG & ASSOCIATES
CONTINENTAL AIRLINES, BOARDING AREA B,
SAN FRANCISCO INTERNATIONAL AIRPORT, CA

DATE: 5/89	JOB NO: 89131.10

Boring PSC-2

BORING NUMBER 2

SHEET 3 OF 3

SAMPLER TYPE	NUMBER OF BLOWS/FT	DRY DENSITY PCF	MOISTURE CONTENT % DRY WT	SAMPLE NUMBER	DEPTH IN FEET	SOIL GRAPH	U.S.C.S	
					40		SC	
					41			
					42			
					43			Boring terminated at 46.5 feet Groundwater level not measured due to drilling mud Casing set from 0' to 7.5'
					44			
					45			
					46			
					47			
					48			
					49			
					50			
					51			
					52			
					53			
					54			
					55			
					56			
					57			
					58			
					59			
					60			

LOG OF BORING

PSC ASSOCIATES INC.

Soils Foundation & Geological Engineers

GORDON H. CHONG & ASSOCIATES
CONTINENTAL AIRLINES, BOARDING AREA B,
SAN FRANCISCO INTERNATIONAL AIRPORT, CA

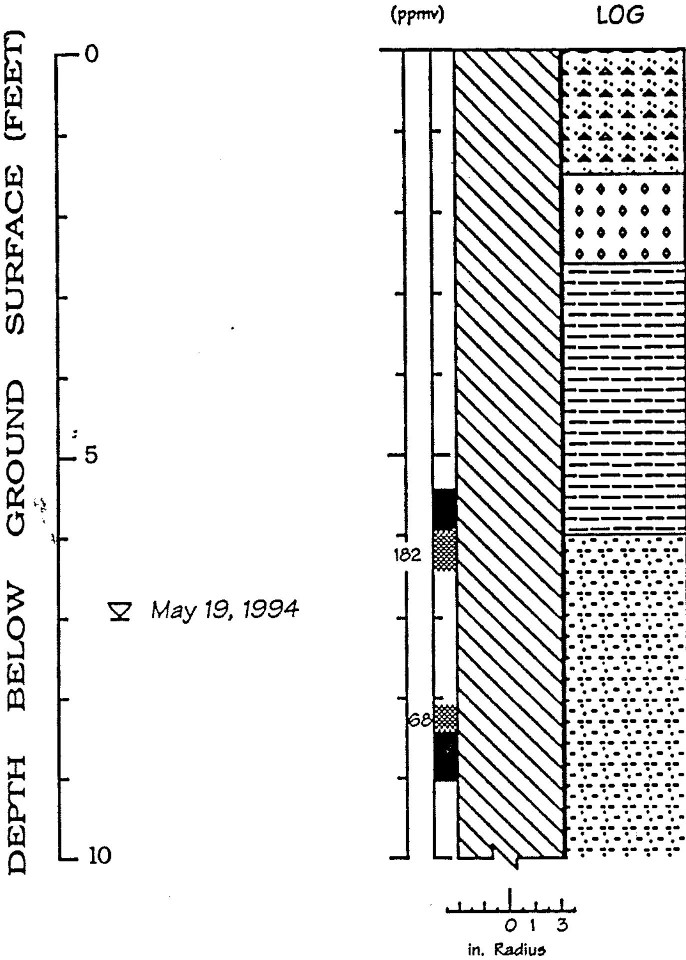
DATE: 5/89

JOB NO: 89131.10

PLATE 11

Versar - Sierra EnviroGroup

BORING B-62



DESCRIPTION

18" Concrete

Well graded GRAVEL with Clay and Sand (GW-GC): dark grayish brown; damp; medium dense; ~30% clay; trace silt; ~20% very fine sand; ~50% subnagular gravel to 1/2" diameter; very low est K

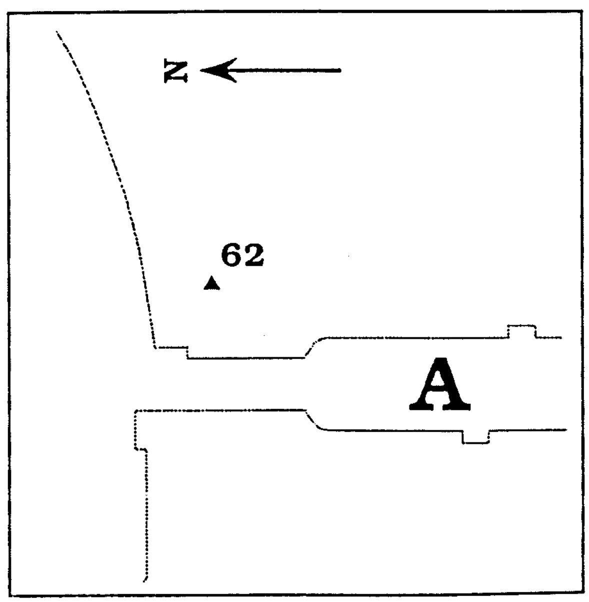
Lean CLAY with Sand (CL): dark gray; damp; stiff; ~50% clay; ~30% silt; ~20% fine to medium sand; very low est K; slight hydrocarbon odor

Sandy SILT (ML): brown mottled gray; wet; stiff; ~20% clay; ~50% silt; ~30% very fine to medium sand; very low est K; slight hydrocarbon odor

Boring Log - Boring B-62

San Francisco International Airport
Boarding Areas A & B, Phase II
San Francisco, California

Logged by: J. Trigg
Supervisor: C. Bramer P.E. #C48846
Drilling Company: Gregg Drilling
C-57#: 485165
Driller: Morris Ruud
Drilling Method: Hollow stem auger
Date Drilled: May 19, 1994
Well Head Completion: Grouted to surface
Type of sampler: Split barrel (2" ID)



BORING B-62

(continued)

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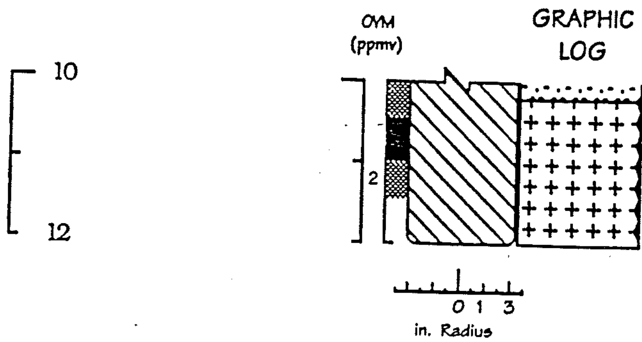
DEPTH BELOW GROUND SURFACE (FEET)



DESCRIPTION

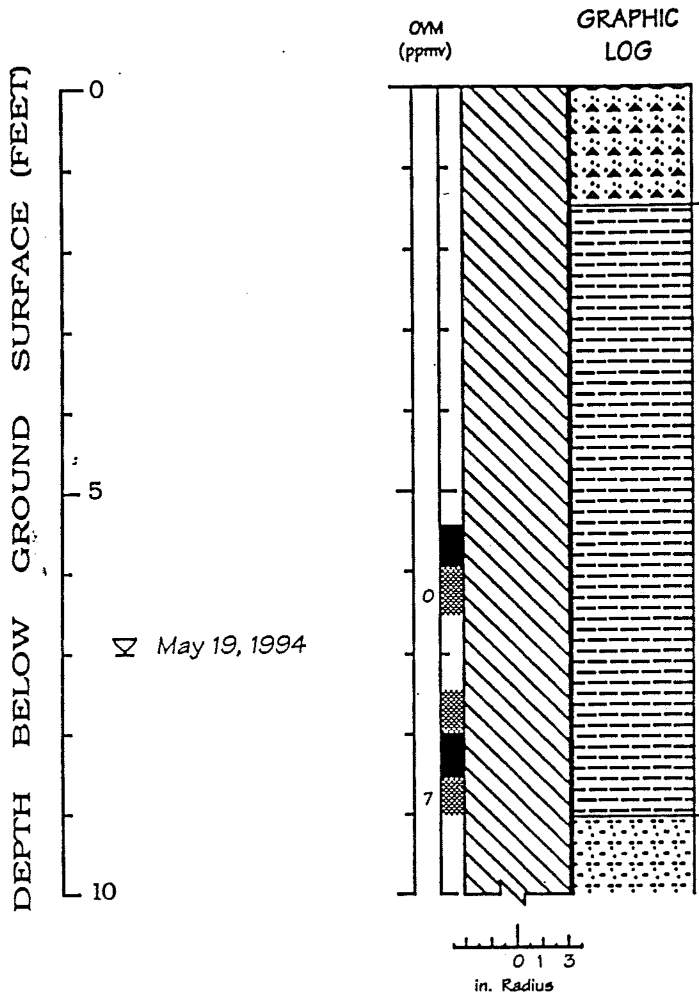
Sandy SILT (ML): *(continued)*

Bay Mud

BOH at 12'

Versar - Sierra EnviroGroup

BORING B-63



DESCRIPTION

18" Concrete

Lean CLAY with Sand (CL): dark gray; damp; stiff; ~50% clay; ~20% silt; ~30% very fine to fine sand; very low est K

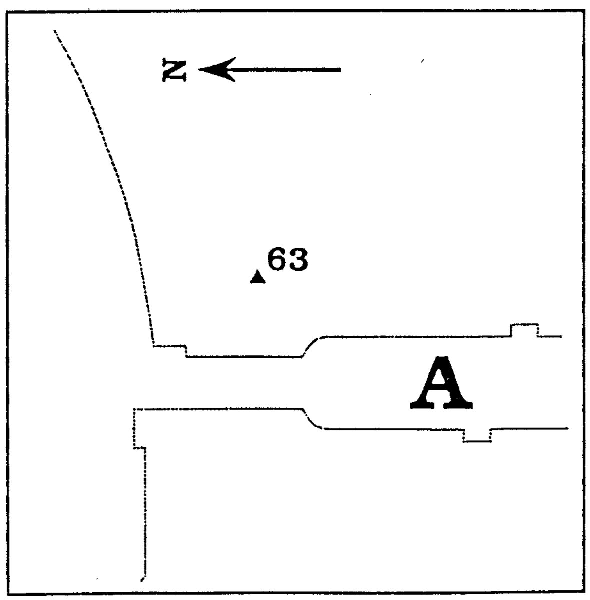
Gray mottled light brown at 6'

Sandy SILT (ML): brown mottled gray; wet; stiff; ~20% clay; ~50% silt; ~30% very fine to medium sand; very low est K

Boring Log - Boring B-63

San Francisco International Airport
Boarding Areas A & B, Phase II
San Francisco, California

Logged by:	J. Trigg
Supervisor:	C. Bramer P.E. #C48846
Drilling Company:	Gregg Drilling
C-57#:	485165
Driller:	Morris Ruud
Drilling Method:	Hollow stem auger
Date Drilled:	May 19, 1994
Well Head Completion:	Grouted to surface
Type of sampler:	Split barrel (2" ID)

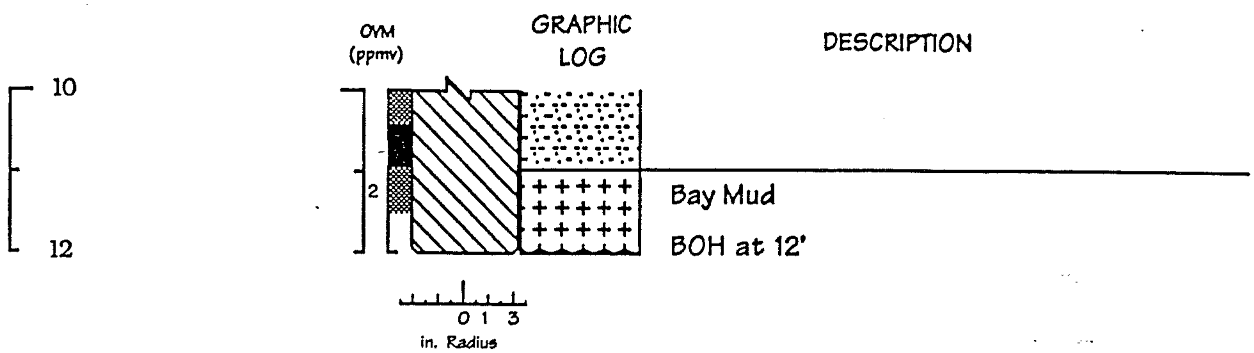


Versar - Sierra EnviroGroup

BORING B-63

(continued)

DEPTH BELOW GROUND SURFACE (FEET)

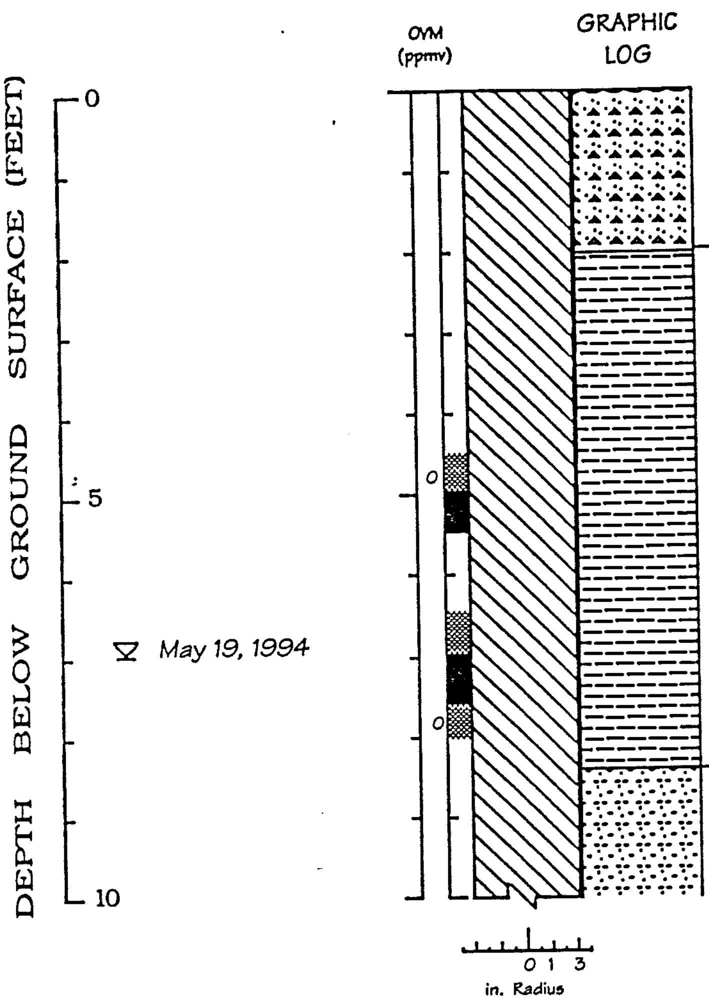


Boring Log – Boring B-63

San Francisco International Airport
Boarding Areas A & B, Phase II
San Francisco, California

Versar - Sierra EnviroGroup

BORING B-64



DESCRIPTION

24" Concrete

Lean CLAY with Sand (CL): grayish brown; damp; stiff; ~60% clay; ~25% silt; ~15% very fine to fine sand; very low est K

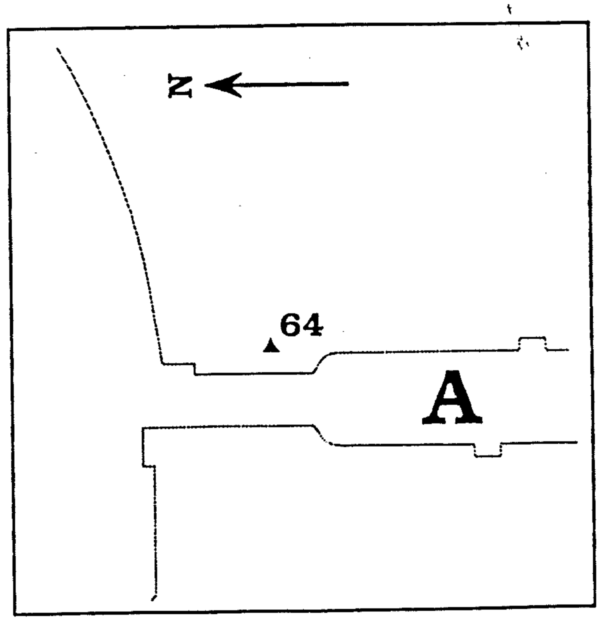
Wet at 7'

Sandy SILT (ML): grayish brown; wet; stiff; ~20% clay; ~60% silt; ~20% fine to medium sand; very low est K

Boring Log - Boring B-64

San Francisco International Airport
Boarding Areas A & B, Phase II
San Francisco, California

Logged by:	J. Trigg
Supervisor:	C. Bramer P.E. #C48846
Drilling Company:	Gregg Drilling
C-57#:	485165
Driller:	Morris Ruud
Drilling Method:	Hollow stem auger
Date Drilled:	May 19, 1994
Well Head Completion:	Grouted to surface
Type of sampler:	Split barrel (2" ID)



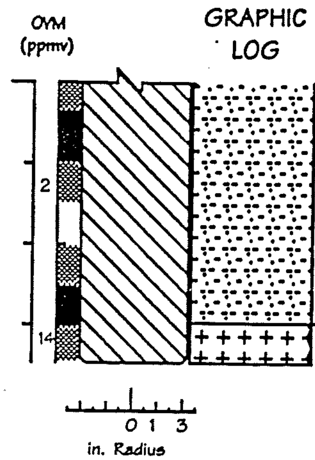
BORING B-64

(continued)

DEPTH BELOW GROUND SURFACE (FEET)

10

13



DESCRIPTION

Sandy SILT (ML): (continued)

Bay Mud
BOH at 13.5'

Boring DM83-1

BORING 1

DATE DRILLED 6-9-83
SURFACE ELEVATION +10.0' *

Depth in feet	Sample No.	Type of strength test	Normal or confining pressure, PSF	Shear strength, PSF	Moisture content, %	Dry density, PCF	Type of sampler	Sampling resistance	U.S.C.S.
0–10	1-1				19.6	96.6	DM	40	
	1-2						ST	42 psi	
	1-3						SPT	24	
	1-4						DM	22	
10–20	1-5				55.0	66.0	DM	5	CH
	1-6				76.0	55.1	ST	150 psi	
	1-7				108.2	41.8	ST	220 psi	
20–30	1-8				110.0	41.0	TW	4	
30–40	1-9						TW	4	
	1-10						TW	3	
40–50	1-11						TW	3	
	1-12						TW	7	SC
50–60	1-13				17.9	114.5	TW	64	
	1-14				20.0	100.5	TW	80/11"	SP
60–70	1-15						TW	77	CH
	1-16				71.7	56.6	TW	18	
70–80	1-17				65.7	60.1	TW	13	
	1-18				56.4	65.5	TW	9	
80–90	1-19				64.7	59.9	DM	7	
	1-20				41.5	78.8	DM	23	
90–100	1-21				17.8	114.0	DM	90/11"	SP
	1-22						DM	100/5"	

LABORATORY TEST DATA — STRENGTH TEST DATA; SAMPLING

DESCRIPTION

- ASPHALT CONCRETE PAVEMENT AND BASE ROCK
- DARK YELLOW-BROWN SILTY SAND/CLAYEY SILT MEDIUM DENSE, FILL
  - WATER LEVEL ELEVATION 4.8' ON 6-7-83
- DARK GRAY SILTY CLAY, SOFT (YOUNGER BAY MUD)
  - NO SAMPLE RECOVERY
- GRAY-GREEN CLAYEY SAND, DENSE
- MOTTLED REDDISH-GREEN GRAVELLY SAND, DENSE
- GREENISH-GRAY SILTY CLAY, STIFF (OLD BAY MUD)
- GRAY-GREEN GRAVELLY COARSE SAND, DENSE TO VERY DENSE
- GRAY-BROWN FRACTURED AND WEATHERED FRANCISCAN SANDSTONE

BORING TERMINATED AT 100 FEET

* Surface Elevation Interpolated From "TOPOGRAPHIC SURVEY SAN FRANCISCO INTERNATIONAL AIRPORT SOUTH TERMINAL" By CITY&COUNTY OF SAN FRANCISCO, DEPT. OF PUBLIC WORKS BUREAU OF ENGINEERING, DATED 6-9-83

LOG OF BORING

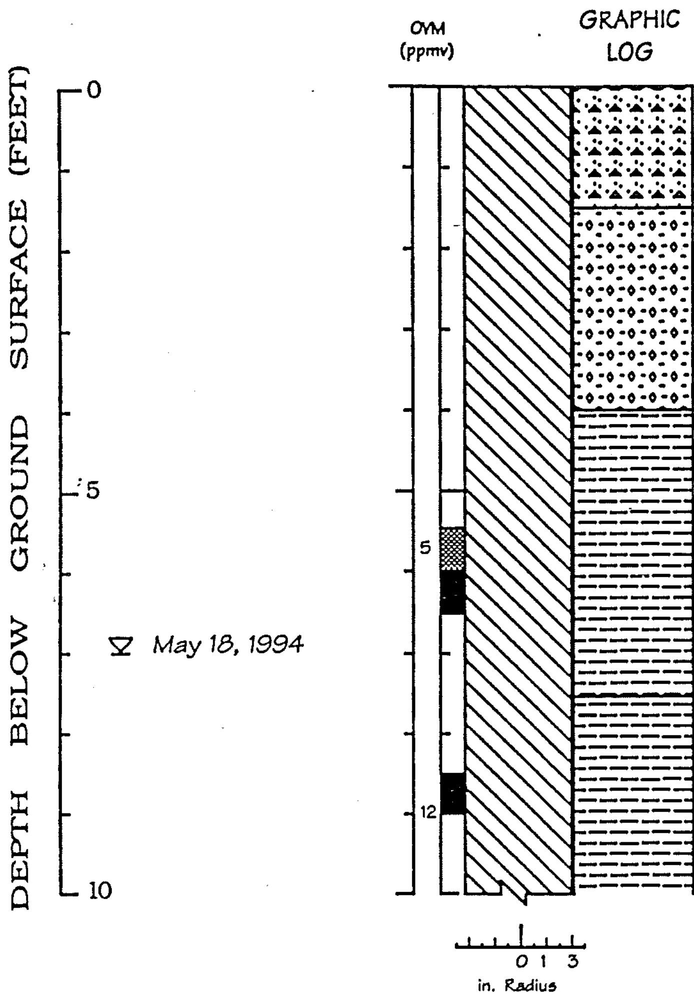
PSC ASSOCIATES, INC. / Dames & Moore

Ref. 185-185-03 (1983)

GEOLOGIC PROFILE D - D'
(Figure 4-6)

Versar - Sierra EnviroGroup

BORING B-44



DESCRIPTION

18" Asphaltic Concrete

Silty GRAVEL with Sand (GM): gray; damp; medium dense; ~10% clay, ~30% silt; ~20% fine sand; 40% subrounded gravel to 1/4" diameter; low est K

Lean Clay (CL): gray; damp; very stiff; ~60% clay; ~20% silt; ~10% fine to medium sand; ~10% subangular gravel to 1/8"; very low est K

Fat CLAY (CH): gray mottled black; wet; stiff; ~70% clay; ~20% silt; ~10% very fine sand; very low est K

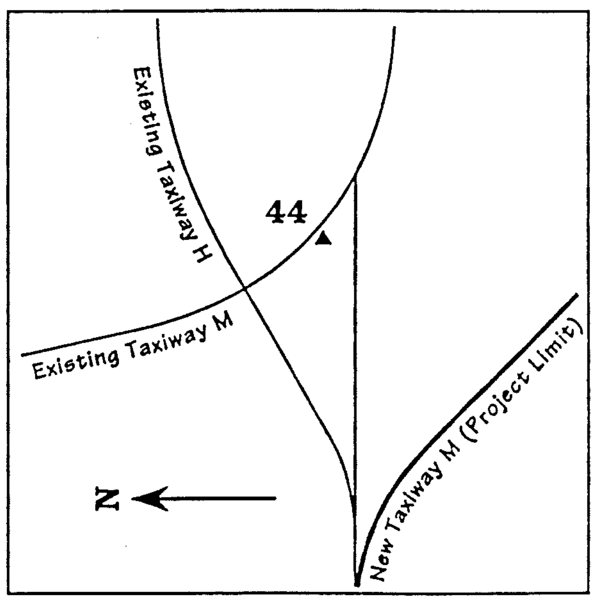
Boring Log - Boring B-44

San Francisco International Airport

Boarding Areas A & B, Phase II

San Francisco, California

Logged by:	J. Trigg
Supervisor:	C. Bramer P.E. #C48846
Drilling Company:	Gregg Drilling
C-57#:	485165
Driller:	Morris Ruud
Drilling Method:	Hollow stem auger
Date Drilled:	May 18, 1994
Well Head Completion:	Grouted to surface
Type of sampler:	Split barrel (2" ID)



MONTGOMERY WATSON
CONSULTING ENGINEERS, INC.
365 LENNON LANE, WALNUT CREEK, CALIFORNIA, 94598 / (510) 975-3400

BORING NUMBER PL1 SB-43
DATE STARTED 9/29/92 COMPLETED 9/29/92
REF. ELEVATION ~7.14 FEET, SURFACE

CLIENT SFIA/ENVIRODYNE
PROJECT SFIA PLOT 1
GEOLOGIST ANNETTE COLE

DEPTH feet	SAMPLE	SAMP. NO.	BLOWS/6 IN	HNU-PID meter units	SOIL CLASS
0		PL1-SB43			CN
1.5–3	☒	2.25	9, 26, 36	1	FL ML / FL SM
3–4.5	☒	4	8, 16, 25	1	
4.5–6	☒	5	7, 13, 19	1	
6–7.5			4, 12, 20	1	
7.5–9	☒	8	5, 7, 9	1	
9–10.5	☒	9.5	3, 5, 5	1	

GEOLOGIC DESCRIPTION

CONCRETE, good condition

FILL clayey sandy SILT (ML), olive-brown 2.5y-(4/4), very stiff, dry, 5% clay, 40% silt, 40% sand, 5% fine to coarse gravel, low est K

as above but becoming silty SAND (SM), 50% silt, 50% sand, faintly thinly laminated, occasional gravel size hard pockets,

FILL slightly clayey silty fine SAND (SM), olive-brown 2.5y (4/4), medium dense, dry, 5% clay, 30% silt, 65% fine sand, locally faintly thinly laminated, occasional off-white shell fragments, mod est K

as above, less silt 25% thinly bedded to laminated, locally more fines and occasional to some pockets of very dark grey to very dark greyish-brown 2.5y (N3-3/2)

as 3.75 to 4.75 feet, more fines, definately thinly laminated to laminated, occasional shell fragments, occasional very dense fine gravel size fragments and organic remains

FILL slightly clayey silty fine SAND (SM), light olive-brown 2.5y (5/6) mottled olive-yellow 2.5y-(6/8) greyish-brown 2.5y (5/2) with pockets of very dark grey 2.5y (N3), 5% clay, 30% silt, dry, mod est K, loose, thinly bedded, becoming very clayey at base

as 5.5 to 8.75 feet, with some shell fragments, low to mod est K, loose, some very hard pockets

Hydro Punch sample collected

DRILLING METHOD/RIG TYPE AUGER/B-53
HOLE DIAMETER 6.25 INCHES
TOTAL DEPTH OF BORING 10.5 FEET
DRILLING CONTRACTOR/DRILLER GREGG DRILLING/STEVE STONE
BIT TYPE HOLLOW STEM AUGER
WELL COMPLETION DEPTH NA

Drilling Log

Project Name	Project Number	Boring Number
UALRP	93-034-4-106-02	B-17

Ground Elevation	Location	Page
7.38	PLOT #1 HYDRANT AREA	1 of 1

Air Monitoring Equipment	Total Footage
OVM (Ser. No: 580A-25316-220)	12

Drilling Type	Hole Size	Overburden Footage	Bedrock Footage	No. Of Samples	No. Of Core Boxes
HSA	6" OD	12	Ø	3	Ø

Drilling Company: Gregg Drilling & Testing	Driller (s): Chris St. Pierre & Doug Woolley
Drilling Rig: Mobile B-53	Type of Sampler: California Split Spoon
Date: 3-15-93 To: 3-15-93	Field Observer (s): Greg Gerike

Depth (feet)	Description	Class	Blow Count	Recov.	Run/ Time	Sample Desig.	PID (ppm) BZ	PID (ppm) BH	PID (ppm) S	Remarks/ Water Levels
0–1.5	Cored Concrete & gravel base			0			0.0			
1.5–3	Silty clayey v. fine sand, dry, dense, poorly graded, hard, dk green gray 5GY4/1	ML/CL	12/22/31	9/18	1147		0.0		0.1, 6.5	
3–4.5	Sand w/silt & clay, hard, dense, greenish gray 5GY6/1, poorly graded, trace peat, damp.	SM/SC	5/7/10	10/18	11:50	SS-1			9.1, 244	
4.5–6	HC odor,		4/5/9	10/18	1155				137.8, 323, 343	
6–7.5	Clr chg to gray-org 10YR 7/4, no HC odor		5/9/8	14/18	1202				319, 64.9, 37.1	
7.5–9	Silty sand, poor grading, moist, dense, hard, dk. yel-org 10YR 6/6.	SM	7/9/10	15/18	1207	SS-2			19.5, 16.7, 21.2	
9–10.5	v. moist, clr chg to gray-green 5GY 6/1, med stiff.		4/5/4	13/18	1212				2.8, 5.0, 7.2	
10.5–12	Silty clayey, v fine sand w/peat, grn-gray 5GY5/1 to blk N2, wet, v. soft, plastic.	ML/CL/PT	1/2/4	14/18	1215	SS-3			2.0, 2.0, 1.3	▽ (~10.8 ft)
12–14	TD = 12' @ 1215									

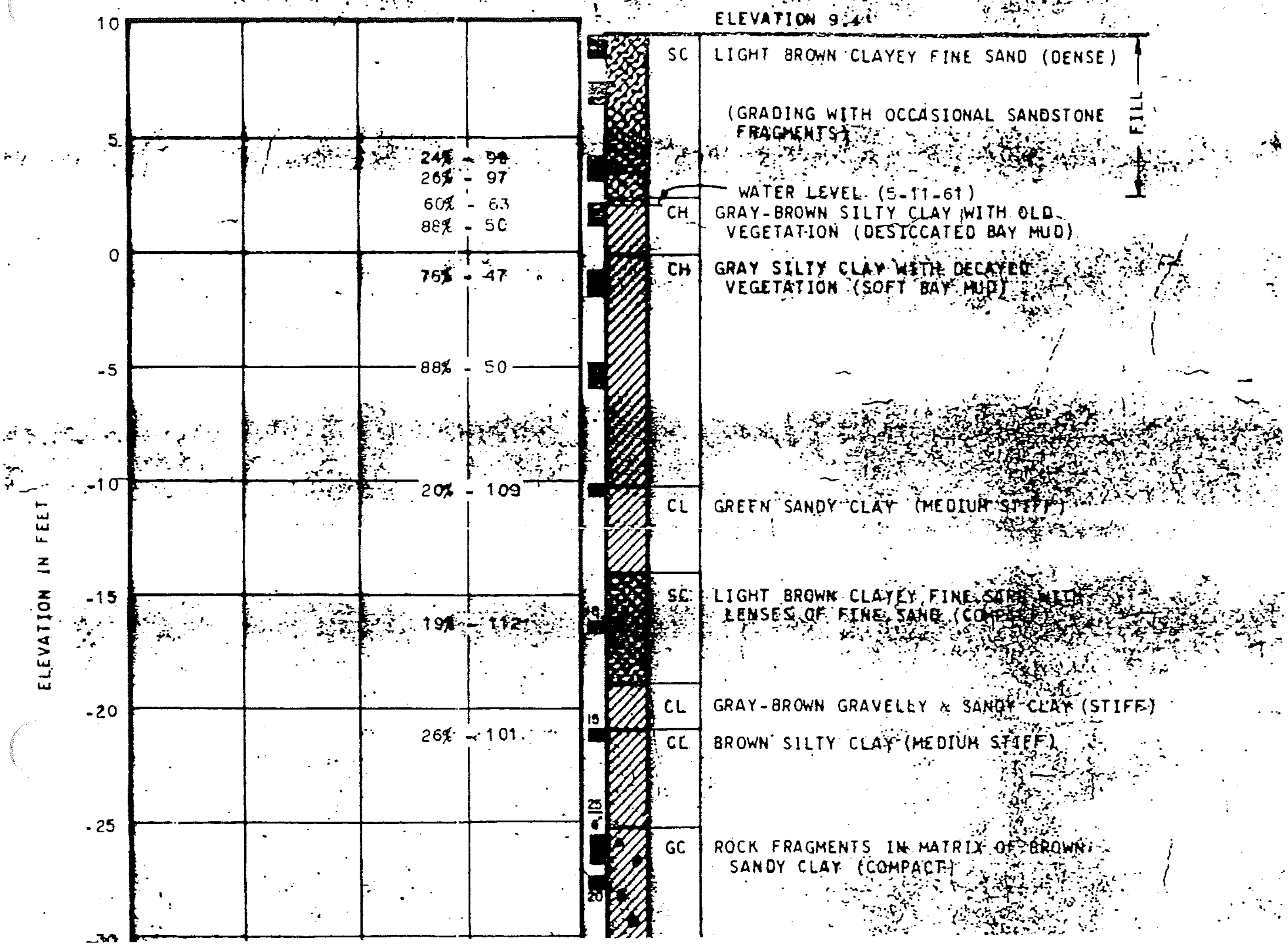
BZ=Breathing Zone BH=Bore Hole S=Sample

Burns & McDonnell Waste Consultants, Inc.

Form WCI-OP2-1

BORING 4

DRILLED 5-5-61, 5-8-61



MONTGOMERY WATSON
CONSULTING ENGINEERS, INC.

365 LENNON LANE, WALNUT CREEK, CALIFORNIA, 94598 / (510) 975-3400

BORING NUMBER PL1 SB-42
DATE STARTED 9/29/92 COMPLETED 9/29/92
REF. ELEVATION 7.32 FEET, SURFACE

CLIENT SFIA/ENVIRODYNE
PROJECT SFIA PLOT 1
GEOLOGIST ANNETTE COLE

DEPTH feet	SAMPLE	SAMP. NO.	BLOWS/6 IN	HNU-PID meter units	GRAPHIC LOG	SOIL CLASS
		PL1-SB42				AS
2	☒	2	12			FL SM
			20			
			30	1		
			13			
4			19			
			25	1		
			9			
	☒	5	10			
6			13	0		FL CL
			3			
	☒	6.5	9			FL SM
			14	1		
			3			
8	☒	8	5			
			5	1		CH
10						
12						
14						
16						
18						

GEOLOGIC DESCRIPTION

ASPHALT over sand and gravel rubble fill

FILL clayey very silty fine SAND (SM), locally a SILT, olive-brown 2.5y (4/3), mottled olive-yellow 2.5y (6/8), medium dense, dry, 5% clay, 35-40% silt, rest fine sand, low to mod est K, pockets of grey N6/N5, thinly laminated locally, occasional assorted fine gravel

as above, locally less silt with occasional to some gravel of fill, subangular to angular, mottled and pockets of very dark grey 2.5y (N3)

as above, loose, dry, very thinly laminated, occasional fine gravel

FILL silty SAND (SM), olive-yellow 2.5y (6/8), loose to medium dense, dry, 30-40% silt, rest sand, mod est K

FILL sandy silty CLAY (CL), light olive-brown 2.5y (5/6), mottled as above, medium dense, dry, 30-40% clay, 50% silt, 10% fine sand, low est K, very thinly laminated with organic remains

FILL silty SAND (SM), light olive-brown 2.5y (5/6) mottled light brownish-grey 2.5y (6/2) and iron staining, loose, dry, 0-10% clay varying, 40-50% silt, 50% fine sand, occasional fine pockets of organic remains

locally clay up to 25%, moist towards base

Bay Mud, silty CLAY (CH), black and dark grey 2.5y (N2/N3), medium stiff, dry to moist, 20% silt, occasional organic remains, low est K

DRILLING METHOD/RIG TYPE AUGER/B-53
HOLE DIAMETER 6.25 INCHES
TOTAL DEPTH OF BORING 9 FEET

DRILLING CONTRACTOR/DRILLER GREGG DRILLING/STEVE STONE
BIT TYPE HOLLOW STEM AUGER
WELL COMPLETION DEPTH NA

GEOLOGIC PROFILE E - E'
(Figure 4-7)

Drilling Log

Project Name	Project Number	Boring Number
JALRP	93-034-4-109-02	B-3

Ground Elevation	~7' MSL
Location	MOC RAMP
Page	1 of 2
Air Monitoring Equipment	OVM 580 B
Total Footage	24.2'

Drilling Type	Hole Size	Overburden Footage	Bedrock Footage	No. Of Samples	No. Of Core Boxes
HSA	6"	24.2'	Ø	7	Ø

Drilling Company	GREGG DRILLING & TESTING
Driller (s)	STEVE STONE, JEFF COOLEY
Drilling Rig	MOBILE B-53 TRUCK MOUNTED
Type of Sampler	CALIF. SPLIT SPOON / SHELBY TUBE
Date	6-17-93 To 6-17-93
Field Observer (s)	J. COLLINS, R. DAVIS

Depth (feet)	Description	Class	Blow Count	Recov.	Run/ Time	Sample Desig.	PID (ppm) BZ	PID (ppm) BH	PID (ppm) S	Remarks/ Water Levels
0–1	ASPHALT; CONCRETE									START 1400 6-17-93 BACKGROUND OVM 0.0 - 2.7
1–2	GRAVEL, TO 3", SOME SAND, SILT, WELL GRADED, VERY DENSE, WET, STAINED DARK REDDISH BROWN (10R 3/4) (CEMENT TREATED BASE)	GW	23/>50	0.3/0.8	1402	SS1	0.0	0.0	0.0	
2	CONCRETE									HIT CONCRETE, CORE DEEPER
3–4	SAND, FINE GRAINED, TRACE COARSE GRAINS, POORLY GRADED, MEDIUM DENSITY, MOIST TO WET, OLIVE GRAY (5Y 4/1)	SP	23/35/7	0.5/1.5	1545	SS2	0.0	5.5	2.7	
4–5	SAND, FINE GRAINED, SOME CLAY, TRACE PEAT, POORLY GRADED, LOOSE DENSITY, MOIST, BLACK (N1) TO OLIVE GRAY (5Y 4/1)	SC	2/2/3	1.0/1.5	1548	SS3	0.0	2.7	2.7, 8.3, 2.7	← GEOT.
5	CLAY, "BAY MUD", TRACE OF PEAT, HIGH PLASTICITY, SOFT, MOIST, OLIVE GRAY (5Y 4/1)	CH								
6–7			1/2/4	1.3/1.5	1555	SS4	0.0	3.4	19, 81, 14	← CHEM; ← GEOT.
7.5–9			2/2/3	1.4/1.5	1600	SS5	0.0	2.7	35, 31, 41	STRONG SEWER ODOR; ← CHEM
9–11				2.3/2.5	1606	ST-1	0.0	0.0	2.7	50 PSI P.P. 0.25 TSF 0.25 TSF 0.25 TSF
11.5–12.5			2/2/3	1.5/1.5	1612	SS6	0.0	0.0	50, 50, 2.7	← GEOT.
13–14				2.5/2.5		ST-2				50 PSI

BZ=Breathing Zone BH=Bore Hole S=Sample

Project Name	UALRP
Project Number	93-034-4-109-02
Boring Number	B-3
Page	2 of 2
Date	6-17-93

Depth (feet)	Description	Class	Blow Count	Recov.	Run/ Time	Sample Desig.	PID (ppm) BZ	PID (ppm) BH	PID (ppm) S	Remarks/ Water Levels
14	CLAY, "BAYMUD", TRACE OF PEAT, HIGH PLASTICITY, SOFT, MOIST, OLIVE GRAY (5Y 4/1)	CH		2.5/2.5	1619	ST-2	0.0	2.7	2.7	PP <0.25TSF <0.25TSF <0.25TSF
15	CLAY, SOME VERY FINE SAND, TRACE PEAT, HIGH PLASTICITY, SOFT, MOIST, OLIVE GRAY (5Y 4/1)	CH	2/3/4	1.3/1.5	1637	SS-7	0.0	0.0	2.7	NOT USING CALIF. LINERS BELOW THIS
16	SAND, VERY FINE TO FINE GRAINED, SOME CLAY, POORLY GRADED, LOOSE DENSITY, MOIST TO WET, OLIVE GRAY (5Y 4/1)	SC								STRONG SEWER ODOR
17			7/13/25	1.4/1.5	1646	SS-8	0.0	2.7	2.7	▽ WET ZONE
18	SAND, VERY FINE GRAINED, TRACE OF SILT, POORLY GRADED, DENSE, MOIST, LIGHT OLIVE GRAY (5Y 5/2)	SP								
	SAND, FINE, LOOSE DENSITY, WET	SP								▽ WET ZONE
19	SAND, VERY FINE GRAINED, POORLY GRADED, DENSE, MOIST, GREENISH GRAY (5GY 6/1)	SP	9/13/20	0.8/1.5	1651	SS-9	0.0	0.0	2.7	
	SAND, FINE GRAINED, TRACE OF SILT, POORLY GRADED, MED. DENSITY, WET, GREENISH GRAY (5GY 6/1)	SP								
20			4/11/20	1.5/1.5	1658	SS-10	0.0	2.7	2.7	
21	SAND, VERY FINE TO FINE GRAINED, POORLY GRADED, MED. DENSITY, MOIST, MOD. YELLOWISH BROWN 10YR5/4	SP								
22			7/17/23	1.5/1.5	1702	SS-11	0.0	2.7	0.0	
23			17/23/25		1706	SS-12	0.0	2.7	2.7	
24	T.D. 24.2'									T.D. 1706 FILL BORE TO 3' BGS WITH "PURE GOLD" BENTONITE CHIPS 175° CONCRETE FROM 3' BGS TO GS
25–28										
29										NOTE: HAD SOME THIN WET ZONES BUT NO FREE WATER LOGGED IN THIS BORING
30–31										

50 PSI (remark at 14 ft)

BZ=Breathing Zone BH=Bore Hole S=Sample

11/11/1992

Burns & McDonnell Waste Consultants, Inc.

Form WCI-GP2-2

Drilling Log

Project Name	Project Number	Boring Number
UALRP	93-034-4-109-02	B-4

Ground Elevation	Location	Page
~ 7' MSL	MOC RAMP	1 of 2

Monitoring Equipment	Total Footage
OVM 580B	25.2'

Drilling Type	Hole Size	Overburden Footage	Bedrock Footage	No. Of Samples	No. Of Core Boxes
HSA	6"	25.2'	Ø	7	Ø

Drilling Company: GREGG DRILLING & TESTING	Driller (s): STEVE STONE, JEFF COOLEY
Drilling Rig: MOBILE B-53 TRUCK MOUNTED	Type of Sampler: CALIF. SPLIT SPOON / SHELBY TUBE
Date: 6-18-93 To 6-18-93	Field Observer (s): T. COLLINS, R. DAVIS

Depth (feet)	Description	Class	Blow Count	Recov.	Run/ Time	Sample Desig.	PID (ppm) BZ	PID (ppm) BH	PID (ppm) S	Remarks/ Water Levels
0	ASPHALT									START 0709 6-18-93 BACKGROUND OVM 0.0 -3.3
1	CONCRETE									
2							0.0	3.3	—	
3	CLAY, SOME VERY FINE SAND, TRACE FINE GRAVEL, HIGH PLASTICITY, STIFF, MOIST, OLIVE GRAY (5Y 4/1) TO BLACK (N1)	CH	12/13/13	1.2/1.5	0710	SS1	0.0	3.3	3.7 / 3.3 / 3.3	STRONG SEWER ODOR
4–5	CLAY, "BAY MUD", TRACE OF PEAT, HIGH PLASTICITY, MEDIUM STIFF, MOIST, OLIVE GRAY 5Y 4/1 TO BLACK (N1)		4/4/7	0.7/1.5	0715	SS2	0.0	3.3	6 / 9.9	
6	CLAY, "BAY MUD", TRACE OF PEAT, HIGH PLASTICITY, SOFT, MOIST TO WET, OLIVE GRAY (5Y 4/1) TO BLACK (N1)	CH	2/2/3	1.1/1.5	0725	SS3	0.0	3.3	6.9 / 6.6	STRONG SEWER ODOR
7–8			3/3/4	1.4/1.5	0728	SS4	0.0	3.3	16 / 97 / 43	←CHEM ←GEOT.
8–9	CLAY, TRACE VERY FINE SAND, HIGH PLASTICITY, VERY SOFT, MOIST TO WET, OLIVE GRAY (5Y 4/1)	CH	2/2/3	1.5/1.5	0734	SS5	0.0	3.3	26 / 113 / 6.6	VERY STRONG SEWER ODOR ←CHEM
10–11	CLAY, SOME VERY FINE SAND, TRACE OF PEAT, HIGH PLASTICITY, MOIST, OLIVE GRAY (5Y 4/1)	CH		2.1/2.5	0738	ST1	0.0	3.3	0.0	50 PSI P.P. < 0.25 TSF <0.25 TSF <0.25 TSF
12–13	CLAY, "BAY MUD", TRACE OF PEAT, HIGH PLASTICITY, MED. STIFF, MOIST, OLIVE (5Y 4/1) TO BLACK (N1)	CH	2/2/3	1.3/1.5	0756	SS6	0.0		169 / 336 / 57	← CHEM
14	CLAY, TRACE OF VERY FINE SAND, HIGH PLASTICITY, SOFT, WET, OLIVE GRAY (5Y 4/1)	CH				SS7				

BZ=Breathing Zone BH=Bore Hole S=Sample

7/11/1992

Burns & McDonnell Waste Consultants, Inc.

Form WCI-OP2-1

Boring Log Continued

Project Name	UALRP	Boring Number	B-4
Project Number	93-034-4-109-02	Page	2 of 2
		Date	6-18-93

Depth (feet)	Description	Class	Blow Count	Recov.	Run/Time	Sample Desig.	PID (ppm) BZ.	PID (ppm) BH	PID (ppm) S	Remarks/Water Levels
14–15	CLAY, TRACE OF VERY FINE SAND, HIGH PLASTICITY, SOFT, WET, OLIVE GRAY (5Y 4/1)	CH	1/3/2	1.4/1.5	0801	SS7	— / — / 0.0	— / — / 3.3	226 / 156 / 33	← GEOT. NOT USING CALIF. LINERS BELOW THIS
15–17				2.4/2.5	0809	ST-2	0.0	6.6	0.0 / 3.3	P.P. 50 PSI <0.25TSF <0.25TSF <0.125TSF
17–20	CLAY, TRACE OF PEAT, HIGH PLASTICITY, SOFT, MOIST TO WET, OLIVE GRAY (5Y 4/1)	CH	2/4/4	1.5/1.5	0817	SS8	0.0	3.3	197	STRONG SEWER ODOR
			3/4/4	1.5/1.5	0823	SS9	0.0	3.3	279	
20–21.5	CLAY, TRACE OF VERY FINE SAND, TRACE OF PEAT, HIGH PLASTICITY, VERY SOFT, MOIST TO WET, OLIVE GRAY (5Y 4/1) TO BLACK (N1)	CH	4/6/6	1.5/1.5	0828	SS10	0.0	3.3	43	
21.5–23	SAND, VERY FINE GRAINED, WITH CLAY, POORLY GRADED, LOOSE DENSITY, MOIST TO WET, SOME COHESIVENESS FROM CLAY, OLIVE GRAY (5Y4/1)	SC	6/9/17	1.5/1.5	0835	SS-11	0.0	3.3	27	
23–24.3	SAND, VERY FINE GRAINED, SOME CLAY, TRACE OF PEAT, POORLY GRADED, MEDIUM DENSITY, MOIST, SOME COHESIVENESS FROM CLAY, GRAYISH GREEN (5G 5/2)	SC								
	SAND VF GRAINED, POORLY GRADED, LOOSE, WET	SP								
–25	SAND, FINE GRAINED, TRACE SILT, POORLY GRADED, DENSE, MOIST, GRAYISH GREEN (5G 5/2)	SP	8/17/32		0840	SS-12	0.0	3.3	30	
25–31	T.D. 25.2									T.D. 0840 6-18-93 0909 FILL BORE TO 3' BGS WITH "PURE GOLD" BENTONITE CHIPS, HYDRATE CHIPS 0926 CONCRETE FROM 3' BGS TO GS. NOTE: HAD SOME WET MATERIAL BUT NO FREE WATER LOGGED IN THIS BORING

BZ=Breathing Zone BH=Bore Hole S=Sample

Burns & McDonnell Waste Consultants, Inc.

1/11/1992 Form WCI-OP2-2

Drilling Log

Project Name	Project Number	Boring Number
UALRP		B-5

Ground Elevation	Location	Page
~7' MSL	MOC RAMP AREA	1 of 2

Air Monitoring Equipment	Total Footage
OVM 580B	25.2'

Drilling Type	Hole Size	Overburden Footage	Bedrock Footage	No. Of Samples	No. Of Core Boxes
HSA	6"	25.2'	∅	7	∅

Drilling Company: GREGG DRILLING & TESTING — Driller (s): STEVE STONE, JEFF COOLEY

Drilling Rig: MOBILE B-53 TRUCK MOUNTED — Type of Sampler: CALIF. SPLIT SPOON / SHELBY TUBE

Date: 6-18-93 To 6-18-93 — Field Observer (s): T. COLLINS, R. DAVIS

Depth (feet)	Description	Class	Blow Count	Recov.	Run/ Time	Sample Desig.	PID (ppm) BZ	PID (ppm) BH	PID (ppm) S	Remarks/ Water Levels
0	ASPHALT									START 1352 6-18-93 BACKGROUND OVM 0.0-3.3
1–2	CONCRETE									▽ WET ZONE
2.5–3.5	CEMENT TREATED BASE		20/40/15	0.4/1.5	1352	SS-1	0.0	0.0	0.0	← PULLED A BASEBALL SIZED PIECE OF GREEN QUARTZITE OUT OF BORE
4–5	NO RECOVERY EXCEPT GRAVEL		5/9/6	0.3/1.5	1403	SS-2	0.0	3.3		
5–6	GRAVEL, SOME SAND, SOME CLAY, WELL GRADED, LOOSE DENSITY, WET OLIVE GRAY (5Y 4/1)	GC	3/4/4	1.3/1.5		SS-3			0.0, 3.3	▽ FR
6–6.5	CLAY, TRACE VERY FINE SAND, HIGH PLASTICITY, SOFT, MOIST TO WET, OLIVE GRAY (5Y 4/1) TO BLACK (N1)	CH			1410		0.0	0.0	0.0	← CHEM
7–8	CLAY, "BAY MUD", TRACE OF PEAT, HIGH PLASTICITY, MEDIUM STIFF, MOIST, OLIVE GRAY (5Y 4/1)	CH	2/4/3	1.4/1.5	1413	SS-4	0.0	3.3	3.3, 3.3, 3.3	← CHEM
8.5–10.5				1.3/2.5	1423	ST-1	0.0	0.0	3.3	P.P. 50 PSI <0.25TSF <0.25TSF <0.25TSF
11–12			2/2/2	1.5/1.5	1430	SS-5	0.0	0.0	3.3, 13, 17	STRONG SEWER ODOR ← CHEM ← GEOT.
12–14	CLAY, "BAY MUD", TRACE OF PEAT, HIGH PLASTICITY, VERY SOFT, MOIST TO WET, OLIVE GRAY (5Y 4/1)	CH		2.5/2.5	1436	ST-2	0.0	3.3	3.3	P.P. 50 PSI <0.25 TSF <0.25 TSF <0.25 TSF

BZ=Breathing Zone BH=Bore Hole S=Sample

Burns & McDonnell Waste Consultants, Inc.

Boring Number	B-5
Project Name	UALRP
Page	2 of 2
Project Number	93-034-4-109-02
Date	6-18-93

Depth (ft)	Description	Class	Blow Count	Recov.	Run/Time	Sample Desig.	PID (ppm) BZ	PID (ppm) BH	PID (ppm) S	Remarks/ Water Levels
14	CLAY, "BAY MUD", TRACE OF PEAT, HIGH PLASTICITY, SOFT, MOIST TO WET OLIVE GRAY (5Y 4/1) TO BLACK (N1)	CH		2.5/2.5	1436	ST-2	0.0	3.3	3.3	
15–16			4/4/5	1.5/1.5	1443	SS-6	0.0	3.3	120	
17			2/4/3	1.5/1.5	1448	SS-7	0.0	0.0	23	
18–19	SAND, VERY FINE GRAINED, SOME CLAY, POORLY GRADED, MEDIUM DENSITY, MOIST, OLIVE GRAY 5Y 4/1 TO LIGHT OLIVE (10Y 5/4)	SC	3/6/15	1.5/1.5	1454	SS-8	0.0	3.3	3.3	
20	SAND, VERY FINE GRAINED, SOME CLAY POORLY GRADED, LOOSE DENSITY, WET, OLIVE GRAY 5Y 4/1	SC	5/16/27	1.5/1.5		SS-9			3.3	
									3.3	
	SAND, FINE GRAINED, SOME CLAY, POORLY GRADED, DENSE, MOIST, LIGHT OLIVE (10Y 5/4)	SC			1500		0.0	3.3	3.3	← GEOT. P.P. 3.25 TSF
21	SAND, FINE, TRACE CLAY, POORLY GRADED, LOOSE DENSITY, WET, OLIVE GRAY 5Y4/1	SP	6/20/33	1.3/1.5	1509	SS-10	0.0	0.0	3.3	
	SAND, FINE GRAINED, SOME SILT, POORLY GRADED, VERY DENSE, MOIST, LIGHT OLIVE (10Y 5/4)	SP								
23	SAND, FINE GRAINED, TRACE OF SILT, POORLY GRADED, VERY DENSE, MOIST, DUSKY YELLOW (5Y 6/4)	SP	16/35/50	1.1/1.5	1513	SS-11	0.0	0.0	0.0	
24–25			20/35/35	1.3/1.5	1523	SS-12	0.0	0.0	3.3	
26	T.D. 25.2'									T.D. 1524; 1530 FILL BORE TO 3' BGS WITH "PURE GOLD" BENTONITE CHIPS
27–31										1603 CONCRETE FROM 3' BGS TO GS

BZ=Breathing Zone BH=Bore Hole S=Sample

11/1992

Barnes & McDonnell Waste Consultants, Inc.

Form WCI-OP2-2

Drilling Log

Project Name	Project Number	Boring Number
UALRP	93-034-4-109-02	B-6

Ground Elevation	Location	Page
~7' MSL	MOC RAMP	1 of 2

Air Monitoring Equipment	Total Footage
OVM 580B	23.7'

Drilling Type	Hole Size	Overburden Footage	Bedrock Footage	No. Of Samples	No. Of Core Boxes
HSA	6"	23.7'	Ø	6	Ø

Drilling Company: GREGG DRILLING & TESTING	Driller (s): STEVE STONE, JEFF COOLEY
Drilling Rig: MOBILE B-53 TRUCK MOUNTED	Type of Sampler: CALIF. SPLIT SPOON / SHELBY TUBE
Date: 6-18-93 To 6-18-93	Field Observer (s): T. COLLINS, R. DAVIS

Depth (feet)	Description	Class	Blow Count	Recov.	Run/ Time	Sample Desig.	PID (ppm) BZ	PID (ppm) BH	PID (ppm) S	Remarks/ Water Levels
0–0.6	ASPHALT									START 1628 6-18-93 BACKGROUND AIR 0.0 - 3.3
0.6–2.3	CONCRETE						0.0	3.3		
2.3–3.5	CEMENT TREATED BASE		18/16/14	0.8/1.5	1628	SS-1	0.0	3.3	0.0, 0.0	
3.5–4.3	CLAY, WITH GRAVEL TO 2", HIGH PLASTICITY, STIFF, MOIST, OLIVE GRAY 5Y4/1	CH								
4.3–5.6	CLAY, "BAY MUD", TRACE OF PEAT, HIGH PLASTICITY, MEDIUM STIFF, MOIST, OLIVE GRAY (5Y4/1) TO BLACK (N1)	CH	9/8/7	1.0/1.5	1634	SS-2	0.0	3.3	0.0, 0.0	
5.6–	CLAY, "BAY MUD", TRACE OF PEAT, HIGH PLASTICITY, SOFT, MOIST TO WET, OLIVE GRAY (5Y4/1) TO BLACK (N1)	CH	3/5/6	1.5/1.5	1641	SS-3	0.0	3.3	3.3, 3.3, 3.3	← CHEM
7–8			2/3/3	1.3/1.5	1645	SS-4	0.0	3.3	0.0, 3.3, 0.0	← CHEM, SEWER ODOR
8.5–9.5			2/2/3	1.5/1.5	1648	SS-5	0.0	0.0	0.0, 0.0, 0.0	
10–12				2.3/2.5	1653	ST-1	0.0	0.0	0.0	P.P 50 < 0.25TSF, 55 < 0.25TSF, < 0.25TSF
12.5–13.5			1/2/2	1.5/1.5	1658	SS-6	0.0	0.0	46, 10, 3.3	← GEOT, STRONG SEWER ODOR; ← GEOT.
14						ST-2				

BZ=Breathing Zone BH=Bore Hole S=Sample

7/11/1992

Burns & McDonnell Waste Consultants, Inc.

Form WCI-OP2-1

Drilling Log Continuation

Boring Number	B-6
Project Name: UALRP	Page 2 of 2
Project Number: 93-034-4-109-02	Date 6-18-93

Depth (feet)	Description	Class	Blow Count	Recov.	Run/ Time	Sample Desig.	PID (ppm) BZ	PID (ppm) BH	PID (ppm) S	Remarks/ Water Levels
14–16	CLAY, "BAY MUD", TRACE OF PEAT, HIGH PLASTICITY, SOFT, MOIST TO WET, OLIVE GRAY (5Y4/1) TO BLACK (N1)	CH	-	2.5/2.5	1704	ST-2	0.0	0.0	10	P.P. 50 PSI; NOT USING CALIF. LINERS BELOW THIS
16–17.5			2/2/3	1.5/1.5	1709	SS-7	0.0	0.0	17	
17.5–19	SAND, VERY FINE GRAINED, SOME CLAY, POORLY GRADED, LOOSE DENSITY, WET, OLIVE GRAY (5Y4/1)	SC	2/4/5	1.5/1.5	1713	SS-8	0.0	3.3	3.3	
19–20.5	SAND, VERY FINE TO FINE GRAINED, TRACE CLAY, POORLY GRADED, DENSE, MOIST, DUSKY YELLOW (5Y 6/4)	SP	6/13/30	1.5/1.5	1719	SS-9	0.0	3.3	0.0	
20.5–22	SAND, FINE GRAINED, TRACE CLAY, POORLY GRADED, VERY DENSE, MOIST, DUSKY YELLOW (5Y 6/4)	SP	6/17/28	1.5/1.5	1723	SS-10	0.0	3.3	3.3	
22–23.5			8/22/35	1.5/1.5	1730	SS-11	0.0	0.0	3.7	
24	T.D. 23.7'									T.D. 1730; 1745 FILL BORING TO 3' BGS WITH "PURE GOLD" BENTONITE CHIPS. HYDRATE CHIPS. CONCRETE FROM 3' BGS TO GS. NOTE: LOGGED WET MATERIALS BUT FREE WATER NOT LOGGED
25–31										

BZ=Breathing Zone BH=Bore Hole S=Sample

Burns & McDonnell Waste Consultants, Inc.

11/11/1992

Form WCI-OP2-2

Drilling Log

Project Name: UALRP	Project Number: 93-034-4-109-02	Boring Number: B-7
Ground Elevation: ~7' MSL	Location: MOC RAMP AREA	Page 1 of 2
Monitoring Equipment: OVM 580B		Total Footage: 25.0'

Drilling Type	Hole Size	Overburden Footage	Bedrock Footage	No. Of Samples	No. Of Core Boxes
HSA	6"	25.0'	Ø	7	Ø

Drilling Company: GREGG DRILLING & TESTING	Driller (s): STEVE STONE, DOUG WOOLEY
Drilling Rig: MOBILE B-53 TRUCK MOUNTED	Type of Sampler: CALIF. SPLIT SPOON / SHELBY TUBE
Date: 6-19-93 To 6-19-93	Field Observer (s): T. COLLINS, R. DAVIS

Depth (feet)	Description	Class	Blow Count	Recov.	Run/ Time	Sample Desig.	PID (ppm) BZ	PID (ppm) BH	PID (ppm) S	Remarks/ Water Levels
0	ASPHALT									START 0724 6-19-93
0–2	CONCRETE									BACKGROUND OVM 0.0 – 3.5
2–3.5	CEMENT TREATED BASE - WET		35/15/10	0.3/1.5	0724	SS1	0.0	0.0	3.5	
3.5–5	GRAVEL, FINE, WITH CLAY, POORLY GRADED, LOOSE DENSITY, WET, OLIVE GRAY (5Y 4/1)	GC	4/4/5	1.2/1.5	0731	SS2	0.0	0.0	0.0 / 3.5	← CHEM
	CLAY, "BAY MUD", TRACE OF PEAT, HIGH PLASTICITY, SOFT, WET, OLIVE GRAY (5Y 4/1) TO BLACK (N1)	CH								
5–6.5			2/1/3	0.3/1.5	0735	SS3	0.0	0.0	0.0	
6.5–8			2/2/2	1.5/1.5	0741	SS4	0.0	3.5	0.0 / 0.0 / 0.0	← CHEM
7.5	CLAY, "BAY MUD", TRACE OF PEAT, HIGH PLASTICITY, MED. STIFF, MOIST TO WET, OLIVE GRAY (5Y 4/1) TO BLACK (N1)	CH								
8–10.5				1.5/2.5	0746	ST-1	0.0	0.0	3.5	50 PSI; P.P. < 0.25 TSF, < 0.25 TSF, < 0.25 TSF
10.5–12			2/2/2	1.5/1.5	0751	SS5	0.0	0.0	7.0 / 7.0 / 3.5	← GEOT. STRONG SEWER ODOR
12–13.5			1/2/2	1.5/1.5	0757	SS6	0.0	3.5	7 / 5.3 / 3.5	← CHEM; ← GEOT
14						ST-2				

BZ=Breathing Zone BH=Bore Hole S=Sample

11/11/1992

Burns & McDonnell Waste Consultants, Inc.

Form WCI-GP2-1

Drilling Log Continuation

Project Name: UALRP	Boring Number: B-7
	Page: 2 of 2
Project Number: 93-034-4-109-02	Date: 6-19-93

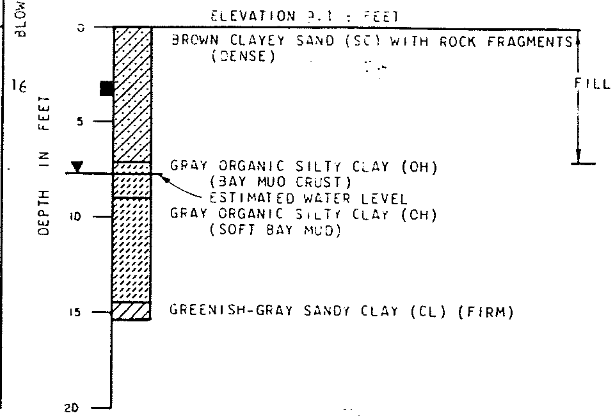
Depth (feet)	Description	Class	Blow Count	Recov.	Run/Time	Sample Desig.	PID (ppm) BZ	PID (ppm) BH	PID (ppm) S	Remarks/ Water Levels
14	CLAY "BAY MUD", TRACE OF PEAT, HIGH PLASTICITY, SOFT TO MEDIUM STIFF, MOIST TO WET, OLIVE GRAY (5Y 4/1) TO BLACK (N1)	CH		2.5/2.5	0802	ST-2	0.0	0.0	0.0	P.P. 50 PSI <0.25 TSF <0.25 TSF <0.25 TSF; CALIF. LINERS NOT USED BELOW THIS
16			2/2/3	1.5/1.5	0829	SS-7	0.0	0.0	56	
17.5			2/4/8	1.5/1.5	0833	SS-8	0.0	3.5	70	
18.7	SAND, VERY FINE GRAINED, WITH CLAY, POORLY GRADED, LOOSE DENSITY, WET, SOME COHESION FROM CLAY, OLIVE GRAY (5Y 4/1)	SC								
19			8/11/17	1.5/1.5	0840	SS-9	0.0	3.5	3.5	
19.8	SAND, VERY FINE TO FINE GRAINED, SOME CLAY, POORLY GRADED, DENSE, MOIST, LIGHT OLIVE GRAY (5Y 5/2)	SP								
20.5			7/10/25	1.3/1.5	0847	SS-10	0.0	3.5	3.5	
21	SAND, VERY FINE TO FINE GRAINED, TRACE COARSE GRAINS, SOME CLAY, POORLY GRADED, DENSE, MOIST, LIGHT OLIVE GRAY (5Y 5/2)	SP								
22	SAND, FINE TO MED. GRAINED, TRACE COARSE GRAINS, TRACE FINE GRAVEL TO 3/8", TRACE SILT, POORLY GRADED, VERY DENSE, MOIST, DUSKY YELLOW (5Y 6/4)	SP	18/37/50	1.4/1.5	0851	SS-11	0.0	0.0	0.0	∇ WET ZONE
23.5			14/23/30		0858	SS-12				
24	SAND, FINE GRAINED, TRACE OF SILT, POORLY GRADED, DENSE, MOIST TO WET NEAR TOP, MOD. YELLOWISH BROWN (10YR 5/4)	SP								
25	T.D. 25.0'									T.D. 0858 FILL BORE TO 3' BGS WITH "PURE GOLD" BENTONITE CHIPS, HYDRATE CHIPS

BZ=Breathing Zone BH=Bore Hole S=Sample

GEOLOGIC PROFILE F-F'
(Figure 4-8)

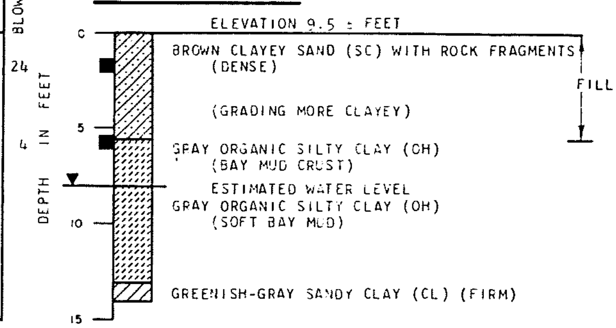
CLASSIFICATION DATA			STRENGTH DATA				MOISTURE-DENSITY DATA		
% FINES (-NO 200)	LIQUID LIMIT	PLASTICITY INDEX	TYPE OF STRENGTH TEST	TEST SURCHARGE PRESSURE, LBS/SQ FT	TEST MOISTURE CONTENT, %	SHEAR STRENGTH, LBS/SQ FT	NATURAL MOISTURE CONTENT, %	DRY DENSITY, LBS/CU FT	BLOWS/FOOT
			DS	1000	NATURAL	2500	12.8	123	16

BORING 12



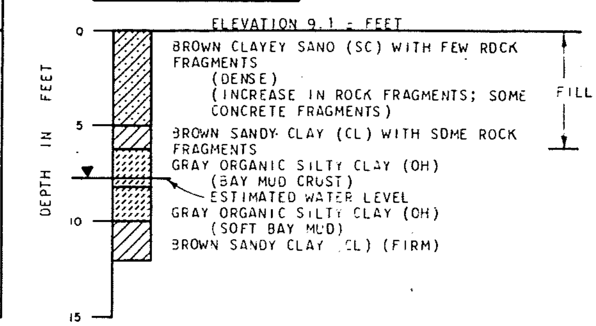
CLASSIFICATION DATA			STRENGTH DATA				MOISTURE-DENSITY DATA		
% FINES (-NO. 200)	LIQUID LIMIT	PLASTICITY INDEX	TYPE OF STRENGTH TEST	TEST SURCHARGE PRESSURE, LBS/SQ FT	TEST MOISTURE CONTENT, %	SHEAR STRENGTH, LBS/SQ FT	NATURAL MOISTURE CONTENT, %	DRY DENSITY, LBS/CU FT	BLOWS/FOOT
28.0	32.1	10.3	DS	1000	NATURAL	2000	18.1	101	24
(TESTED CLAYEY SAND)			DS	600	NATURAL	600	21.1	108	4

BORING 13



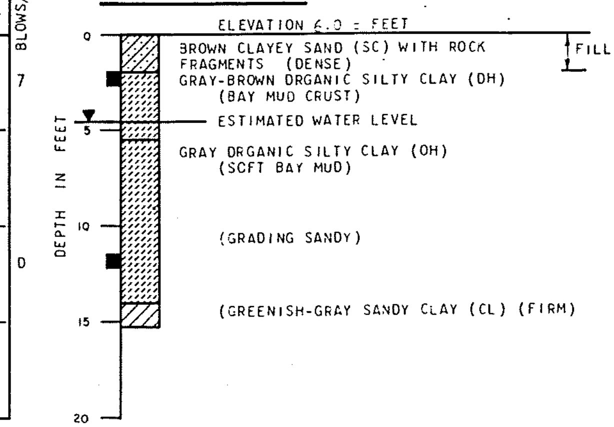
CLASSIFICATION DATA			STRENGTH DATA				MOISTURE-DENSITY DATA	
% FINES (-NO. 200)	LIQUID LIMIT	PLASTICITY INDEX	TYPE OF STRENGTH TEST	TEST SURCHARGE PRESSURE, LBS/SQ FT	TEST MOISTURE CONTENT, %	SHEAR STRENGTH, LBS/SQ FT	NATURAL MOISTURE CONTENT, %	DRY DENSITY, LBS/CU FT

BORING 14



CLASSIFICATION DATA			STRENGTH DATA				MOISTURE-DENSITY DATA		
% FINES (-NO. 200)	LIQUID LIMIT	PLASTICITY INDEX	TYPE OF STRENGTH TEST	TEST SURCHARGE PRESSURE, LBS/SQ FT	TEST MOISTURE CONTENT, %	SHEAR STRENGTH, LBS/SQ FT	NATURAL MOISTURE CONTENT, %	DRY DENSITY, LBS/CU FT	BLOWS/FOOT
							39.0	71	7
							23.8	83	0

BORING 15



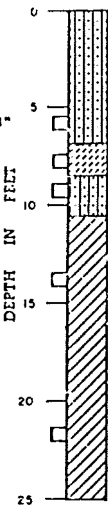
BORING LOGS

COOPER · CLARK & ASSOCIATES
FOUNDATION ENGINEERS & ENGINEERING GEOLOGISTS

CLASSIFICATION DATA			STRENGTH DATA				MOISTURE-DENSITY DATA		
% FINES (-NO. 200)	LIQUID LIMIT	PLASTICITY INDEX	TYPE OF STRENGTH TEST	TEST SURCHARGE PRESSURE, LBS/SQ FT	TEST MOISTURE CONTENT, %	SHEAR STRENGTH, LBS/SQ FT	NATURAL MOISTURE CONTENT, %	DRY DENSITY, LBS/CU FT	BLOWS/FOOT
									20/8"
							54.6	79	2+
			DS	1500	NATURAL	900	13.2	111	1-
			DS	1300	NATURAL	3800	17.7	110	21
							18.7	108	13

BORING 24

ELEVATION 11.0 ± FEET



BROWN SILTY SAND (SM) (DENSE)

(GRADING GRAY)

(SOME ROCK FRAGMENTS AND PIECES OF ASPHALT)

FILL

GRAY ORGANIC SILTY CLAY (OH) (BAY MUD CRUST)

GRAYISH-BROWN SILTY SAND (SM) WITH TRACE OF ORGANIC MATTER (MEDIUM DENSE TO DENSE)

YELLOWISH-BROWN SANDY CLAY (CL) (STIFF)

(GRADING HARD)

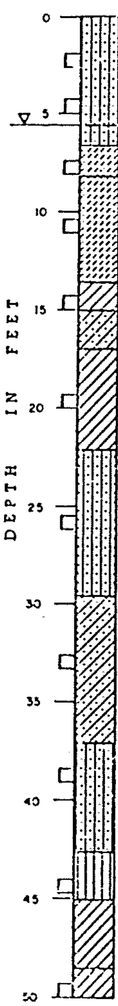
(THIN SANDY LAYER)

(GRADING MORE SANDY)

CLASSIFICATION DATA			STRENGTH DATA				MOISTURE-DENSITY DATA		
% FINES (-NO. 200)	LIQUID LIMIT	PLASTICITY INDEX	TYPE OF STRENGTH TEST	TEST SURCHARGE PRESSURE, LBS/SQ FT	TEST MOISTURE CONTENT, %	SHEAR STRENGTH, LBS/SQ FT	NATURAL MOISTURE CONTENT, %	DRY DENSITY, LBS/CU FT	BLOWS/FOOT
			DS	300	NATURAL	1350	5.1	113	24
			DS	500	NATURAL	1400	19.6	102	17
			DS	1500	NATURAL	2150	19.8	102	
	63.8	27.9	DS	800	NATURAL	700	48.8	67	2
	108.7	68.2	DS	1000	NATURAL	800	77.3	54	1
							18.1	112	6
			DS	1400	NATURAL	1650	20.0	106	9
			DS	1700	NATURAL	1850	20.0	109	30
			DS	3000	NATURAL	2700	17.2	112	
			DS	2000	NATURAL	2000	20.5	109	44
			DS	3500	NATURAL	3500	16.9	113	
			DS	2500	NATURAL	2600	18.7	113	35
							31.6	92	16
							29.1	92	11

BORING 25

ELEVATION 11.0 ± FEET



BROWN SILTY SAND (SM) (DENSE)

(SOME ASPHALT AND CONCRETE FRAGMENTS)

(GRADING GRAY)

FILL

WATER LEVEL 5/23/65

GRAY ORGANIC SILTY CLAY (OH) (BAY MUD CRUST)

GRAY ORGANIC SILTY CLAY (OH) (MODERATELY SOFT BAY MUD)

(GRADING SOFT)

GREENISH-GRAY SANDY CLAY (CL) (STIFF)

BROWN CLAYEY SAND (SC) (DENSE)

BROWN SANDY CLAY (CL) (STIFF)

BROWN SILTY SAND (SM) WITH SOME GRAVEL (DENSE)

BROWN CLAYEY SAND (SC) (DENSE)

(GRADING GRAY)

(THIN CLAYEY LENS)

GRAYISH-BROWN SILTY COARSE SAND (SM) (DENSE)

GRAY SANDY SILT (ML) (DENSE)

GRAY SANDY CLAY (CL) (STIFF)

GREENISH-GRAY SILTY CLAY (CL) (STIFF)

BORING LOGS

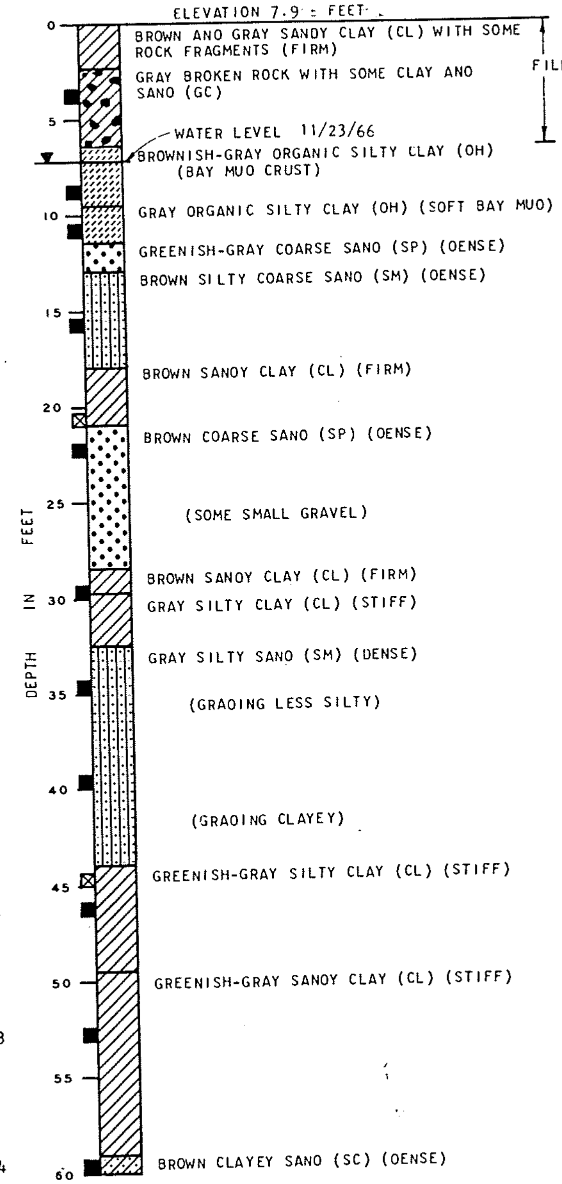
COOPER-CLARK & ASSOCIATES

FOUNDATION ENGINEERS & ENGINEERING GEOLOGISTS

CLASSIFICATION DATA			STRENGTH DATA				MOISTURE-DENSITY DATA		
% FINES (-NO. 200)	LIQUID LIMIT	PLASTICITY INDEX	TYPE OF STRENGTH TEST	TEST SURCHARGE PRESSURE, LBS/SQ FT	TEST MOISTURE CONTENT %	SHEAR STRENGTH, LBS/SQ FT	NATURAL MOISTURE CONTENT, %	DRY DENSITY, LBS/CU FT	BLOWS/FOOT
			TR TR	1500 3900	NATURAL NATURAL	600 1200	7.9	112	25
	83.3	50.6	DS	1000	NATURAL	560	93.8	44	2
	88.4	52.1	DS	1050	NATURAL	370	81.9	52	0
			TR TR	1750 4250	NATURAL NATURAL	950 1700	21.3	120	19
									36
			DS	1800	NATURAL	1500	24.0	100	35
	62.3	33.3	DS	2200	NATURAL	1450	42.7	78	9
	(TESTED SILTY CLAY)								
							23.9	100	25
							23.4	105	34
									34
			DS	3000	NATURAL	2400	25.7	97	33
			OS	3000	NATURAL	1850	23.1	101	28
							24.5	100	74

BORING 7

ELEVATION 7.9 ± FEET



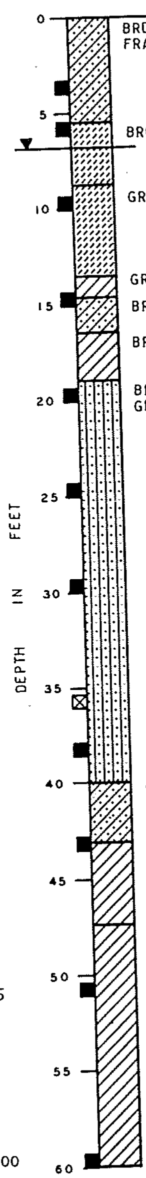
BORING LOG

COOPER · CLARK & ASSOCIATES
FOUNDATION ENGINEERS & ENGINEERING GEOLOGISTS

CLASSIFICATION DATA			STRENGTH DATA				MOISTURE-DENSITY DATA		
% FINES (-NO. 200)	LIQUID LIMIT	PLASTICITY INDEX	TYPE OF STRENGTH TEST	TEST SURCHARGE PRESSURE, LBS/SQ FT	TEST MOISTURE CONTENT, %	SHEAR STRENGTH, LBS/SQ FT	NATURAL MOISTURE CONTENT, %	DRY DENSITY, LBS/CU FT	BLOWS/FOOT
							19.6	87	14
	78.9	42.8	DS	600	NATURAL	750	45.5	71	4
	94.0	59.2	DS	1000	NATURAL	350	83.1	51	1
			DS	500	NATURAL	600	19.6	107	20
			DS	2500	NATURAL	2100	19.7	107	
			TR	2250	NATURAL	1350	19.7	111	22
			TR	7500	NATURAL	4300			
							27.8	92	20
			DS	2100	NATURAL	1550	19.6	108	25
									50
							21.7	104	54
			DS	3000	NATURAL	2600	22.1	103	27
	29.0	15.4					29.6	87	25
			DS	3000	NATURAL	2700	22.4	103	100

BORING 8

ELEVATION 8.0 ± FEET



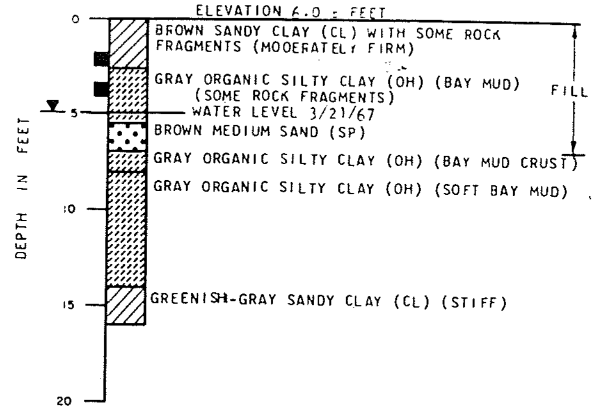
- BROWN CLAYEY SAND (SC) WITH ROCK FRAGMENTS (DENSE) (MIXED WITH BAY MUD, ASPHALT FRAGMENTS) — FILL
- BROWNISH-GRAY ORGANIC SILTY CLAY (OH) WATER LEVEL 11/23/66 (BAY MUD CRUST)
- GRAY ORGANIC SILTY CLAY (OH) (SOFT BAY MUD)
  - (FEW BROKEN SHELLS)
- GREENISH-GRAY SANDY CLAY (CL) (FIRM)
- BROWN CLAYEY SAND (SC) (DENSE)
- BROWN SANDY CLAY (CL) (STIFF)
- BROWN SILTY COARSE SAND (SM) WITH GRAVEL (DENSE)
  - (GRADING CLAYEY)
  - (GRADING LESS CLAYEY)
  - (GRADING FINER)
- GRAY CLAYEY SAND (SC) (DENSE)
- GREENISH-GRAY SILTY CLAY (CL) (STIFF)
- GREENISH-GRAY SANDY CLAY (CL) (STIFF)
  - (GRADING BROWN)

BORING LOG

COOPER · CLARK & ASSOCIATES
FOUNDATION ENGINEERS & ENGINEERING GEOLOGISTS

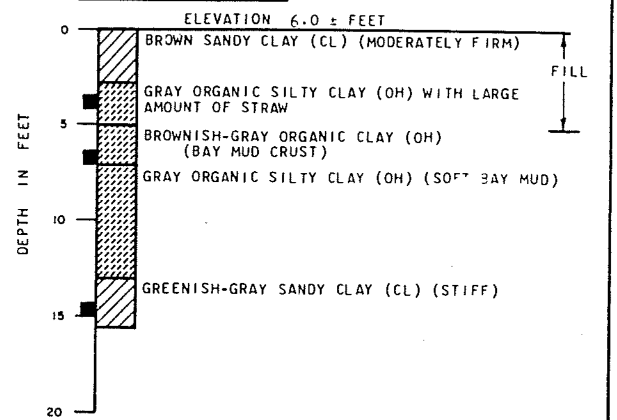
CLASSIFICATION DATA			STRENGTH DATA				MOISTURE-DENSITY DATA	
% FINES (-NO 200)	LIQUID LIMIT	PLASTICITY INDEX	TYPE OF STRENGTH TEST	TEST SURCHARGE PRESSURE, LBS/SQ FT	TEST MOISTURE CONTENT, %	SHEAR STRENGTH, LBS/SQ FT	NATURAL MOISTURE CONTENT, %	DRY DENSITY, LBS/CU FT
			DS	[illegible]	NATURAL	[illegible]	20.5	92
			DS	400	NATURAL	360	60.6	57

BORING 16



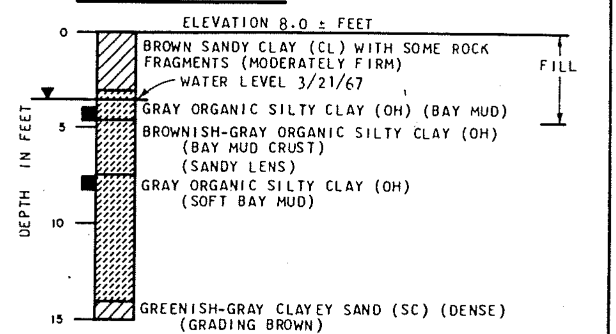
CLASSIFICATION DATA			STRENGTH DATA				MOISTURE-DENSITY DATA	
% FINES (-NO 200)	LIQUID LIMIT	PLASTICITY INDEX	TYPE OF STRENGTH TEST	TEST SURCHARGE PRESSURE, LBS/SQ FT	TEST MOISTURE CONTENT, %	SHEAR STRENGTH, LBS/SQ FT	NATURAL MOISTURE CONTENT, %	DRY DENSITY, LBS/CU FT
			DS	440	NATURAL	240	72.1	48
	112.2	59.9	DS	600	NATURAL	260	80.7	51
			DS	1000	NATURAL	1350	18.7	111

BORING 17



CLASSIFICATION DATA			STRENGTH DATA				MOISTURE-DENSITY DATA	
% FINES (-NO 200)	LIQUID LIMIT	PLASTICITY INDEX	TYPE OF STRENGTH TEST	TEST SURCHARGE PRESSURE, LBS/SQ FT	TEST MOISTURE CONTENT, %	SHEAR STRENGTH, LBS/SQ FT	NATURAL MOISTURE CONTENT, %	DRY DENSITY, LBS/CU FT
	68.9	37.1	DS	500	NATURAL	550	54.9	60
			DS	700	NATURAL	250	103.3	43

BORING 18



FIELD NOTES

1. THE BORINGS WERE DRILLED ON MARCH 21, 1967 WITH A TRUCK-MOUNTED, POWER-DRIVEN 12-INCH-DIAMETER, SCREW-TYPE AUGER.
2. UNDISTURBED SAMPLES, THE LOCATIONS OF WHICH ARE SHOWN BY THE FOLLOWING SYMBOL ■ , WERE TAKEN IN A $2\frac{1}{2}$-INCH-DIAMETER, SPLIT-TUBE BARREL WHICH WAS PUSHED INTO THE SOIL BY HYDRAULIC PRESSURE.
3. THE ELEVATIONS OF THE BORINGS WERE DETERMINED BY INTERPOLATION BETWEEN THE PLOT PLAN CONTOURS (REFERENCE = SAN FRANCISCO AIRPORT DATUM).

LABORATORY NOTES AND ABBREVIATIONS

THE TABULATED SHEAR STRENGTHS ARE YIELD POINT VALUES.

DS = STRAIN CONTROLLED DIRECT SHEAR TEST AT NATURAL MOISTURE CONTENT.

TR = STRAIN CONTROLLED, CONSOLIDATED, UNDRAINED TRIAXIAL SHEAR TEST AT NATURAL MOISTURE CONTENT.

BORING LOGS

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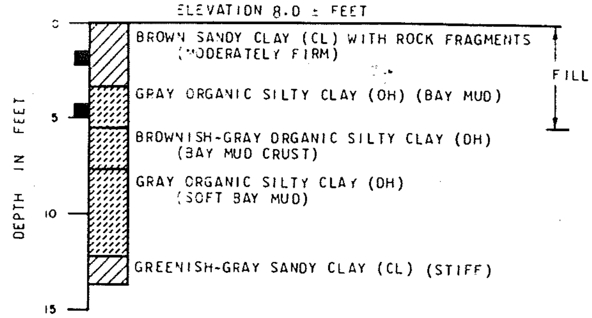
CLASSIFICATION DATA			STRENGTH DATA				MOISTURE-DENSITY DATA	
% FINES (-NO. 200)	LIQUID LIMIT	PLASTICITY INDEX	TYPE OF STRENGTH TEST	TEST SURCHARGE PRESSURE, LBS/SQ FT	TEST MOISTURE CONTENT, %	SHEAR STRENGTH, LBS/SQ FT	NATURAL MOISTURE CONTENT, %	DRY DENSITY, LBS/CU FT
			TR TR	1750 5050	NATURAL NATURAL	850 1150	15.4	115
	74.0	42.7	DS	500	NATURAL	560	48.3	65

BORING 19

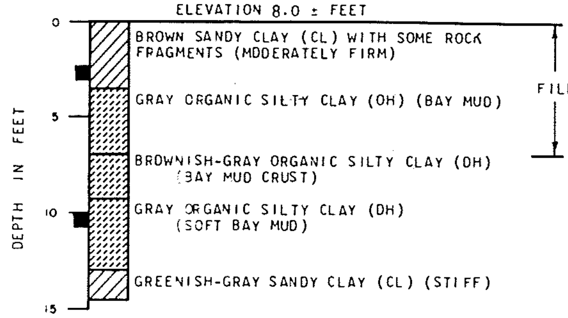
ELEVATION 8.0 ± FEET



CLASSIFICATION DATA			STRENGTH DATA				MOISTURE-DENSITY DATA	
% FINES (-NO. 200)	LIQUID LIMIT	PLASTICITY INDEX	TYPE OF STRENGTH TEST	TEST SURCHARGE PRESSURE, LBS/SQ FT	TEST MOISTURE CONTENT, %	SHEAR STRENGTH, LBS/SQ FT	NATURAL MOISTURE CONTENT, %	DRY DENSITY, LBS/CU FT
			DS	300	NATURAL	450	17.7	105
	107.0	70.2	DS	600	NATURAL	640	81.2	52

BORING 20

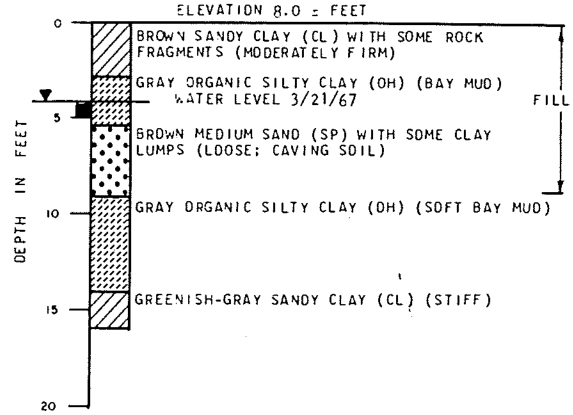
ELEVATION 8.0 ± FEET



CLASSIFICATION DATA			STRENGTH DATA				MOISTURE-DENSITY DATA	
% FINES (-NO. 200)	LIQUID LIMIT	PLASTICITY INDEX	TYPE OF STRENGTH TEST	TEST SURCHARGE PRESSURE, LBS/SQ FT	TEST MOISTURE CONTENT, %	SHEAR STRENGTH, LBS/SQ FT	NATURAL MOISTURE CONTENT, %	DRY DENSITY, LBS/CU FT
							50.8	77

BORING 21

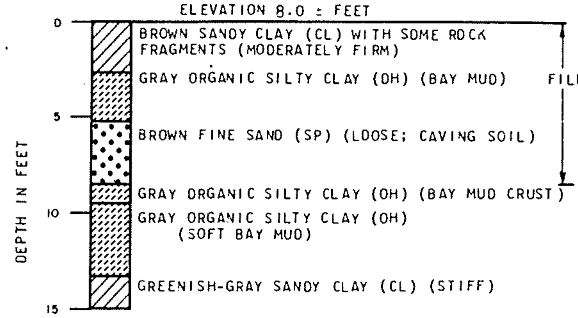
ELEVATION 8.0 ± FEET



CLASSIFICATION DATA			STRENGTH DATA				MOISTURE-DENSITY DATA	
% FINES (-NO. 200)	LIQUID LIMIT	PLASTICITY INDEX	TYPE OF STRENGTH TEST	TEST SURCHARGE PRESSURE, LBS/SQ FT	TEST MOISTURE CONTENT, %	SHEAR STRENGTH, LBS/SQ FT	NATURAL MOISTURE CONTENT, %	DRY DENSITY, LBS/CU FT

BORING 22

ELEVATION 8.0 ± FEET



BORING LOGS

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