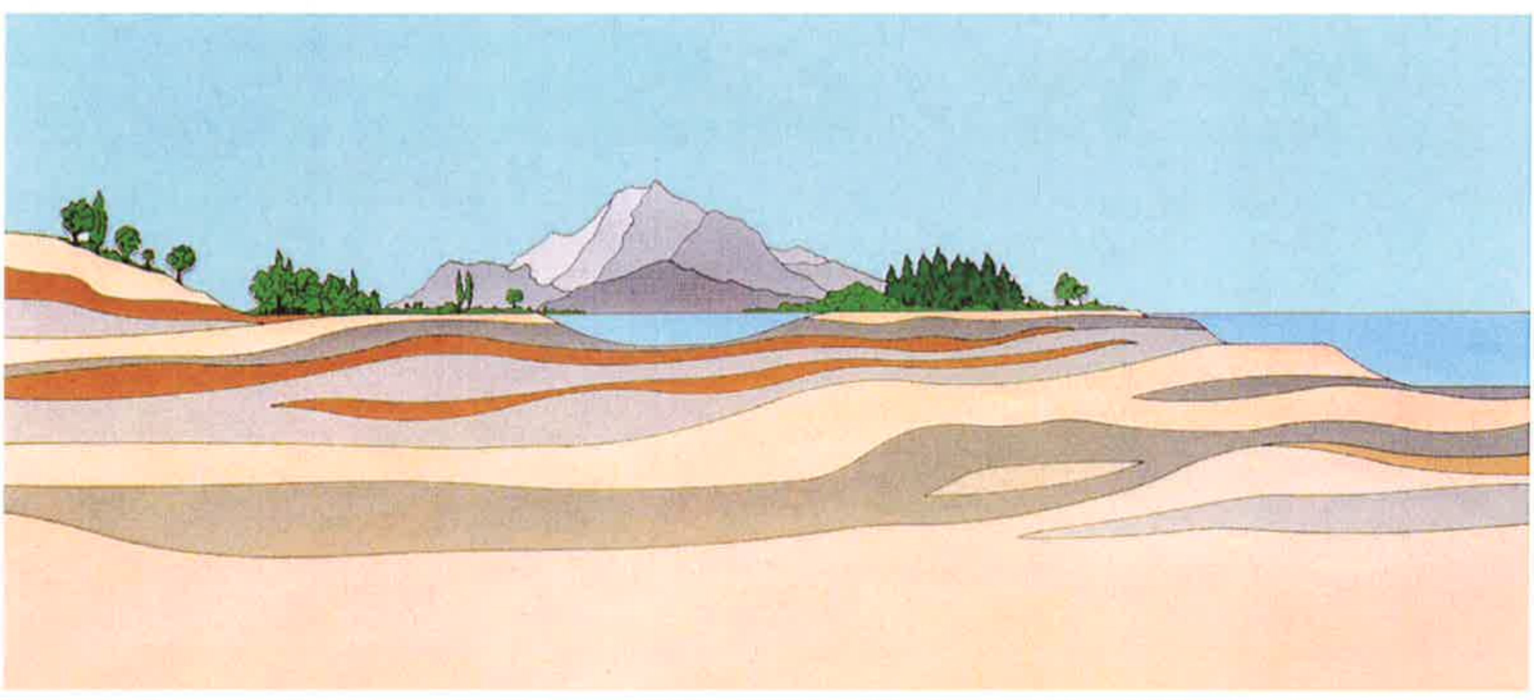
FUGRO WEST, INC.

INTERIM REPORT
PASQUINI PROPERTY HYDROGEOLOGIC INVESTIGATION
NIPOMO, CALIFORNIA

Prepared for:
NIPOMO COMMUNITY SERVICES DISTRICT

Prepared by:
FUGRO WEST, INC.

February 2010



FUGRO WEST, INC.

660 Clarion Court, Suite A
San Luis Obispo, California 93401
Tel: (805) 542-0797
Fax: (805) 542-9311

February 19, 2010
Project No. 3596.005

Nipomo Community Services District
Post Office Box 326
148 S. Wilson Street
Nipomo, California 93444

Attention: *Mr. Peter Sevcik*
District Engineer

Subject: **Interim Report**
Pasquini Property Hydrogeologic Investigation, Nipomo, California

Dear Mr. Sevcik:

Fugro West Inc. is pleased to submit this Interim Report that summarizes the initial results of a hydrogeologic investigation of the Pasquini property as part of the planned upgrade and expansion of the Nipomo Community Services District's Southland Wastewater Treatment Facility (WWTF). The objective of the study was to assess the feasibility of the site as a supplemental treated wastewater effluent disposal site. This report presents our understanding of the hydrogeology of the site, specifically related to the infiltration capacity and potential for groundwater mounding in the northern portion of the site.

Sincerely,

FUGRO WEST, INC.

Timothy A. Nicely, P.G., C.Hg.
Project Hydrogeologist

Nels C. Ruud, PhD
Project Hydrogeologist

Paul Sorensen, P.G., C.Hg.
Principal Hydrogeologist
Project Manager

CONTENTS

TABLES

PLATES

APPENDICES

INTERIM REPORT
PASQUINI PROPERTY HYDROGEOLOGIC INVESTIGATION
NIPOMO, CALIFORNIA

SITE DESCRIPTION AND BACKGROUND

The Nipomo Community Services District (District) is planning for the expansion of the District's Southland Wastewater Treatment Facilities (WWTF). One site being investigated for expansion of the effluent disposal component of the WWTF is a 35-acre portion of a 192-acre parcel known as the Pasquini property, which is located south of Orchard Road (APN 091-311-001) in Nipomo, California. The Pasquini property extends approximately 3,500 feet southwest of Orchard Road to Riverside Road, the southern edge of which is characterized by a steep bluff that is approximately 80 to 130 feet high. The 35-acre portion of the property extends approximately 1,200 feet southwest of Orchard Road. The location of the site is presented on Plate 1 – Vicinity Map. A map of the area of investigation (project site) on the Pasquini property is presented on Plate 2 – Site Map.

The northerly third of the Pasquini parcel, the subject of this investigation, occupies approximately 35 acres. A generalized cross section of the property, which presents the relative locations of the proposed pond system, the bluff, the alluvium of the Santa Maria River Basin, and the regional water table is presented as Plate 3 – Conceptualization of Subsurface. Generally, the 35-acre site is located about 150 feet higher than the Santa Maria River Basin alluvium. As indicated on Plate 3, the regional water table is located approximately 250 feet below ground surface (bgs) in the vicinity of this investigation.

Following expansion of the WWTF, the District is planning for a facility to dispose of up to approximately 1.8 million gallons per day (MGD) of treated wastewater. Recent modeling has shown that the existing Southland WWTF can dispose of approximately 0.57 MGD on a long-term basis without causing any further increases in groundwater elevations at the existing monitoring wells (that is, the underlying effluent mound will not continue to grow and expand; Fugro 2008a). In order to dispose of the remaining 1.23 MGD of treated effluent, the District needs to identify additional locations for disposal of treated wastewater. The District is considering the Pasquini site as a potential location for the development of a percolation pond disposal facility.

A feasibility level exploration program was previously conducted on the Pasquini property (Fugro 2008b). That preliminary investigation estimated the percolation capacity, the local hydrogeology, and the depth to groundwater. The conclusions presented in that report indicated that relatively lower permeability layers may exist at variable depths in the unsaturated zone, particularly at depths below about 75 feet within the southerly parts of the site. Although the lateral continuity of these low permeability layers is not known, their presence creates a concern relative to the ultimate fate of wastewater discharged in percolation ponds on the parcel. The preliminary conclusions of that report were that discharge of wastewater in the northerly third of the parcel would occur at a sufficient distance from the bluff along the southern portion of the site such that "daylighting" of the applied water on the slope face would not occur.

Since the time of the feasibility-level exploratory work conducted during the Spring and Summer of 2008, the property has been fully planted in strawberries. Development of the agricultural operations has altered the conditions of the site from the time of the initial investigation through the significant irrigation loading of the strawberry plants. Two high-production water wells have been installed along the southwestern edge of the property, as shown on Plate 4 - Site Map and Exploration Locations.

WORK PERFORMED

PURPOSE AND SCOPE

The purpose of this investigation was to conduct an evaluation of the suitability of the property for the development of an effluent disposal facility. Critical to the success of the potential supplemental percolation pond facility is the ability of the wastewater to percolate and flow more or less vertically through the relatively deep unsaturated zone and merge with the water table of the regional water table aquifer at an elevation below the base of the bluff, located approximately 2,000 feet to the southwest. In order to determine the degree to which the surficial materials would accept applied treated effluent, we performed a series of conventional percolation tests. We also dug four exploratory test pits near the center of the site to determine the nature of the shallow geologic materials, within which we built a single prototype percolation pond. Within the pond we performed a percolation test designed to mimic the methods to be used in the proposed ponds. We also collected a water quality sample from one of the onsite water supply wells to determine the chemical characteristics of the deep aquifer (receiving water). Finally, we applied an analytical evaluation and solution to evaluate the fate and transport of wastewater discharged into the proposed percolation ponds, the shape and size of the anticipated effluent mound, and the expected relationship of the effluent mound to the bluff face.

CONVENTIONAL PERCOLATION TESTING

In order to evaluate the percolation capacity of the near-surface sediments underlying the site, we performed a series of seven conventional percolation tests near the anticipated grade (elevation) of the base of the proposed percolation ponds. Because the exact elevation of the base of the percolation ponds was not known, each conventional percolation test was performed at a depth of approximately five feet below the current grade. The conventional percolation tests were performed in accordance with San Luis Obispo County requirements for testing related to private sewage disposal systems. Based on the locations of the conceptual percolation ponds (AECOM, 2009), which included 24-acres of gross area for the percolation ponds, we performed a total of seven conventional percolation tests and one prototype percolation pond test. The locations of the conventional percolation tests and the prototype percolation pond are presented on Plate 2 – Site Map.

Each percolation test was performed by digging an approximately 6-inch diameter hole to a depth of five feet, then emplacing a slotted thin-wall PVC casing within the hole to the bottom. Prior to testing, the property had been heavily irrigated in preparation for planting of strawberries. The resulting soil moisture from field irrigation was considered as pre-saturation of the hole. The bottom of each hole was filled with gravel to a depth of several inches. Each hole was then filled with potable water to a depth approximately one foot below the ground surface. A pressure transducer was installed at the bottom of each percolation hole and programmed to record water levels at 20 second intervals for a period of at least 3 hours. Using the water level data, a hydrograph of each percolation test was created, from which percolation rates were calculated at several water level depths. The hydrographs of the conventional percolation tests are presented as Plate 5 – Conventional Percolation Test, Site 1 through Plate 11 – Conventional Percolation Test, Site 9. A summary of the conventional percolation test results is presented as Table 1 – Summary of Conventional Percolation Test Results.

Table 1. Summary of Conventional Percolation Test Results

Site	Hole Depth, (feet)	General Location	Percolation Rate, 12-inch depth, (gpd/ft^2)	Percolation Rate, 12-inch depth, (feet/day)
Site 1	5	Northern corner	40	5.3
Site 2	11	Central	20	2.7
Site 5	5	Northeastern edge	40	5.3
Site 6	5	Southwestern edge	29	3.9
Site 7	5	Eastern central	20	2.7
Site 8	5	Southern corner	50	6.7
Site 9	5	Southeastern edge	50	6.7

Inspection of the hydrographs and Table 1 indicate that percolation rates range between 20 and 50 gpd/ft^2 (between 2.7 and 6.7 feet/day) for a water depth of approximately 1 foot. In general, percolation rates varied proportionally with water depth, that is, at the highest water levels, the percolation rates were highest and percolation rates were lower at lower water levels. Analysis of the early-time data indicated that percolation rates were significantly higher than those values presented on Table 1. These early-time data were generally believed to be unreasonably high, and therefore were not considered representative of the geologic materials encountered.

TEST PIT EXPLORATION

A series of four exploratory test pits were excavated adjacent to the prototype percolation pond (Plate 2). Each test pit was excavated with a backhoe to a depth of 14 to 15 feet to allow logging of the materials encountered. Fugro staff logged each test pit, photographed the exposed materials, and collected multiple bulk samples of materials from each pit.

The materials within the test pits consisted principally of mixtures of silty sand and sand. Generally, the silty sand was present at the surface and underlain by pale yellowish sand with beds of silty sand below depths of 6 to 10 feet. The lithologic materials were moist to depths of 8 to 15 feet and wet below these depths. Descriptions of the geologic materials are included in Appendix A. Photographs of the test pits are included in Appendix B.

PROTOTYPE PERCOLATION POND TESTING

Based on the conventional percolation testing results, we constructed a prototype percolation pond near the center of the site to allow for larger scale testing of the percolation capacity of the near-surface sediments. Based on anticipated percolation rates in the range of 10 to 50 gpd/ft^2, a 20-foot square (400 ft^2) percolation pond was installed to a depth of approximately two feet. Geologic materials within the excavation for the pond consisted entirely of silty sand. A metered supply of water pumped from the on-site agricultural wells was supplied to fill the pond. The water was delivered through the irrigation system to a 21,000 gallon tank temporarily placed adjacent the percolation pond. Gate valves and one float valve were installed to control water levels and inflow rates. A dedicated pressure transducer was installed in the percolation pond to measure and record water levels at 5-minute intervals throughout the entire test program. A staff gauge was also installed to monitor water level within the pond. Photographs of the constructed pond are provided in Appendix B.

The pond was flooded with water and filled to a stage of approximately 18 inches. A constant head above the base of the pond was controlled with the use of a float valve. Throughout the entire test period, water levels in the test pond were monitored and automatically recorded at 5-minute intervals. A hydrograph of the water level in the test pond is presented as Plate 12 – Prototype Percolation Pond Hydrograph.

At the relatively constant inflow rate of approximately four gallons per minute (gpm) that was maintained throughout testing, the percolation rate of the near-surface sediments underlying the test pond was calculated to be approximately 15 gpd/ft^2 (2 feet/day).

After 10 days of testing, the inflow into the pond was turned off and the test terminated. A falling head test was then conducted by recording the declining water level in the test pond over time until the pond emptied. The partially-full tank was drained into the pond and a second falling head test was conducted by again recording the declining water level in the pond for several hours. Hydrographs of the two falling head tests are presented as Plates 13 and 14.

Inspection of Plate 12 indicates that after approximately three days of initial filling and pre-saturation, the inflow rate varied narrowly between 4.3 gpm (days 3 through 6) and 3.9 gpm (days 6 through 9). This was equal to about 15 gpd/ft^2 at a head of approximately 18 inches. The falling head tests that were started on September 25 (Plate 13) and September 30 (Plate 14) resulted in percolation rates between 7.5 gpd/ft^2 and 12.7 gpd/ft^2.

The range of values indicates that the later tests had slightly lower percolation rates, likely due to minor algal growth within the pond and associated clogging. For the proposed full-scale percolation ponds, algal and turbidity-related clogging will need to be addressed, both of which can decrease percolation rates significantly.

The calculated percolation rates are characteristic of hydraulic conductivity values of materials described as "silt" to "silty sands" (Freeze and Cherry, 1979). According to Driscoll (1986), these percolation values are representative of "silt and loess" to "fine to coarse sand". According to Roscoe Moss (1990), these values are representative of materials somewhere between "silt" and "fine sand". We believe the calculated values of percolation rates reasonably represent the silty sand and sand present in the surficial sediments at the site.

WATER QUALITY ANALYSIS

For the prototype percolation pond test, the supply water was pumped from the two on-site agricultural production wells and delivered to the pond through the irrigation distribution system. The wells are approximately 500 feet apart and are located in the southern portion of the site adjacent to the bluff face (Plate 2). Both wells are perforated between 220 and 380 feet bgs. Well completion details are documented on State of California Well Completion Reports included in Appendix C.

To assess the water quality of the supply water for the percolation test, a water sample was collected from the irrigation distribution system and submitted to an analytical laboratory. The sample was analyzed for general mineral, general physical, and inorganic constituents. The water quality data was reviewed and is presented on Table 2 – Water Quality Data, Receiving Aquifer.

Table 2 - Water Quality Data, Receiving Aquifer
(units in milligrams per liter, unless otherwise noted)

Constituent	On-Site Well September 25, 2009
Total dissolved solids	660
pH (pH units)	7.4
Calcium	79
Magnesium	35
Sodium	63
Potassium	3.3
Alkalinity, Total (as $CaCO_3$)	200
Chloride	83
Sulfate	180
Fluoride	0.36
Nitrate as NO_3	4.9
Hardness (as $CaCO_3$)	320
Iron	0.11
Manganese	0.18

A review of the water quality results indicates that the underlying groundwater is calcium sulfate to calcium bicarbonate in chemical character with a total dissolved solids concentration of 660 milligrams per liter (mg/l). The full water quality analytical results are presented in Appendix C.

ANALYTICAL MOUNDING ANALYSIS

The second major objective of this study was to evaluate the groundwater mounding potential above each of three major zones of fine-grained sediments identified in the previous Fugro (2008b) report from CPT, boring, and well drilling logs. For this, a mathematical model developed by Khan et al. (1976) was used to calculate the mound height and lateral spread on each zone due to long-term discharge of treated wastewater effluent in the proposed pond system. In this section, the results of the mounding analysis are presented. This section includes a conceptualization of the site subsurface stratigraphy, a review of the available hydraulic conductivity estimates of the subsurface sediments, and a description of the Khan analytical method and the assumptions invoked in its application.

Conceptualization of Site Subsurface Stratigraphy

A conceptualization of the subsurface underlying the Pasquini property is shown on Plate 4 – Conceptualization of Subsurface. As mentioned previously, the Pasquini property is located on the southern end of the Nipomo Mesa. The western boundary of the property nearly coincides with a westward-facing bluff that separates the Nipomo Mesa from the lower-lying Santa Maria River Basin. The ground surface elevation of the Santa Maria River Basin alluvium varies from about 148 to 164 feet (MSL) near the bluff face whereas the ground surface elevation of the Pasquini property varies from about 295 to 312 feet (MSL). These ground surface elevation differences result in a bluff height of about 150 feet (i.e., the Pasquini property is about 150 feet higher in elevation than the Basin alluvium).

The percolation pond system is planned to occupy up to 80 percent (i.e., 24 acres) of the 35-acre area. In this study, the center of the pond system is assumed to be 2,200 feet east of the nearest point on the bluff face and the distance from the center of the pond to the Santa Maria River Fault (which is believed to run more or less along Orchard Drive) may be as close as 1,200 feet. Based on historical groundwater level measurements in the area, the regional water table is located at a depth of about 250 feet bgs in the site vicinity. The sediments between the ground surface and the water table consist largely of sand, silty sand, sand with silt, clay with gravel, and clay. A geotechnical investigation conducted by Fugro (2008b) indicated thin layers of silt interbedded with sandy sediments at shallow depths (10-12 feet bgs) and a thicker fine-grained layer at a depth of 65 to 70 feet bgs beneath the site. These silty sediments generally have lower hydraulic conductivities in comparison to the coarser-grained sediments and may therefore impede the downward migration of discharged effluent. However, the lateral continuity of the silty layers from the pond site to the bluff face is uncertain.

Two irrigation wells were drilled during 2008 in the southeastern corner of the property (see Plate 3 for the locations of the wells) and both were completed to depths of 400 feet bgs. The well completion report for well no. 1 indicates a 34-foot thick layer described as 'gray clay' at a depth interval of 180 to 214 feet bgs. The well completion report for well no. 2 indicates a 30-foot thick layer described as 'brown clay with gravel' at a depth interval of 120 to 150 feet bgs and a 5-foot 'clay' layer between 190 to 195 feet bgs. Assuming that the Basin alluvium ground surface elevation is about 150 feet below the ground surface of the pond site, the 'gray clay' layer associated with well no. 1 would be located about 30 feet below the ground surface of the Basin alluvium at the base of the bluff face. Conversely, the top of the 'brown clay with gravel' layer associated with well no. 2 would be about 30 feet above the ground surface of the Basin alluvium at the base of the bluff face (see Plate 3).

Overall, the CPT data, boring logs, and well completion reports indicate three potential relatively thick zones of low permeable sediments beneath the Pasquini property, including 1) a silty sand beginning at 65 feet bgs, 2) a layer of brown clay with gravel at 120 feet bgs, and 3) a layer of gray clay at 180 feet bgs. It is important to note that the lateral continuity of these three layers is not known. This is especially true of the two deeper layers, that is, the layers at 120 feet and 180 feet.

The potential presence of the two deeper layers was unknown to us until after we had been able to receive the State Well Completion Reports for the two new onsite irrigation wells. The wells had not been drilled at the time of our previous investigation (Fugro 2008b), and the standard subsurface investigation methods used during that investigation could not drill to the depths necessary to reach the clay layers represented on the Well Completion Reports. It is also important to note that the lithologic descriptions on Well Completion Reports for water wells are usually not as detailed or as specific as to actual lithology as the descriptions performed for geotechnical investigations. Because a water well drilling contractor is focused on maximizing the water supply capability of the well, he may not necessarily adequately describe a layer other than simply noting that it is a "clay" or "clay with gravel." However, those distinctions are critically important to this investigation.

Thus, the suggestion that these two relatively low permeability layers may exist at depth, and/or may be laterally continuous, is vitally important to evaluate in order to assess the fate of the effluent discharge and the lateral growth of the effluent mound.

As discussed earlier, the existence of significant lateral continuity for any of these layers beneath the pond site and above the water table may cause the layer to behave as a perching layer. Long-term discharge of effluent in the pond would percolate downward through the underlying sediments and form a groundwater mound on the perching layer. The effluent would be expected to continue percolating through the mound and the perching layer, although at a much slower rate than through the overlying sediments, while at the same time spreading out laterally on top of the perching layer. Of particular concern in the planning and long-term operation of the pond system is the potential for breakout of discharged effluent along the bluff face due to lateral spreading of the mound on top of a perching layer. In other words, the width of the mound may increase over time, eventually reaching the bluff face and seeping through it.

Although it is important to conduct additional field work to evaluate the presence and continuity of the two deep clay layers, it was decided to conduct the analysis of the known 65-foot deep layer in order to evaluate the potential impacts of the layer on the growth of the mound. Thus, the analytical method developed by Khan et al. (1976) was used to evaluate the groundwater mounding behavior for the low permeable sediments observed in the logs at the 65-foot level.

Groundwater Levels

The well completion reports for the two wells constructed on the Pasquini property during 2008 indicate depths to groundwater of 250 and 255 feet bgs. The ground surface elevations of these wells likely vary between 279 to 295 feet (MSL). Consequently, the water table elevation associated with these wells is in the neighborhood of 30 to 50 feet (MSL). Contour maps of groundwater elevations during the spring seasons of 1995, 2000, and 2002 show groundwater elevations beneath the property in the range of 50 to 100 feet (MSL). Assuming a water table elevation of 50 feet (MSL) as observed during the construction of the wells, the depth to groundwater beneath the Basin alluvium is between 98 to 114 feet bgs.

CPT and borings were performed during the previous geotechnical investigation at several locations on the Pasquini property (Plate 3). Several CPT and boring logs indicate wet sediments at elevations distinctly above the regional water table. Prior to the 2009 water year, however, the Pasquini property was not known to have ever been irrigated. Therefore, the observed wetness likely represents partially saturated sediments as a result of long-term deep percolation of precipitation through the vadose zone.

Estimated Horizontal and Vertical Hydraulic Conductivities

Four subsurface cross-sections (i.e., A-A' to D-D') were generated using the CPT and boring log descriptions and presented in the geotechnical report (Fugro, 2008b). Of particular note in the immediate vicinity of the proposed pond site are four CPTs (C-103, C-104, C-105, and C-107) and one boring (B-103). Inspection of boring B-103 shows the occurrence of a thin layer of sand with silt (SP-SM) at a depth of 10 to 12 feet bgs. Laboratory permeability tests were performed during the geotechnical investigation on sediment samples at different depths from borings B-102 and B-103 and the results are reproduced in Table 3. The estimated vertical hydraulic conductivity from the permeability test on the 10-foot sample for B-103 is about 1.0 feet/day. The sediments from 0 to 10 feet bgs in boring B-103 are also described as silty sand (SM) with interbeds of sandy silt (ML). A permeability test on the 10-foot sample in boring B-102 yielded a similar vertical hydraulic conductivity of 1.2 feet/day. A permeability test was also performed on the 70-foot sample in B-103 yielding a vertical hydraulic conductivity estimate of 1.5 feet/day for a sediment classification of silty sand (SM). These permeability test results suggest a range of 1.0 to 1.5 feet/day for the vertical hydraulic conductivity of silty sand (SM) sediments beneath the Pasquini property. In general, the vertical hydraulic conductivity of loamy soils is reported to range from 0.3 to 3 feet/day (EPA, 2006). Consequently, the lab permeability test estimates of vertical hydraulic conductivity for the silty sand samples are consistently within the reported range for loamy soils (Table 3).

Table 3. Estimated Vertical Hydraulic Conductivity Values

Boring No.	Depth (feet)	Classification	Vertical Hydraulic Conductivity (feet/day)
B-102	10	Silty sand (SM)	1.2
B-102	50	Sand (SP), poorly graded	28.3
B-102	70	Sand with silt (SP-SM)	26.6
B-103	10	Silty sand (SM)	1.0
B-103	20	Sand (SP), poorly graded	34.0
B-103	70	Silty sand (SM)	1.5

The sediment texture of dune sands is generally characterized as fine- to medium-grained sand. The 50-foot bgs and 70-foot bgs sediment samples in B-102 were classified as sand (SP) and sand with silt (SP-SM), respectively (Table 3). The 20-foot bgs sediment sample in B-103 was also classified as sand (SP). Permeability tests conducted on these sandy samples resulted in a range of vertical hydraulic conductivity estimates of 26.6 to 34 feet/day (Table 3). The vertical hydraulic conductivity of fine sand is reported to vary from 3 to 16 feet/day, whereas the range for medium sand is 16 to 66 feet/day (EPA, 2006). The lab permeability test estimates of vertical hydraulic conductivity for the three sandy samples were therefore consistently within the above reported ranges for fine to medium sand (Table 3).

The anisotropy ratio is equal to the ratio of horizontal hydraulic conductivity to vertical hydraulic conductivity. Dune sand deposits are generally well sorted and are characterized by low anisotropy ratios in the range of 2 to 5. Applying this anisotropy ratio range to the estimated vertical hydraulic conductivities for the three sandy samples yields an overall horizontal hydraulic conductivity range of approximately 50 to 170 feet/day for sands and sands with silt. The corresponding horizontal hydraulic conductivities of the sediment samples described as silty sand (see Table 3) are therefore in the range of 2 to 7.5 feet/day. According to the CPT logs, the vertical profile between the ground surface and the top location of the thick zone of silty sand material starting at about 65 feet bgs consists predominantly of sands and sands with silt and thin layers of silty sands. The effective or average horizontal hydraulic conductivity in the upper 65 feet of the subsurface can be estimated as a thickness-weighted average of the horizontal hydraulic conductivities of the sands and sands with silt (50 to 170 feet/day) and silty sands (2 to 7.5 feet/day).

As will be discussed later, the horizontal hydraulic conductivity of the upper stratum of sediments underlying the proposed pond site and above a potential perching layer will control the mound height beneath the pond and above the perching layer. Therefore, a reasonable range of horizontal hydraulic conductivity values for the upper stratum in the mounding analysis conducted in this study was chosen to be 10 to 100 feet/day. The lower end value of 10 feet/day is considered conservative and is likely more representative of the upper stratum between the ground surface and the deep clay layer at 180 feet bgs. The upper end value of

100 feet/day is probably more representative of the upper stratum between the ground surface and the silty sand layer at 65 feet bgs.

Analysis

The potential for breakout along the bluff face was evaluated at the pond site using an analytical solution to a mathematical problem describing the formation of a groundwater mound on a perching layer under steady-state conditions (Khan et al., 1976). A schematic displaying the modeled system is displayed on Plate 4. In this problem, recharge is applied at the ground surface in either a rectangular or circular area at a constant rate. The underlying aquifer is composed of an upper stratum and a lower stratum. The upper stratum is assumed to have a horizontal hydraulic conductivity (K_1) that is significantly greater than the vertical hydraulic conductivity (K_2) of the lower stratum (e.g., K_1/K_2=50, 100, ..., 1000). The actual infiltration rate (q) (i.e., volumetric recharge rate divided by recharge area) is assumed to be less than the saturated vertical hydraulic conductivity of the upper stratum and significantly greater than the vertical hydraulic conductivity of the perching layer. Based on the results of the conventional percolation tests presented in Table 1, an infiltration capacity of 2 feet/day was assumed for the near-surface sediments at the proposed site. Given a constant recharge rate, a groundwater mound with a steady-state shape forms on the lower stratum which acts as the perching layer. The water table in the problem is assumed to be located at a significant distance from the top of the perching layer. As part of the analytical solution to the shape of the steady-state perched groundwater mound, Khan et al. (1976) developed the following relationship:

$$w_{max} = L\frac{K_2}{q} \qquad (1)$$

where w_{max} is the maximum half-width of the recharge area and L is the distance from the center of the pond to the edge of the mound. For design purposes, equation (1) can be used to evaluate the feasibility of a proposed pond system given information describing the vertical hydraulic conductivity of any potential perching layers as well as anticipated effluent discharge rates and pond areas. For the proposed pond system on the Pasquini property, equation (1) will be used to determine whether the assigned hydraulic conductivities of the 65-foot deep low permeable layer beneath the site may potentially generate a groundwater mound that will eventually reach and seep through the bluff face.

Mound height (H) above the perching layer at any horizontal distance (x) from the center of the pond system can be estimated using the following equations derived from Dupuit-Forchheimer seepage theory by Khan et al. (1976):

$$H = w\left[\frac{K_2}{K_1}\left(\frac{q}{K_2}-1\right)\left(\frac{q}{K_2}-\frac{x^2}{w^2}\right)\right]^{1/2} \qquad 0 \le x < w \qquad (2)$$

$$H = w\left(\frac{K_2}{K_1}\right)^{1/2}\left[\frac{q}{K_2} - 1\right] \qquad x = w \qquad (3)$$

$$H = w\left(\frac{K_2}{K_1}\right)^{1/2}\left[\frac{q}{K_2} - \frac{x}{w}\right] \qquad w < x \le L \qquad (4)$$

Equation (2) estimates mound height for a horizontal distance less than the half-width of the pond system; equation (3) estimates mound height at a horizontal distance equal to the half-width of the pond system; and equation (4) estimates mound height for horizontal distances from the pond center greater than the half-width and less than or equal to the distance of the mound edge.

Results and Analysis

A schematic illustrating the silty sand layer, the clay with gravel layer, and the deep clay layer is presented on Plate 3. The Khan method was used to estimate the mounding height on the 65-foot layer as a function of the distance from the pond system center towards the bluff face. Similar analyses for the two deeper clay layers (the 65-foot layer and the 120-foot layer) are not shown here because of the uncertainty of the presence and lateral continuity of the layers.

A vertical hydraulic conductivity of 0.1 feet/day was initially assigned to the 65-foot deep silty sand layer. This assigned value is within the range of vertical hydraulic conductivity for the textures the layer represents. In particular, K_2=0.1 feet/day is chosen to be just below the low end range value of 0.3 feet/day for loamy soils and is conservative in comparison to the lab permeability test estimates of vertical hydraulic conductivity for silty sands. The mound height was then estimated using equations (2) to (4) by varying the horizontal hydraulic conductivity of the upper stratum (i.e., aquifer region overlying the low permeable perching layer) over the values of 10, 20, 50, and 100 feet/day. The analysis was also conducted assuming a 5-acre size percolation pond and a 1.23 MGD effluent discharge rate.

Plate 15 shows the estimated mound height as a function of horizontal distance from the pond center for the silty sand layer (K_2=0.1 feet/day) and for the four different values of horizontal hydraulic conductivity of the upper stratum (K_1=10, 20, 50, and 100 feet/day). The results for the silty sand layer are also summarized in Table 4. For K_2=0.1 feet/day and for each value of K_1, the maximum mound height beneath the center of the pond was estimated to be below the ground surface (Table 4). Given a constant value of K_2, the lower the value of the horizontal hydraulic conductivity of the upper stratum the greater the mound height. Consequently, K_1=10 feet/day generated the greatest mound height beneath the pond. However, as discussed previously, K_1=10 feet/day represents a conservatively low value of horizontal hydraulic conductivity for the upper stratum, particularly in comparison to lab permeability test estimates of vertical hydraulic conductivity for sands and sands with silt in the range of 26.6 to 34 feet/day (Table 3).

The distance of the mound edge from the pond center is controlled by the vertical hydraulic conductivity of the low permeable perching layer. Therefore, the distance of the mound edge from the center of the pond for a value of K_2=0.1 feet/day was 674 feet. The values of horizontal hydraulic conductivity for the upper stratum and the vertical hydraulic conductivity of the silty sand layer evaluated by the Khan method did not result any breakout of the mound at the bluff face approximately 2,200 feet from the pond center (Table 4).

Table 4. Estimated Mounding on the 65-foot bgs Silty Sand Layer

Silty Sand Shallow Layer Vertical Hydraulic Conductivity (feet/day)	Upper Stratum Horizontal Hydraulic Conductivity (feet/day)	Maximum Mound Height (feet)	Depth to Mound beneath Pond Site (feet, bgs)	Distance from Pond Center Mound Edge (feet)	Mound Height at Bluff Face (feet)	Mound Breakout at Bluff Face?
0.1	10	63	2	674	0	No
0.1	20	44	21	674	0	No
0.1	50	28	37	674	0	No
0.1	100	20	45	674	0	No

CONCLUSIONS

In this study, a hydrogeologic assessment of the Pasquini property was performed to evaluate the property as a potential site for a percolation pond system that will be capable of receiving and infiltrating up to 1.23 MGD of treated wastewater effluent from the WWTF. The assessment consisted of two major tasks: 1) the performance of a series of field tests to quantify the percolation capacity of the near-surface sediments at the site, and 2) application of an analytical method developed by Khan et al. (1976) to evaluate the groundwater mounding potential above a layer of fine-grained sediments identified in logging data.

The results of seven conventional percolation tests performed at different locations on a 24-acre portion of the property indicate that percolation rates range between 20 and 50 gpd/ft^2 (i.e., between 2.7 and 6.7 feet/day) for a water depth of about one foot. Excavation of four exploratory test pits in the site area also revealed that the near-surface sediments to a depth of about 15 feet bgs consisted largely of silty sand and sand.

In order to conduct larger scale testing of the percolation capacity of the near-surface sediments, a 400-square foot prototype percolation pond with a depth of 2 feet was constructed near the center of the proposed site. A constant head test with a steady inflow rate of 4 gpm resulted in a measured percolation rate of 15 gpd/ft^2 (2 feet/day) for a constant head of 18 inches. Two falling head tests performed in the prototype pond resulted in percolation rates of 7.5 and 12.7 gpd/ft^2 (i.e., 1.0 and 1.7 feet/day). It is important to note that the percolation rates estimated in this study were measured in field tests that used essentially clean, debris-free potable water. Percolation rates of discharged wastewater effluent in the pond system, even if highly treated, may be lower. The presence of suspended solids in the discharge and microbial growth on the pond bottom may significantly reduce the actual infiltration rates in a percolation pond system.

Based on previous field work that included CPT data and boring logs, a layer of fine-grained sediments at a depth of approximately 65 feet below ground surface was identified as a zone that could potentially act as a perching layer for the long-term discharge of treated wastewater effluent in the proposed pond system. Given available local hydrogeologic information and the results of the infiltration tests performed by Fugro, the analytical method developed by Khan et al. (1976) was used to evaluate the mounding potential on this low permeable layer for reasonable values of horizontal hydraulic conductivity for the upper stratum and vertical hydraulic conductivity for the perching layer. In particular, the mounding height was calculated to determine the potential for breakout along the bluff face as well as to evaluate the separation of the mound height from the ground surface associated with the pond system site.

For the 65-foot bgs silty sand layer, the Khan method estimated that the resulting mound would neither break out through the bluff face nor intersect the ground surface associated with the pond system site. The horizontal distance of the mound edge from the pond center was estimated to be 674 feet for a vertical hydraulic conductivity of the silty sand layer of K_2=0.1 feet/day. As noted earlier, K_2=0.1 feet/day was chosen to be just below the low end range value of 0.3 feet/day for loamy soils (EPA, 2006) and is conservative in comparison to the lab permeability test estimates of vertical hydraulic conductivity for silty sands.

Inspection of the State Well Completion Reports of the two recently drilled irrigation wells on the property, which were drilled subsequent to our previous work on the site, suggest the possible existence of two more low permeability layers at depths below the reach of conventional geotechnical drilling methods. The well completion report for one of the wells indicates a 34-foot thick layer described as 'gray clay' at a depth interval of 180 to 214 feet bgs. The well completion report for the other well indicates a 30-foot thick layer described as 'brown clay with gravel' at a depth interval of 120 to 150 feet bgs. It is important to note that the only evidence that these layers actually exist is the reference to the zones on the Well Completion Reports. Furthermore, the lateral continuity of these layers is not known. However, the possible significance of these layers is potentially critical to the mounding analysis and evaluation whether the buildup of a mound on these layers could daylight on the bluff.

Thus, it is our opinion that additional field investigation is necessary to evaluate whether the layers of low permeability exist at depths of 120 feet and 180 feet, and if they exist, whether they are laterally continuous. If the layers exist, then samples can be taken of the materials and laboratory permeability tests conducted to determine the permeability of the sediments. Finally, a similar mounding analysis can then be performed to evaluate the significance of the layers with respect to buildup of the effluent mound and possible daylighting of the mound in the bluff face.

RECOMMENDATIONS

- The results of this analysis indicate the need to perform additional site characterization to evaluate the vertical and lateral extent, and permeabilities of deep clay layers beneath the pond site.

REFERENCES

AECOM (2009), "Draft Conceptual Percolation Pond Layout, Pasquini Property (APN 090-311-001)", June, 2009.

Cooper, William S. (1967), "Coastal Dunes of California", The Geological Society of America, Memoir 104.

Driscoll, F.G. (1986), Groundwater and Wells, Johnson Division., St. Paul, Minnesota, pg. 1021

Environmental Protection Agency (EPA) (2006), Process Design Manual, Land Treatment of Municipal Wastewater Effluents, EPA/625/R-06/016, 194 pages.

Fetter, C.W. (1988), Applied Hydrogeology, Merrill Publishing Company, Columbus, Ohio.

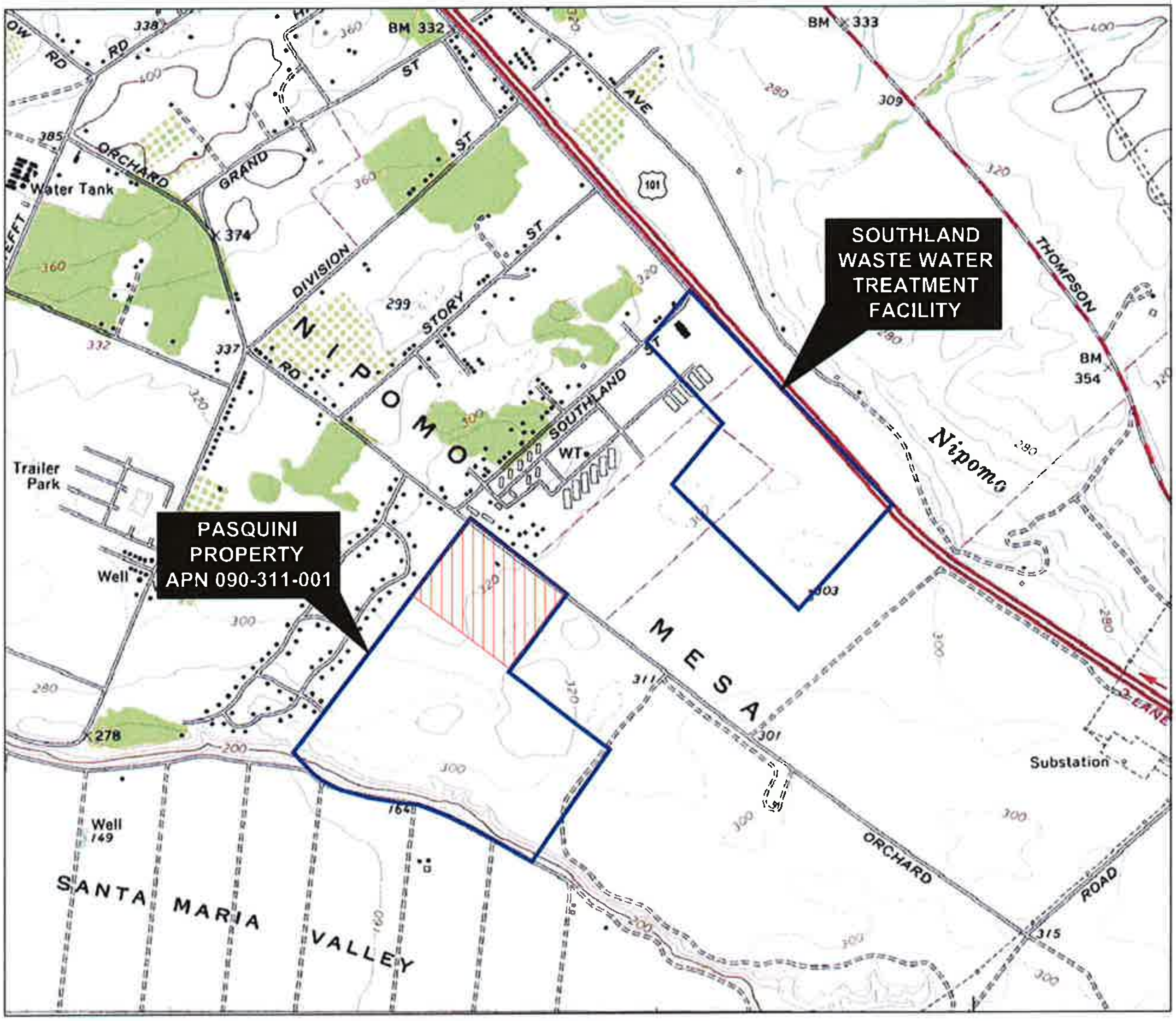
Freeze, R.A, and Cherry, J.A. (1979), Groundwater, Englewood Cliffs, New Jersey, Prentice-Hall, Inc.

Fugro (2008a), *Supplemental Groundwater Modeling Analysis*, prepared for Nipomo Community Services District, June 2008.

Fugro (2008b), *Hydrogeologic and Geotechnical Assessment of APN 090-311-001, Nipomo, California*, prepared Nipomo Community Services District, July 2008.

Khan, M.Y. and Kirkham, D. (1976), Shapes of Steady State Perched Groundwater Mounds, *Water Resources Research*, Vol. 12, No. 3, pp. 429-36.

PLATES



BASE MAP SOURCE: USGS NIPOMO QUADRANGLE TOPOGRAPHIC MAP

NORTH
0 2000
FEET

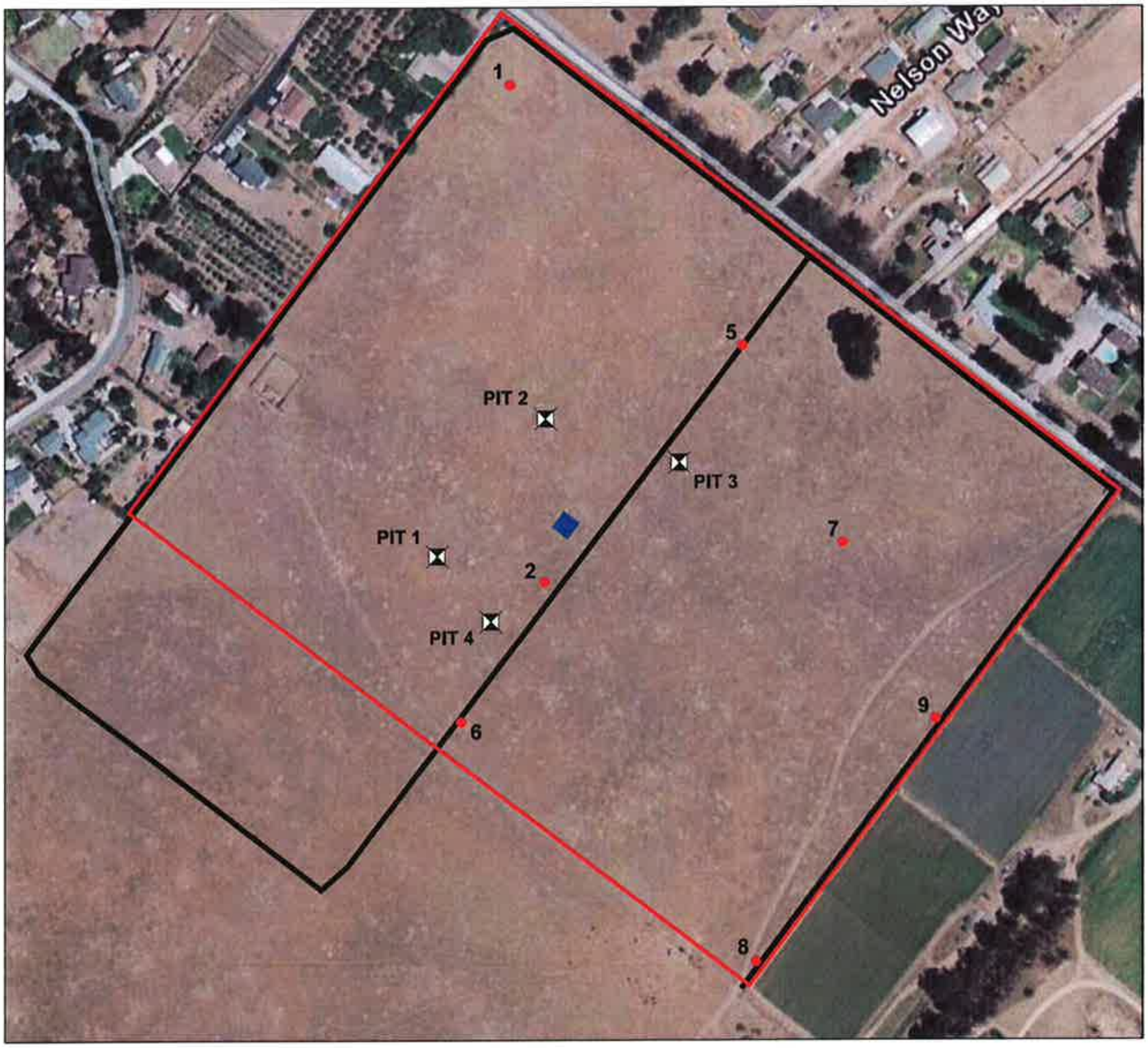
LEGEND

Area of Investigation (Plate 2)

M:\Drafting\JOBFILES\2010\3596\3596.005\Drawings\A3596.005-01 vicn.dwg 01-05-2010 - 3:11pm

VICINITY MAP
Pasquini Property Investigation
Nipomo, California

PLATE 1



BASE MAP SOURCE: Aerial photograph from Google Earth Pro (July 2007).

LEGEND

- 9 ● Conventional Percolation Test Location
- Prototype Percolation Pond (dimensions of approximately 20 feet by 20 feet).
- PIT 1 Exploration Pit Location
- Access Roads
- Area of Investigation

NORTH

0 300

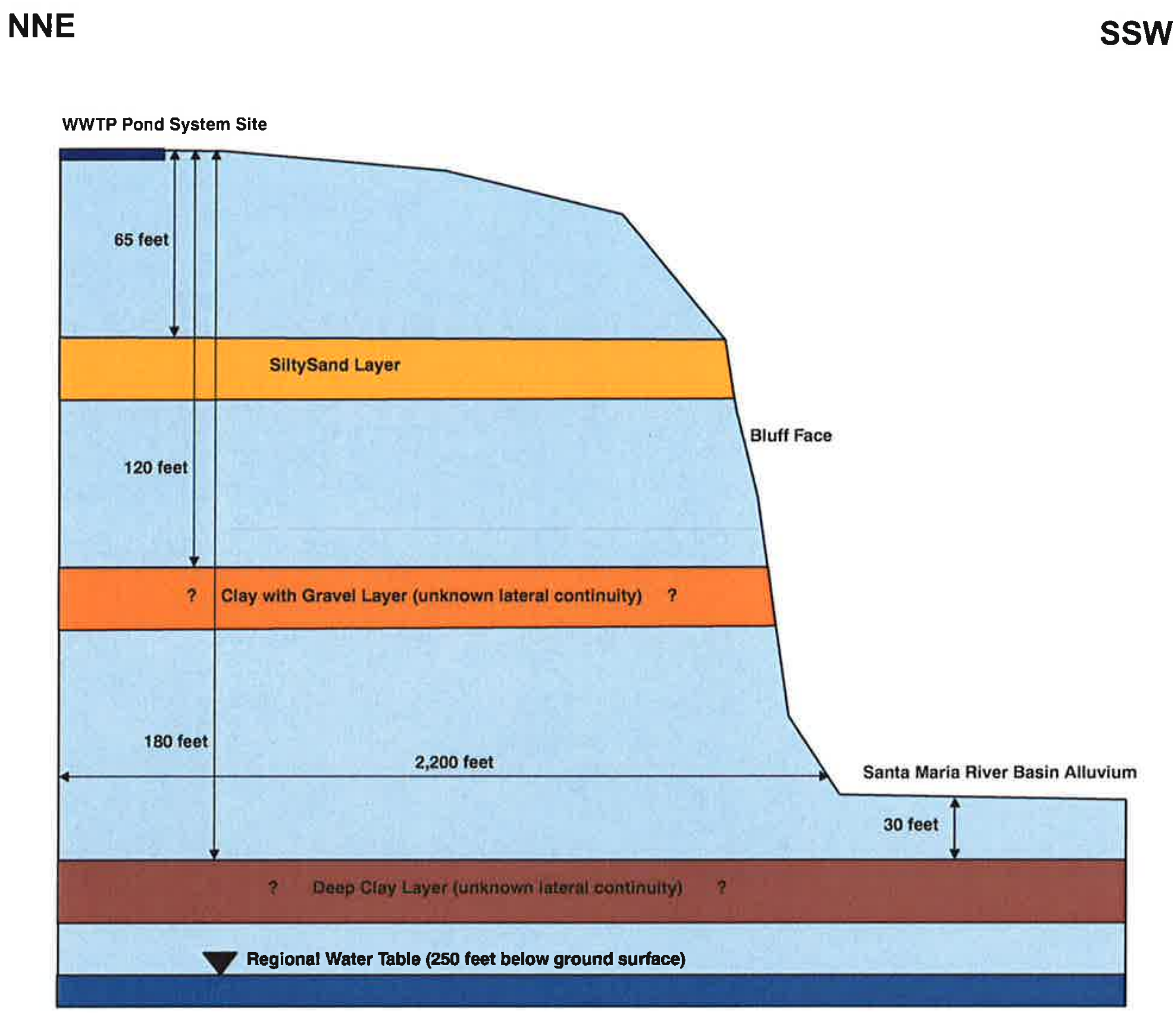
FEET

M:\Drafting\JOBFILES\2010\3596\3596.005\Drawings\A3596.005-02 site.dwg 01-05-2010 - 3:13pm

SITE MAP

Pasquini Property Investigation
Nipomo, California

PLATE 2



NOT TO SCALE

M:\Drafting\JOBFILES\2010\3596\3596.005\Drawings\A3596.005-03 concept.cdr, 01-07-10

CONCEPTUALIZATION OF SUBSURFACE
Pasquini Property Investigation
Nipomo, California

Nipomo Community Services District
Project No. 3596.005

BASE MAP SOURCE: GOOGLE EARTH PRO

LEGEND

- C-113 — Approximate Location of CPT Soundings
- B-103 — Approximate Location of Borings
- CB-4595 — Approximate Location of CPT Soundings from previous investigation
- DH-301 — Approximate Location of Boring from previous investigation
- Approximate Location of Water Well

NORTH

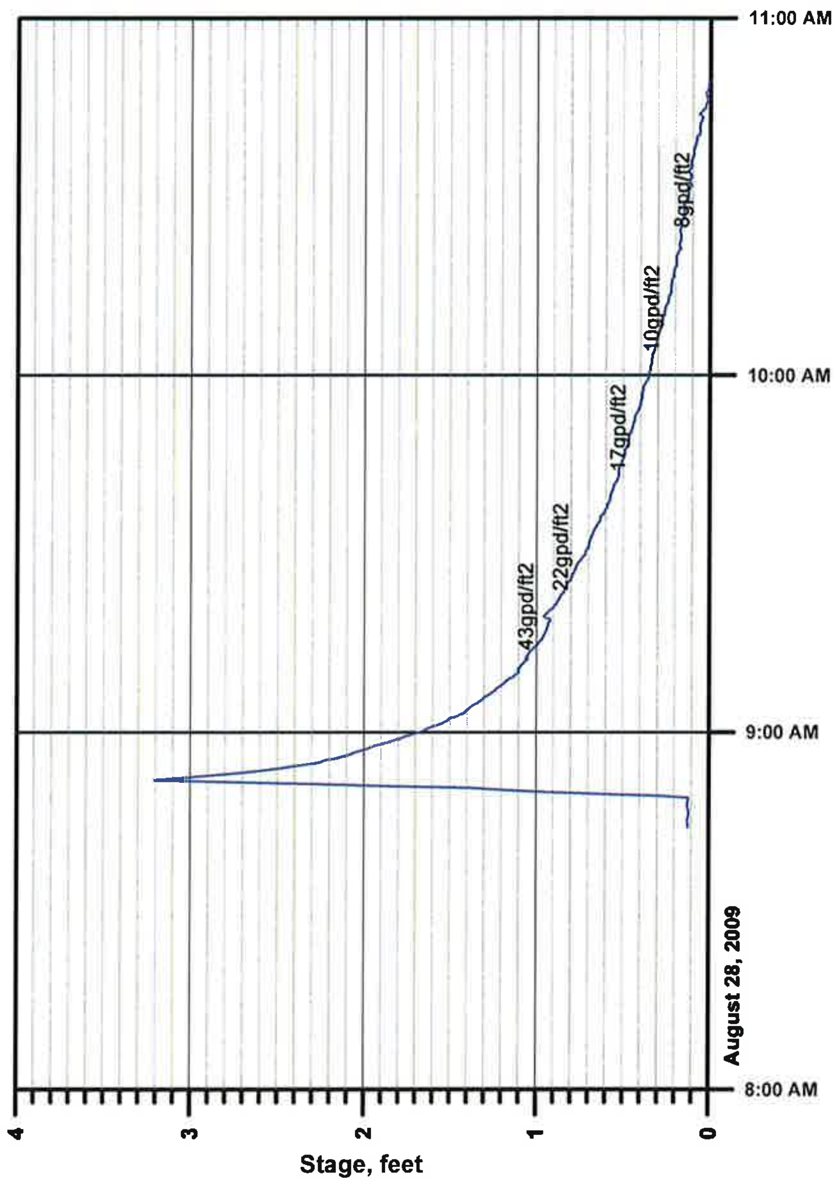
0 — 1000 FEET

SITE MAP AND EXPLORATION LOCATIONS

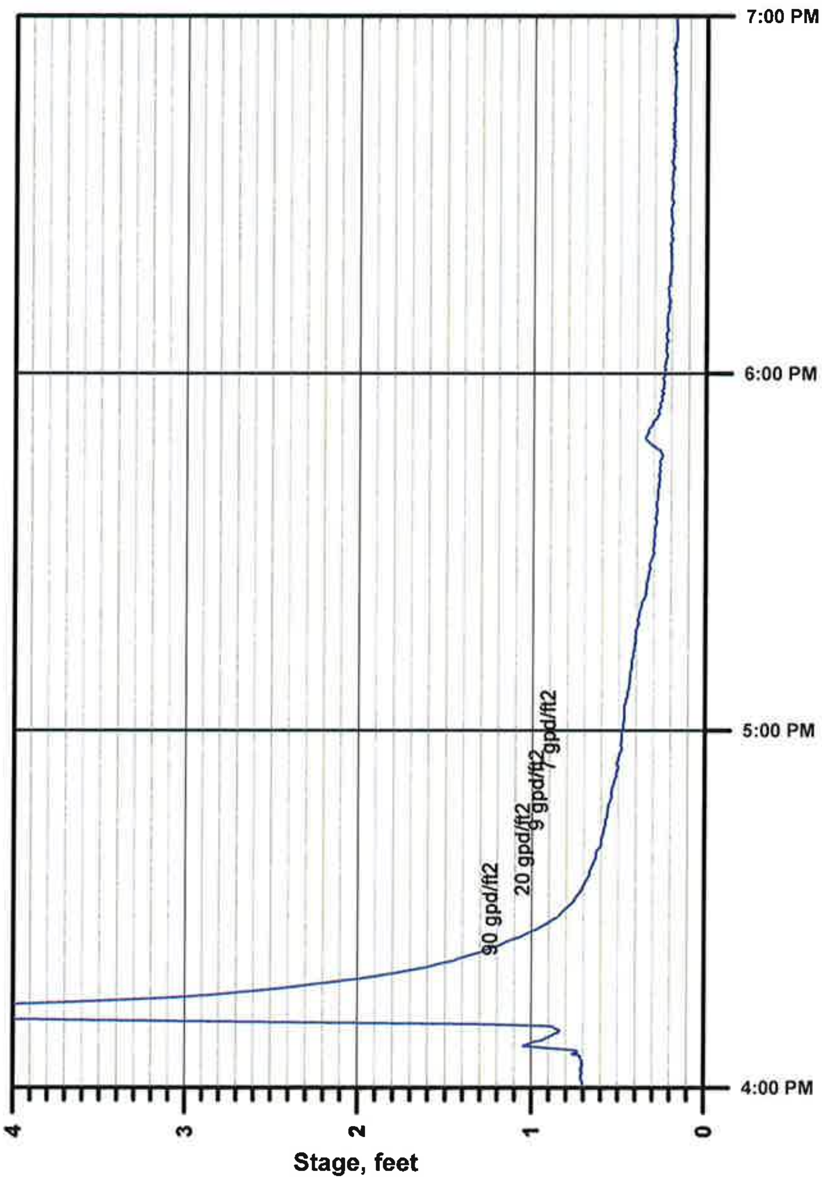
Pasquini Property Investigation
Nipomo, California

PLATE 4

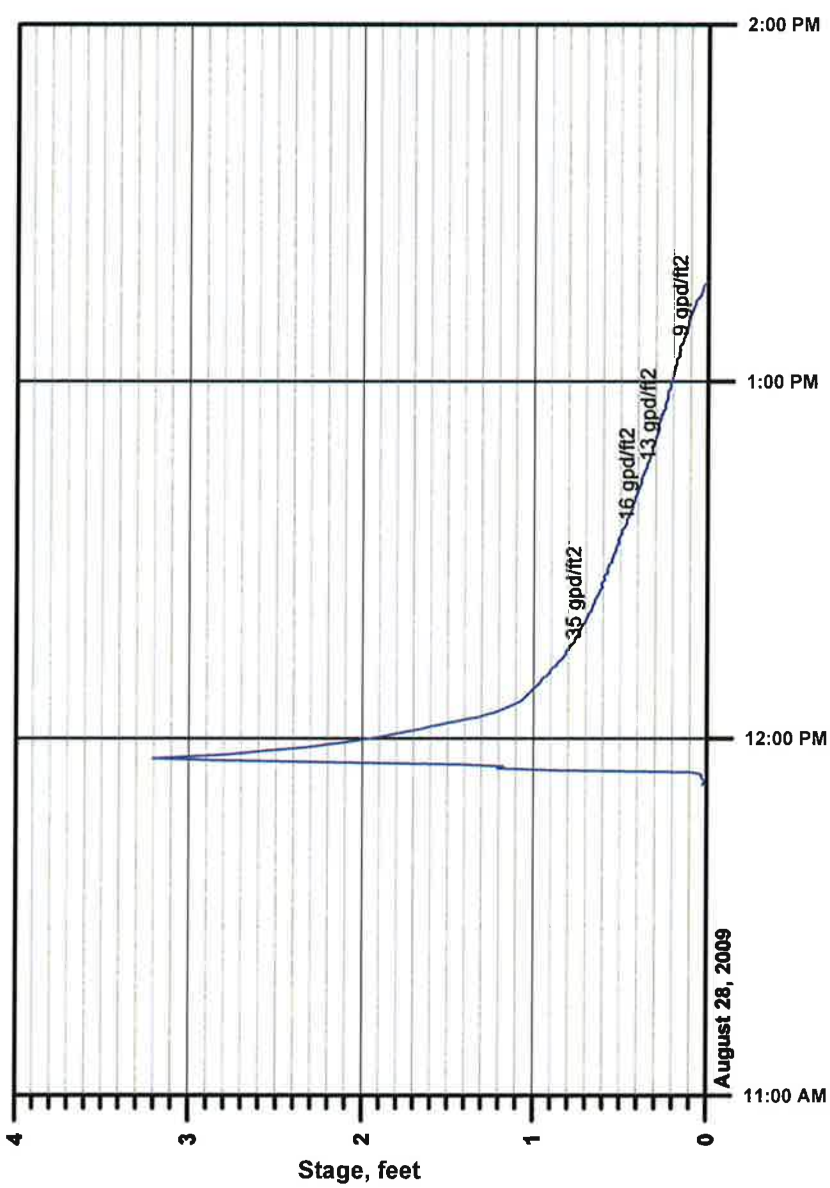
M:\Drafting\JOBFILES\2010\3596\3596.005\Drawings\A3596.005-03 explor.dwg 01-07-2010 - 8:05am



CONVENTIONAL PERCOLATION TEST, SITE 1
Pasquini Property Investigation
Nipomo, California



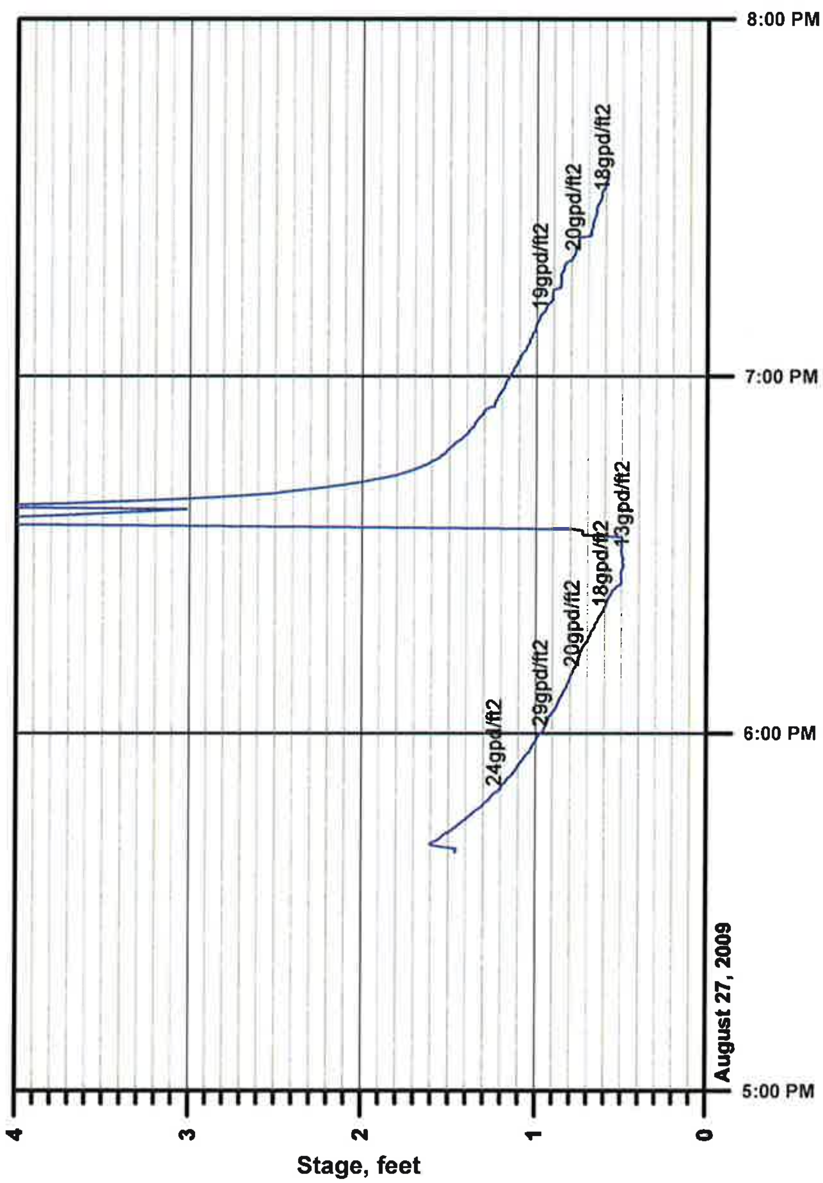
CONVENTIONAL PERCOLATION TEST, SITE 2
Pasquini Property Investigation
Nipomo, California



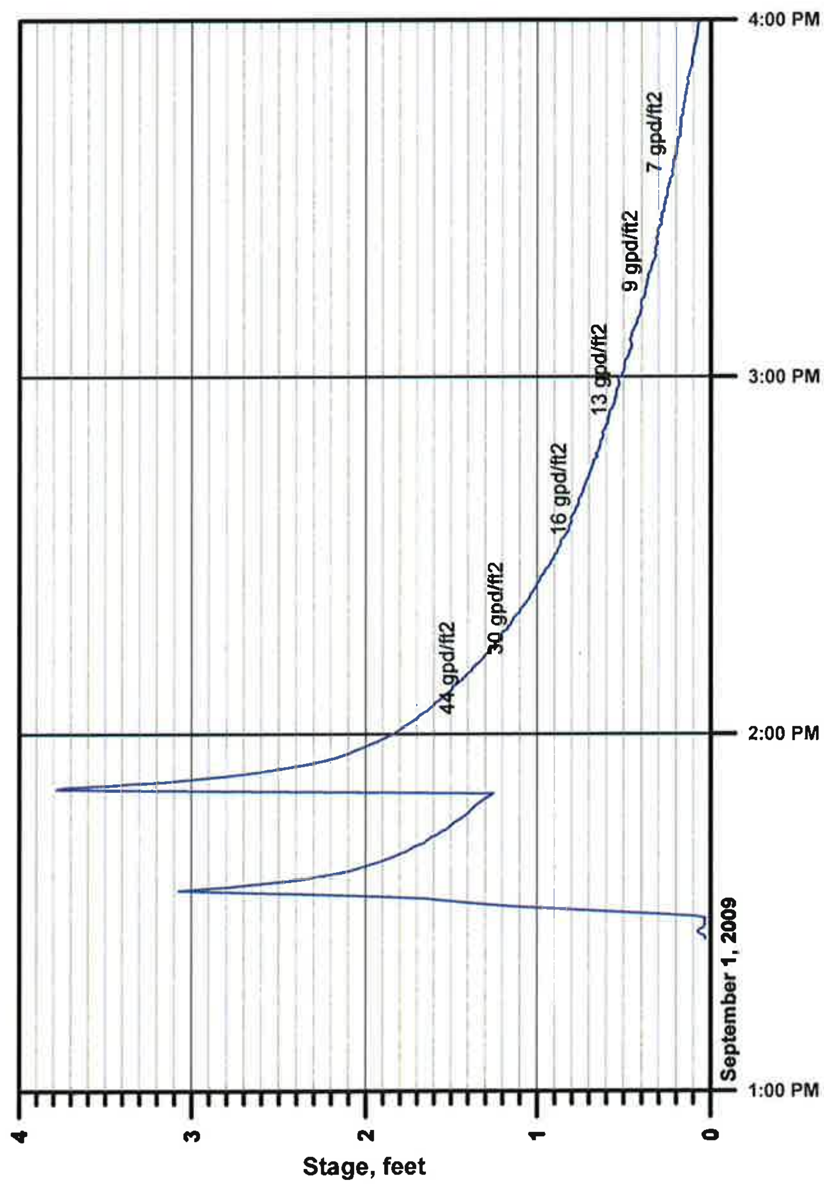
CONVENTIONAL PERCOLATION TEST, SITE 5

Pasquini Property Investigation

Nipomo, California



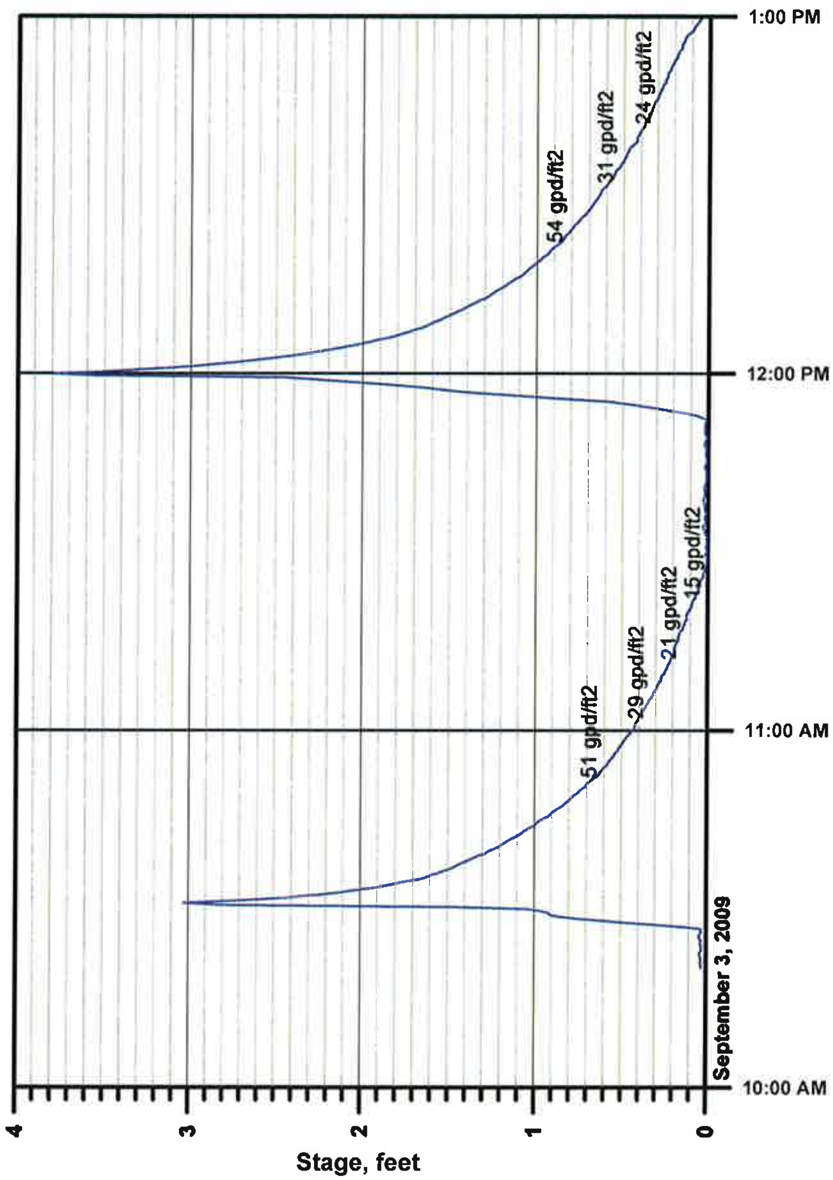
CONVENTIONAL PERCOLATION TEST, SITE 6
Pasquini Property Investigation
Nipomo, California



CONVENTIONAL PERCOLATION TEST, SITE 7

Pasquini Property Investigation

Nipomo, California



CONVENTIONAL PERCOLATION TEST, SITE 8
Pasquini Property Investigation
Nipomo, California