**Geotechnical Report**

# Neckel Road Sewer and Water Pipeline Crossing
## Imperial, California

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**Geotechnical Report**
**Neckel Road Water and Sewer Pipelines Crossing**
**State Hwy 86 at Neckel Road**
**Imperial, California**
***LCI Report No. LE15112***

Dear Mr. Danielson:

We are pleased to present this geotechnical report for the proposed construction of the water main and force sewer main pipelines crossing under State Hwy 86 at Neckel Road in northern Imperial, California. The proposed project will consist of a bore and jack pit on both sides of State Hwy 86 for the installation of the water and sewer force main pipelines.

Our geotechnical report was conducted in response to your request for our services. The enclosed report describes the exploration conducted and presents our professional opinions regarding geotechnical aspects of design and construction of the project.

This executive summary presents ***selected*** elements of our findings and professional opinions. It ***does not*** present all details needed for the proper application of our findings and professional opinions. Our findings, professional opinions, and application options are best related ***through reading the full report***, and are best evaluated with the active participation of the engineer of record who developed them.

The findings of this study indicate that the soils at the proposed bore and jack pits consist of surficial clayey silts and silty clay to a depth of approximately 11 feet. A saturated, loose clayey sandy silt and clay layer extends from 11 to 17 feet. A very stiff silty clay was encountered from 17 feet to a maximum depth of 26.5 feet below ground surface.

The soil is highly corrosive to metals and contains sufficient sulfates and chlorides to require special concrete mixes (4,500 psi with a 0.45 maximum water cement ratio and Type V cement) and protection of embedded steel components when concrete is placed in contact with native soil. All metal fittings, valves and appurtenances should be coated or wrapped in accordance with AWWA Standards for corrosion protection.

Groundwater depth was measured at 9.8 to 10.7 feet below ground surface in piezometers set at the project site. Dewatering prior to excavation should be anticipated.

We appreciate the opportunity to provide our findings and professional opinions regarding geotechnical conditions at the site. If you have any questions or comments regarding our findings, please call our office at (760) 370-3000.

Respectfully Submitted,
***Landmark Consultants, Inc.***

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## APPENDICES

# Section 1
# INTRODUCTION

## 1.1 Project Description

This report presents the findings of our geotechnical study for the proposed construction of the water and force sewer main pipelines crossing under State Hwy 86 at Neckel Road in northern Imperial, California. The pipeline alignment will be on the north side of Neckel Road and extend under the divided, four-lane State Hwy 86.

## 1.2 Purpose and Scope of Work

The purpose of this geotechnical study was to classify and/or test the upper 26.5 feet of subsurface soils for physical/engineering properties and set two (2) piezometers at each of the bore and jack pits. From this field and laboratory study, professional opinions are being provided regarding geotechnical design parameters at this site for the proposed construction. The scope of our services included the following:

- Field exploration and in-situ testing of the site soils at selected locations and depths
- Laboratory testing for physical and/or chemical properties and soil classification of selected samples
- Review of published geologic and seismologic literature in the project vicinity
- Analysis and evaluation of the data collected
- Groundwater level monitoring for an approximately 6-month duration after installation of piezometers
- Preparation of this report presenting our findings and professional opinions for the geotechnical aspects of project design and construction.

This report addresses the following geotechnical issues:

- Subsurface soil and groundwater conditions
- Site geology, regional faulting and seismicity, and site acceleration
- Aggressive soil conditions to metals and concrete

Professional opinions considering the above issues are presented for the following:

- Lateral earth pressures
- Excavation conditions and buried utility installations
- Backfill requirements
- Allowable soil bearing pressures
- Mitigation of the potential effects of salt concentrations (corrosivity) in native soils to concrete mixes and steel pipes

Our scope of work for this report did not include an evaluation of the site for the presence of potential environmental hazards or evaluation of effectiveness of dewatering methods.

### 1.3 Authorization

Mr. William Malone, Vice President of Albert A. Webb Associates, provided authorization by written agreement to proceed with our work on July 13, 2015 per Task Order Agreement 2015-0107. We conducted our work according to our written revised proposal dated June 2, 2015.

## Section 2
## METHODS OF INVESTIGATION

### 2.1 Field Exploration

Subsurface exploration was performed on July 9, 2015 using 2R Drilling of Ontario, California to advance two (2) borings to depths of 26.5 feet below existing ground surface. The borings were advanced with a truck-mounted, CME 75 drill rig using 8-inch diameter, hollow-stem, continuous-flight augers. The boring locations are shown on the Site and Exploration Plan (Plate A-2).

A staff engineer observed the drilling operations and maintained a log of the soil encountered and sampling depths, visually classified the soil encountered during drilling in accordance with the Unified Soil Classification System, and obtained drive tube and bulk samples of the subsurface materials at selected intervals. Relatively undisturbed soil samples were retrieved using a 2-inch outside diameter (OD) split-spoon sampler or a 3-inch OD Modified California Split-Barrel (ring) sampler. The samples were obtained by driving the sampler ahead of the auger tip at selected depths. The drill rig was equipped with a 140-pound CME automatic hammer for conducting Standard Penetration Tests (SPT). The number of blows required to drive the samplers 12 inches into the soil is recorded on the boring logs as “blows per foot”. Blow counts (N values) reported on the boring logs represent the field blow counts. No corrections have been applied for effects of overburden pressure, automatic hammer drive energy, drill rod lengths, liners, and sampler diameter. Pocket penetrometer readings were also obtained to evaluate the stiffness of cohesive soils retrieved from sampler barrels.

After logging and sampling the soil, 2-inch diameter PVC piezometers were set in the exploratory borings for periodic measurement of stabilized groundwater level readings. The slotted section of the piezometers was encapsulated in a cloth filter fabric. Native soil was used for backfill of the annular space. The backfill was loosely placed and was not compacted to the requirements specified for engineered fill. Steel covers with a concrete apron were set to protect the piezometers from traffic. Initial groundwater depth measurements of the piezometers were made on July 13, 2015, approximately 4 days after initial drilling.

The subsurface logs are presented on Plates B-1 and B-2 in Appendix B. A key to the log symbols is presented on Plate B-3. The stratification lines shown on the subsurface log represent the approximate boundaries between the various strata. However, the transition from one stratum to another may be gradual over some range of depth.

## 2.2 Laboratory Testing

Laboratory tests were conducted on selected soil samples to aid in classification and evaluating selected engineering properties. The tests were conducted in general accordance with the procedures of the American Society for Testing and Materials (ASTM) or other standardized methods as referenced below. Our laboratory testing program consisted of the following tests:

- Particle Size Analyses (ASTM D422)
- Plasticity Index (ASTM D4318)
- Unit Dry Densities (ASTM D2937) and Moisture Contents (ASTM D2216)
- Direct Shear (ASTM D3080)
- Chemical Analyses (soluble sulfates & chlorides, pH, and resistivity) (Caltrans Methods)

The laboratory test results are presented on the subsurface logs (Appendix B) and on Plates C-1 through C-4 in Appendix C.

Engineering parameters of soil physical properties, strength, and insitu density were utilized for developing design criteria provided within this report were derived from data obtained from the field and laboratory testing program.

## Section 3
## DISCUSSION

### 3.1 Site Conditions

The proposed project will consist of placing a water pipeline and a sewer force main pipeline along the north side of Neckel Road that will require crossing below State Hwy 86, a divided four-lane expressway. Bore and jack pits are planned to be constructed on both sides of Hwy 86 to allow installation of the pipelines in steel sleeves.

Adjacent properties are flat-lying and are approximately at the same elevation with the roads. Residential homes and multi-family dwellings are located to the east side of Hwy 86. A vacant lot is located to the southwest and a Holiday Inn Express (under construction) is located to the northwest. The Dahlia Lateral 8 Canal is located on the east side of Hwy 86 and is undergrounded (pipelined) south of Neckel Road. The Dahlia 8 Drain (10 foot deep open earthen drainage channel) is located on the west side of Hwy 86.

The project site lies at an elevation of approximately 60 feet below mean sea level (MSL) (El. 980 to 930 local datum) in the Imperial Valley region of the California low desert. The surrounding properties lie on terrain which is flat (planar), part of a large agricultural valley, which was previously an ancient lake bed covered with fresh water to an elevation of 43± feet above MSL. Annual rainfall in this arid region is less than 3 inches per year with four months of average summertime temperatures above 100 $^{o}$F. Winter temperatures are mild, seldom reaching freezing

### 3.2 Geologic Setting

The project site is located in the Imperial Valley portion of the Salton Trough physiographic province. The Salton Trough is a topographic and geologic structural depression resulting from large scale regional faulting. The trough is bounded on the northeast by the San Andreas Fault and Chocolate Mountains and the southwest by the Peninsular Range and faults of the San Jacinto Fault Zone.

The Salton Trough represents the northward extension of the Gulf of California, containing both marine and non-marine sediments since the Miocene Epoch. Tectonic activity that formed the trough continues at a high rate as evidenced by deformed young sedimentary deposits and high levels of seismicity. Figure 1 shows the location of the site in relation to regional faults and physiographic features.

The Imperial Valley is directly underlain by lacustrine deposits, which consist of interbedded lenticular and tabular silt, sand, and clay. The Late Pleistocene to Holocene lake deposits are probably less than 100 feet thick and derived from periodic flooding of the Colorado River which intermittently formed a fresh water lake (Lake Cahuilla). Older deposits consist of Miocene to Pleistocene non-marine and marine sediments deposited during intrusions of the Gulf of California. Basement rock consisting of Mesozoic granite and Paleozoic metamorphic rocks are estimated to exist at depths between 15,000 - 20,000 feet.

### 3.3 Seismicity and Faulting

Faulting and Seismic Sources: We have performed a computer-aided search of known faults or seismic zones that lie within a 62 mile (100 kilometer) radius of the project site as shown on Figure 1 and Table 1. The search identifies known faults within this distance and computes deterministic ground accelerations at the site based on the maximum credible earthquake expected on each of the faults and the distance from the fault to the site.

Seismic Risk: The project site is located in the seismically active Imperial Valley of southern California and is considered likely to be subjected to moderate to strong ground motion from earthquakes in the region. The proposed site structures should be designed in accordance with the 2010 California Building Code (CBC) for a “Maximum Considered Earthquake” (MCE) and with the appropriate site coefficients.

Seismic Hazards.

- **Groundshaking.** The primary seismic hazard at the project site is the potential for strong groundshaking during earthquakes along the Imperial, Brawley, and Superstition Hills Faults. A further discussion of groundshaking follows in Section 3.4.

‣ **Surface Rupture.** The project site does not lie within a State of California, Alquist-Priolo Earthquake Fault Zone. Surface fault rupture is considered to be unlikely at the project site because of the well-delineated fault lines through the Imperial Valley as shown on USGS and CDMG maps. However, because of the high tectonic activity and deep alluvium of the region, we cannot preclude the potential for surface rupture on undiscovered or new faults that may underlie the site.

‣ **Liquefaction.** Liquefaction can potentially occur at the site because of underlying saturated sandy substrata. In general, liquefaction studies performed by our firm in this region may result in ½ to 3 inches of settlement in the mass soil structure. The flexible nature of the water and sewer pipeline joints will generally accept this type of deflection.

<u>Other Secondary Hazards.</u>

‣ **Landsliding.** The hazard of landsliding is unlikely due to the regional planar topography. No ancient landslides are shown on geologic maps of the region and no indications of landslides were observed during our site investigation.

‣ **Volcanic hazards.** The site is not located in proximity to any known volcanically active area and the risk of volcanic hazards is considered very low.

‣ **Tsunamis, seiches, and flooding.** The site does not lie near any large bodies of water, so the threat of tsunami, seiches, or other seismically-induced flooding is unlikely.

‣ **Expansive soil.** In general, much of the near surface soils in the Imperial Valley consist of silty clays and clays which are moderate to highly expansive.

### 3.4 General Ground Motion Analysis

<u>Site Acceleration:</u> Ground motions are dependent primarily on the earthquake magnitude and distance to the seismogenic (rupture) zone. Accelerations also are dependent upon attenuation by rock and soil deposits, direction of rupture and type of fault; therefore, ground motions may vary considerably in the same general area.

CBC General Ground Motion Parameters: The 2013 CBC general ground motion parameters are based on the Risk-Targeted Maximum Considered Earthquake ($MCE_R$). The U.S. Geological Survey "U.S. Seismic Design Maps Web Application" (USGS, 2014) was used to obtain the site coefficients and adjusted maximum considered earthquake spectral response acceleration parameters. **The site soils have been classified as Site Class D (stiff soil profile).**

Design spectral response acceleration parameters are defined as the earthquake ground motions that are two-thirds (2/3) of the corresponding $MCE_R$ ground motions. Design earthquake ground motion parameters are provided in Table 2. **A Risk Category I was determined using Table 1604A.5 and the Seismic Design Category is D since $S_1$ is less than 0.75g.**

The Maximum Considered Earthquake Geometric Mean ($MCE_G$) peak ground acceleration ($PGA_M$) value was determined from the "U.S. Seismic Design Maps Web Application" (USGS, 2015) for liquefaction and seismic settlement analysis in accordance with 2013 CBC Section 1803A.5.12 and CGS Note 48 ($PGA_M = F_{PGA}$*PGA). **A $PGA_M$ value of 0.72g has been determined for the project site.**

### 3.5 Subsurface Soils

Subsurface soils encountered during the field exploration conducted July 9, 2015 are fine grained lake bed sediments consisting of surficial clayey silts and silty clay to a depth of approximately 11 feet. A saturated, loose clayey sandy silt and clay layer extends from 11 to 17 feet. A very stiff silty clay was encountered from 17 feet to a maximum depth of 26.5 feet below ground surface. The subsurface logs (Plates B-1 and B-2) depict the stratigraphic relationships of the various soil types.

### 3.6 Groundwater

Two (2) temporary piezometers (2-inch diameter slotted PVC pipe) were installed in the borings to a depth of 25 feet. Initial groundwater levels were measured on July 13, 2015 (approximately four days after drilling). The following table shows the groundwater level elevations measured from the existing ground surface at each piezometer location on July 13, 2015 and July 15. 2015.

| Location | 7/13/15 | 7/15/15 |
|---|---|---|
| B-1 (East side) | 10.67 | 10.55 |
| B-2 (West side) | 9.83 | 9.80 |

There is uncertainty in the accuracy of short-term water level measurements, particularly in fine-grained soil. Groundwater levels may fluctuate with precipitation, irrigation of adjacent properties, drainage, and site grading. The referenced groundwater level should not be interpreted to represent an accurate or permanent condition.

### 3.7 Recharge Rates of Piezometers

A pump test was conducted on each of the monitoring wells to obtain information for dewatering of the bore and jack pits. The pump test was conducted on July 15, 2015 by pumping the wells dry and recording the rate at which the wells recover to the stabilized water levels.

| Location | Initial Groundwater Level (ft) | Pumped Groundwater Level (ft) | Time to Recharge to Initial Level | Recharge Rate (gal/min) |
|---|---|---|---|---|
| B-1 | 10.55 | 19.75 | 43 min. | 0.035 |
| B-2 | 9.80 | 21.40 | 32 min | 0.059 |

This information along with the boring logs should be provided to the dewatering contractor for design of dewatering wells for this project.

# Section 4
# RECOMMENDATIONS

## 4.1 Excavations for Pipeline and Jack Pits

The water and sewer force main pipelines will be installed beneath State Hwy 86 by "bore and jack" methods. The bore and jack operations should proceed with good construction practice so as not to interfere with the highway or result in caving of soils ahead of the tunneling sleeve which can cause settlement of the roadway above. The Dahlia 8 Drain and Dahlia Lateral 8 Canal are pipelined in the area of the project site. The depth of these pipelines should be considered prior to beginning bore and jack operations.

Caution is necessary because of saturated, loose sandy silt soils at depths between 11 and 17 feet below ground surface. An option to mitigate the saturated silt is to stabilize the soil in line with the bore sleeve with compaction grouting techniques. This would allow the bore sleeve to advance through a solid mass rather than running soil. Jacking operations should comply with "*Standard Specifications for Public Works Construction*", Section 306-2.

After dewatering, all site excavations should conform to CalOSHA requirements for Type B soils (silts and sands). The contractor is solely responsible for the safety of workers entering trenches. Shallow, temporary excavations with depths of 4 feet or less may be cut nearly vertical for short duration. Temporary slopes should be no steeper than 1(H):1(V) for Type B soils, unless trench shoring is used.

An adequately designed, braced excavation such as sheet pile retention system may be used for temporary shoring of the bore and jack pit excavation. The strut loads may be designed by apparent earth pressure. The apparent earth pressure may be taken as a trapezoidal distribution that is maximum from 0.2 to 0.8H below the top of the trench and has the value of 35H psf where H is the height of the supported earth in feet.

Statements in this section regarding stable excavation slopes assume minimal equipment vibration and adequate setback of excavated material and construction equipment from the top of the excavation. We recommended that the minimum setback distance be equal to the depth of excavation and at least 10 feet from the top edge of the excavation.

If excavated materials are stockpiled adjacent to the excavation, the weight of the material should be considered as a surcharge load for slope stability.

The project specifications should clearly state that all excavations be constructed in conformance to the Cal OSHA requirements. The project documents should state that the contractor has sole responsibility for the safety of his personnel.

### 4.2 Bedding and Backfill of Pipeline

Trench backfill for utilities should conform to San Diego Regional Standard Drawing S-4 (Appendix D), using either Type A, B or C backfill.

***Type A*** backfill for HDPE pipe (above groundwater) consists of a 4 to 6 inch bed of ¾-inch crushed rock below the pipe and pipezone backfill (to 12” above top of pipe) consisting of crusher fines (sand). Sewer pipes (SDR-35), water mains, and stormdrain pipes of other than HDPE pipe may use crusher fines for bedding. The crusher fines shall be compacted to a minimum of 95% of ASTM D1557 maximum density. Pipe deflection should be checked to not exceed 2% of pipe diameter. Native clay/silt soils may be used to backfill the remainder of the trench. Soils used for trench backfill shall be compacted to a minimum of 90% of ASTM D1557 maximum density.

***Type B*** backfill for HDPE pipe (shallow cover) requires 6 inches of ¾-inch crushed rock as bedding and to springline of the pipe. Thereafter, sand/cement slurry (3 sack cement factor) should be used to 12 inches above the top of the pipe. Native clay and silt soils may be used in the remainder of the trench backfill as specified above.

***Type C*** backfill for HDPE pipe (below or partially below groundwater) shall consist of a geotextile filter fabric encapsulating ¾-inch crushed rock. The crushed rock thickness shall be 6 inches below and to the sides of the pipe and shall extend to 12 inches above the top of the pipe. The filter fabric shall cover the trench bottom, sidewalls and over the top of the crushed rock. Native clay and silt soils may be used in the remainder of the trench backfill as specified above.

**Type C backfill must be used in wet soils and below groundwater for all buried utility pipelines. Dewatering (by well points) is required to at least 24 inches below the trench bottom prior to excavation. Type A backfill may be used in the case of a dewatered trench condition in clay soils only.**

On-site soil free of debris, vegetation, and other deleterious matter may be suitable for use as utility trench backfill above pipezone, but may be difficult to uniformly maintain at specified moistures and compact to the specified densities. If wet native soils are present, the soils should be dried to 0 to 5% above optimum moisture prior to placement in the excavation. If the wet native soils cannot be dried back, suitable import soil may be used for trench backfill. Native backfill should only be placed and compacted after encapsulating buried pipes with suitable bedding and pipe envelope material. Imported granular material is acceptable for backfill of utility trenches.

Backfill soil of utility trenches within all street areas should be placed in layers not more than 6 inches in thickness and mechanically compacted to a minimum of 90% of the ASTM D1557 maximum dry density at 0 to 5% above optimum moisture. The designer may consider lesser backfill compaction in areas outside of street right-of-way and where some settlement of the backfill is not detrimental.

### 4.3 Bearing Capacity of Thrust Blocks

Resistance to lateral forces can be assumed to be provided by friction at the base of thrust blocks and by passive earth pressure. Thrust blocks for the pipeline may be designed using a lateral bearing capacity based on an allowable lateral soil pressure of 250 pcf, computed as an equivalent fluid pressure. An ultimate value of coefficient of friction of 0.35 may be used between the thrust block and the supporting natural soil or compacted fill. The allowable vertical soil pressure may be taken as 1,500 psf.

### 4.4 Dewatering

Groundwater has been encountered in the temporary piezometers at depths ranging from 9.8 to 10.55 feet below ground surface. The contractor is cautioned to evaluate soil moisture and groundwater conditions at the time of bidding. Running ground conditions should be anticipated below the groundwater level. Dewatering (by well points) will be necessary (prior to excavation) to conduct bore and jack operations below groundwater elevation. Groundwater elevations should be lowered to a minimum of 2 feet below the bottom of the proposed bore and jack pit depth prior to excavation. The responsibility for dewatering methods and selection of an appropriate system is beyond the scope of this report.

### 4.5 Concrete Mixes and Corrosivity

Selected chemical analyses for corrosivity were conducted on a soil sample at the anticipated depth of the pipeline elevation (Plate C-5). The native soil was found to have low sulfate ion concentration (441 ppm). Sulfate ions in high concentrations can attack the cementitious material in concrete, causing weakening of the cement matrix and eventual deterioration by raveling.

A minimum of 6.0 sacks per cubic yard of concrete (4,500 psi) of Type V Portland Cement with a maximum water/cement ratio of 0.45 (by weight) should be used for concrete placed in contact with native soil on this project. Admixtures may be required to allow placement of this low water/cement ratio concrete.

The native soil has moderate chloride ion concentrations (330 ppm). Chloride ions can cause corrosion of reinforcing steel and buried metallic conduits. Resistivity determinations on the soil indicate severe potential for metal loss because of electrochemical corrosion processes. A minimum concrete cover of 3.0 inches shall be provided around steel reinforcing or embedded components exposed to native soil. If the 3-inch concrete edge distance cannot be achieved, all embedded steel components shall be epoxy dipped for corrosion protection or a permanent waterproofing membrane shall be placed along the exterior face of any structures.

Additionally, the concrete should be thoroughly vibrated at footings during placement to decrease the permeability of the concrete. All exposed metals/pipeline fittings should be coated or wrapped in polyethylene in accordance with AWWA Standards for corrosive protection.

### 4.6 Seismic Design

This site is located in the seismically active southern California area and the site structures are subject to strong ground shaking due to potential fault movements along the Laguna Salada, Superstition Hills, and Imperial faults. Engineered design and earthquake-resistant construction are the common solutions to increase safety and development of seismic areas. Designs should comply with the latest edition of the CBC for Site Class D using the seismic coefficients given in Section 3.4 of this report.

## Section 5
## LIMITATIONS AND ADDITIONAL SERVICES

### 5.1 Limitations

The findings and professional opinions within this report are based on current information regarding the proposed water and sewer force main pipelines extending under State Hwy 86 on the north side of Neckel Road in northern Imperial, California. The professional opinions of this report are invalid if:

- The sewer line is relocated.
- The Additional Services section of this report is not followed.
- This report is used for adjacent or other property.
- Changes of grade or groundwater occur between the issuance of this report and construction other than those anticipated in this report.
- Any other change that materially alters the project from that proposed at the time this report was prepared.

Findings and professional opinions in this report are based on selected points of field exploration, geologic literature, laboratory testing, and our understanding of the proposed project. Our analysis of data and professional opinions presented herein are based on the assumption that soil conditions do not vary significantly from those found at specific exploratory locations. Variations in soil conditions can exist between and beyond the exploration points or groundwater elevations may change. If detected, these conditions may require additional studies, consultation, and possible design revisions.

***This report contains information that may be useful in the preparation of contract specifications. However, the report is not worded is such a manner that we recommend its use as a construction specification document without proper modification. The use of information contained in this report for bidding purposes should be done at the contractor's option and risk.***

This report was prepared according to the generally accepted *geotechnical engineering standards of practice* that existed in Imperial County at the time the report was prepared. No express or implied warranties are made in connection with our services.

This report should be considered invalid for periods after two years from the report date without a review of the validity of the findings and professional opinions by our firm, because of potential changes in the Geotechnical Engineering Standards of Practice.

The client has responsibility to see that all parties to the project including, designer, contractor, and subcontractor are made aware of this entire report. The use of information contained in this report for bidding purposes should be done at the contractor's option and risk.

### 5.2 Additional Services

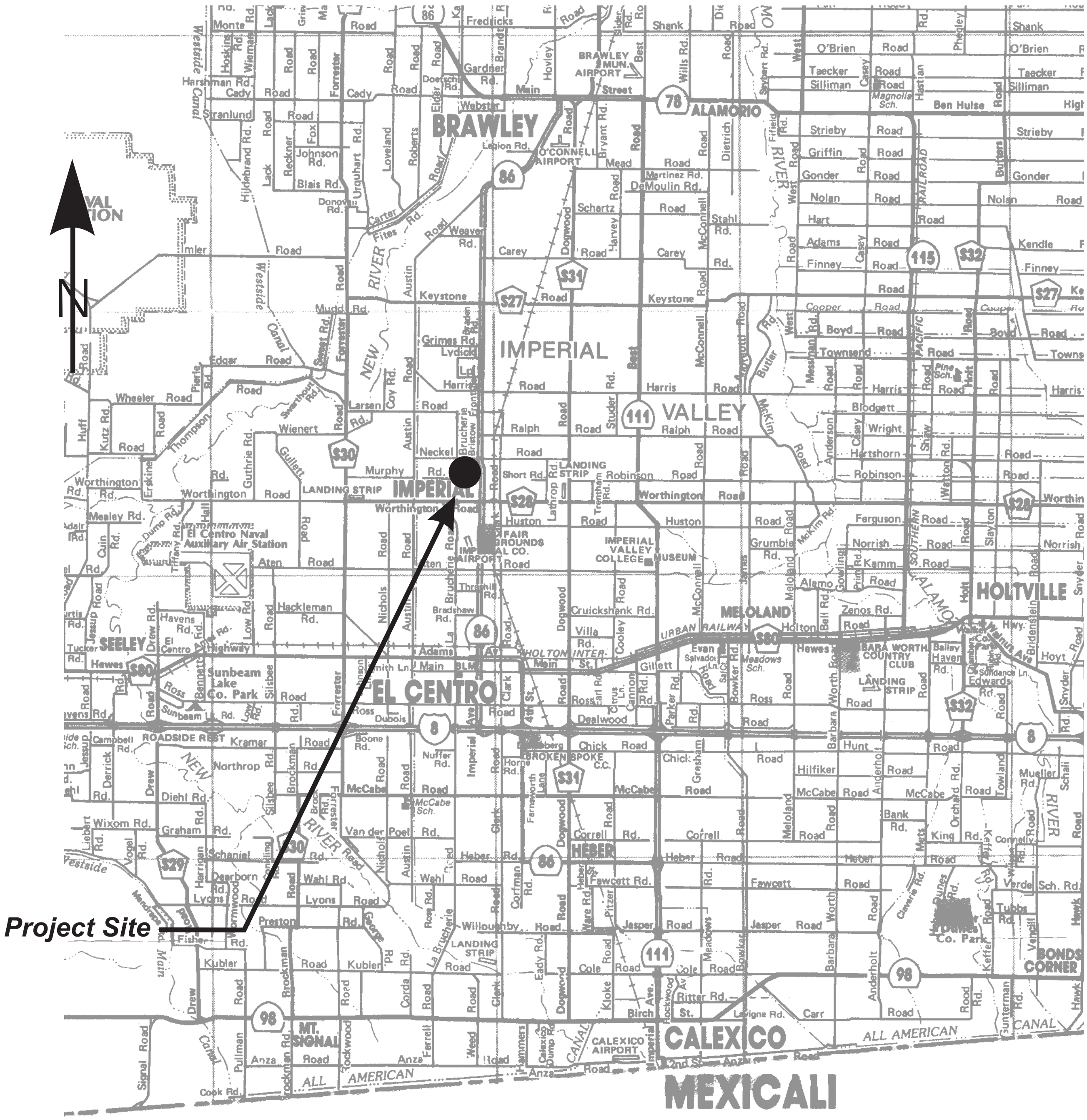
The professional opinions provided in this report are based on the assumption that an adequate program of tests and observations will be conducted during construction to check the field subsurface conditions and compliance of the professional opinions. *The geotechnical engineering firm providing the tests and observations shall assume the responsibility of geotechnical engineer of record.*

These tests and observations should include, but not necessarily be limited to the following:

- Observation and testing by the geotechnical consultant of record during excavation and backfilling of trenches.
- Consultation as may be required during construction.

In addition, we should review the project plans and specifications to check for compatibility with our professional opinions and conclusions. Additional information concerning the scope and cost of these services can be obtained from our office.

# APPENDIX A

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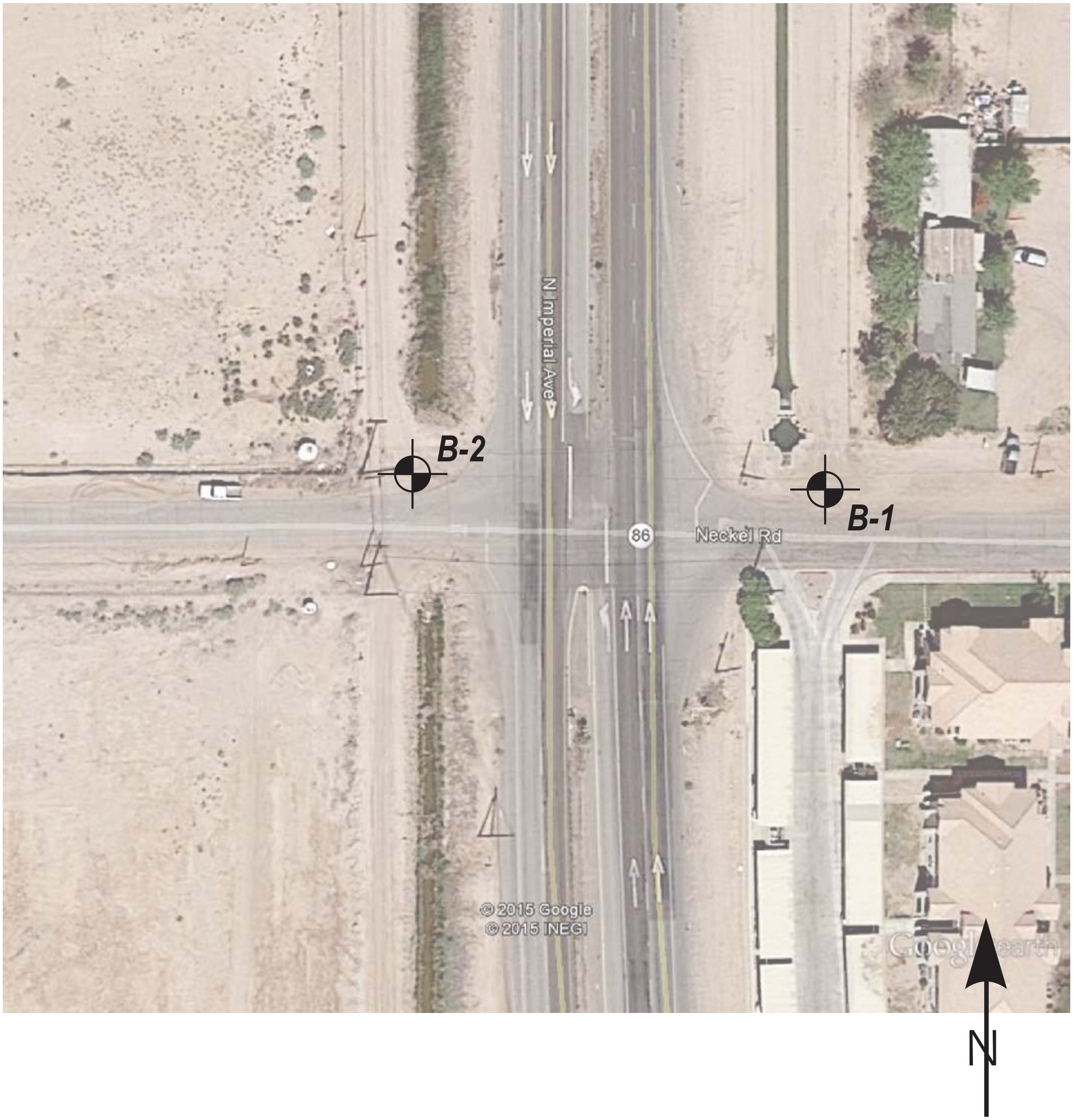
**Vicinity Map**

**Plate A-1**

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Site and Exploration Map

Plate A-2


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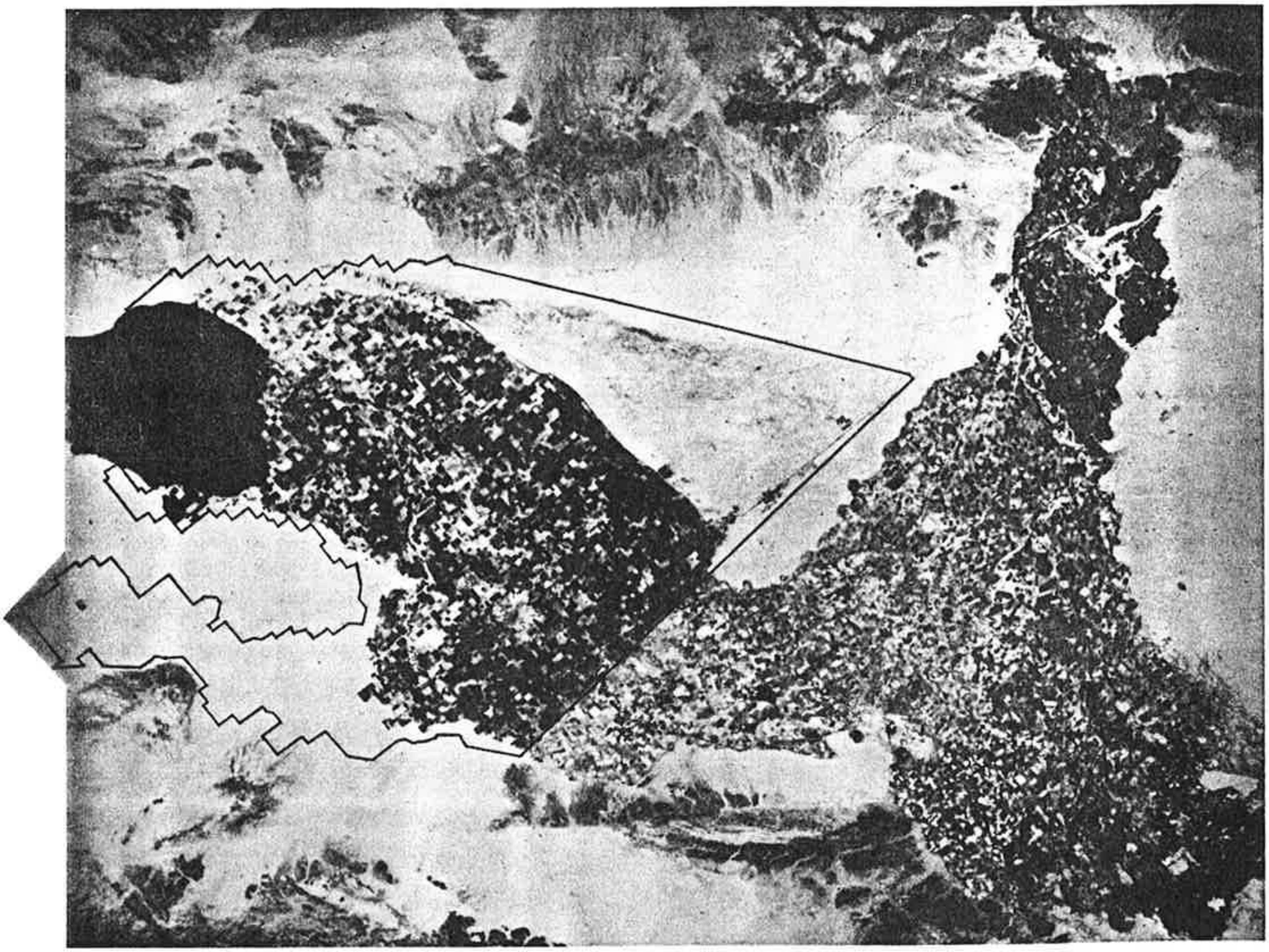
**Soil Survey Map**

**Plate**
**A-3**

Soil Survey of

# IMPERIAL COUNTY CALIFORNIA IMPERIAL VALLEY AREA



United States Department of Agriculture Soil Conservation Service
in cooperation with
University of California Agricultural Experiment Station
and
Imperial Irrigation District

TABLE 11.--ENGINEERING INDEX PROPERTIES

[The symbol > means more than. Absence of an entry indicates that data were not estimated]

| Soil name and map symbol | Depth | USDA texture | Classification | | Fragments > 3 inches | Percentage passing sieve number-- | | | | Liquid limit | Plasticity index |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Unified | AASHTO | | 4 | 10 | 40 | 200 | | |
| | In | | | | Pct | | | | | Pct | |
| 100----------------<br>Antho | 0-13 | Loamy fine sand | SM | A-2 | 0 | 100 | 100 | 75-85 | 10-30 | --- | NP |
| | 13-60 | Sandy loam, fine sandy loam. | SM | A-2, A-4 | 0 | 90-100 | 75-95 | 50-60 | 15-40 | --- | NP |
| 101*:<br>Antho------------- | 0-8 | Loamy fine sand | SM | A-2 | 0 | 100 | 100 | 75-85 | 10-30 | --- | NP |
| | 8-60 | Sandy loam, fine sandy loam. | SM | A-2, A-4 | 0 | 90-100 | 75-95 | 50-60 | 15-40 | --- | NP |
| Superstition------ | 0-6 | Fine sand------- | SM | A-2 | 0 | 100 | 95-100 | 70-85 | 15-25 | --- | NP |
| | 6-60 | Loamy fine sand, fine sand, sand. | SM | A-2 | 0 | 100 | 95-100 | 70-85 | 15-25 | --- | NP |
| 102*.<br>Badland | | | | | | | | | | | |
| 103----------------<br>Carsitas | 0-10 | Gravelly sand--- | SP, SP-SM | A-1, A-2 | 0-5 | 60-90 | 50-85 | 30-55 | 0-10 | --- | NP |
| | 10-60 | Gravelly sand, gravelly coarse sand, sand. | SP, SP-SM | A-1 | 0-5 | 60-90 | 50-85 | 25-50 | 0-10 | --- | NP |
| 104*<br>Fluvaquents | | | | | | | | | | | |
| 105----------------<br>Glenbar | 0-13 | Clay loam------- | CL | A-6 | 0 | 100 | 100 | 90-100 | 70-95 | 35-45 | 15-30 |
| | 13-60 | Clay loam, silty clay loam. | CL | A-6 | 0 | 100 | 100 | 90-100 | 70-95 | 35-45 | 15-30 |
| 106----------------<br>Glenbar | 0-13 | Clay loam------- | CL | A-6, A-7 | 0 | 100 | 100 | 90-100 | 70-95 | 35-45 | 15-25 |
| | 13-60 | Clay loam, silty clay loam. | CL | A-6, A-7 | 0 | 100 | 100 | 90-100 | 70-95 | 35-45 | 15-25 |
| 107*---------------<br>Glenbar | 0-13 | Loam----------- | ML, CL-ML, CL | A-4 | 0 | 100 | 100 | 100 | 70-80 | 20-30 | NP-10 |
| | 13-60 | Clay loam, silty clay loam. | CL | A-6, A-7 | 0 | 100 | 100 | 95-100 | 75-95 | 35-45 | 15-30 |
| 108----------------<br>Holtville | 0-14 | Loam----------- | ML | A-4 | 0 | 100 | 100 | 85-100 | 55-95 | 25-35 | NP-10 |
| | 14-22 | Clay, silty clay | CL, CH | A-7 | 0 | 100 | 100 | 95-100 | 85-95 | 40-65 | 20-35 |
| | 22-60 | Silt loam, very fine sandy loam. | ML | A-4 | 0 | 100 | 100 | 95-100 | 65-85 | 25-35 | NP-10 |
| 109----------------<br>Holtville | 0-17 | Silty clay------ | CL, CH | A-7 | 0 | 100 | 100 | 95-100 | 85-95 | 40-65 | 20-35 |
| | 17-24 | Clay, silty clay | CL, CH | A-7 | 0 | 100 | 100 | 95-100 | 85-95 | 40-65 | 20-35 |
| | 24-35 | Silt loam, very fine sandy loam. | ML | A-4 | 0 | 100 | 100 | 95-100 | 65-85 | 25-35 | NP-10 |
| | 35-60 | Loamy very fine sand, loamy fine sand. | SM, ML | A-2, A-4 | 0 | 100 | 100 | 75-100 | 20-55 | --- | NP |
| 110----------------<br>Holtville | 0-17 | Silty clay------ | CH, CL | A-7 | 0 | 100 | 100 | 95-100 | 85-95 | 40-65 | 20-35 |
| | 17-24 | Clay, silty clay | CH, CL | A-7 | 0 | 100 | 100 | 95-100 | 85-95 | 40-65 | 20-35 |
| | 24-35 | Silt loam, very fine sandy loam. | ML | A-4 | 0 | 100 | 100 | 95-100 | 55-85 | 25-35 | NP-10 |
| | 35-60 | Loamy very fine sand, loamy fine sand. | SM, ML | A-2, A-4 | 0 | 100 | 100 | 75-100 | 20-55 | --- | NP |

See footnote at end of table.

TABLE 11.--ENGINEERING INDEX PROPERTIES--Continued

| Soil name and map symbol | Depth | USDA texture | Classification | | Frag- ments > 3 inches | Percentage passing sieve number-- | | | | Liquid limit | Plas- ticity index |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Unified | AASHTO | | 4 | 10 | 40 | 200 | | |
| | In | | | | Pct | | | | | Pct | |
| 111*: | | | | | | | | | | | |
| Holtville---------- | 0-10 | Silty clay loam | CL, CH | A-7 | 0 | 100 | 100 | 95-100 | 85-95 | 40-65 | 20-35 |
| | 10-22 | Clay, silty clay | CL, CH | A-7 | 0 | 100 | 100 | 95-100 | 85-95 | 40-65 | 20-35 |
| | 22-60 | Silt loam, very fine sandy loam. | ML | A-4 | 0 | 100 | 100 | 95-100 | 65-85 | 25-35 | NP-10 |
| Imperial---------- | 0-12 | Silty clay loam | CL | A-7 | 0 | 100 | 100 | 100 | 85-95 | 40-50 | 10-20 |
| | 12-60 | Silty clay loam, silty clay, clay. | CH | A-7 | 0 | 100 | 100 | 100 | 85-95 | 50-70 | 25-45 |
| 112----------------- Imperial | 0-12 | Silty clay------- | CH | A-7 | 0 | 100 | 100 | 100 | 85-95 | 50-70 | 25-45 |
| | 12-60 | Silty clay loam, silty clay, clay. | CH | A-7 | 0 | 100 | 100 | 100 | 85-95 | 50-70 | 25-45 |
| 113----------------- Imperial | 0-12 | Silty clay------- | CH | A-7 | 0 | 100 | 100 | 100 | 85-95 | 50-70 | 25-45 |
| | 12-60 | Silty clay, clay, silty clay loam. | CH | A-7 | 0 | 100 | 100 | 100 | 85-95 | 50-70 | 25-45 |
| 114----------------- Imperial | 0-12 | Silty clay------- | CH | A-7 | 0 | 100 | 100 | 100 | 85-95 | 50-70 | 25-45 |
| | 12-60 | Silty clay loam, silty clay, clay. | CH | A-7 | 0 | 100 | 100 | 100 | 85-95 | 50-70 | 25-45 |
| 115*: | | | | | | | | | | | |
| Imperial---------- | 0-12 | Silty clay loam | CL | A-7 | 0 | 100 | 100 | 100 | 85-95 | 40-50 | 10-20 |
| | 12-60 | Silty clay loam, silty clay, clay. | CH | A-7 | 0 | 100 | 100 | 100 | 85-95 | 50-70 | 25-45 |
| Glenbar----------- | 0-13 | Silty clay loam | CL | A-6, A-7 | 0 | 100 | 100 | 90-100 | 70-95 | 35-45 | 15-25 |
| | 13-60 | Clay loam, silty clay loam. | CL | A-6, A-7 | 0 | 100 | 100 | 90-100 | 70-95 | 35-45 | 15-25 |
| 116*: | | | | | | | | | | | |
| Imperial---------- | 0-13 | Silty clay loam | CL | A-7 | 0 | 100 | 100 | 100 | 85-95 | 40-50 | 10-20 |
| | 13-60 | Silty clay loam, silty clay, clay. | CH | A-7 | 0 | 100 | 100 | 100 | 85-95 | 50-70 | 25-45 |
| Glenbar----------- | 0-13 | Silty clay loam | CL | A-6, A-7 | 0 | 100 | 100 | 90-100 | 70-95 | 35-45 | 15-25 |
| | 13-60 | Clay loam, silty clay loam. | CL | A-6 | 0 | 100 | 100 | 90-100 | 70-95 | 35-45 | 15-30 |
| 117, 118----------- Indio | 0-12 | Loam------------ | ML | A-4 | 0 | 95-100 | 95-100 | 85-100 | 75-90 | 20-30 | NP-5 |
| | 12-72 | Stratified loamy very fine sand to silt loam. | ML | A-4 | 0 | 95-100 | 95-100 | 85-100 | 75-90 | 20-30 | NP-5 |
| 119*: | | | | | | | | | | | |
| Indio------------- | 0-12 | Loam------------ | ML | A-4 | 0 | 95-100 | 95-100 | 85-100 | 75-90 | 20-30 | NP-5 |
| | 12-72 | Stratified loamy very fine sand to silt loam. | ML | A-4 | 0 | 95-100 | 95-100 | 85-100 | 75-90 | 20-30 | NP-5 |
| Vint-------------- | 0-10 | Loamy fine sand | SM | A-2 | 0 | 95-100 | 95-100 | 70-80 | 25-35 | --- | NP |
| | 10-60 | Loamy sand, loamy fine sand. | SM | A-2 | 0 | 95-100 | 95-100 | 70-80 | 20-30 | --- | NP |
| 120*--------------- Laveen | 0-12 | Loam------------ | ML, CL-ML | A-4 | 0 | 100 | 95-100 | 75-85 | 55-65 | 20-30 | NP-10 |
| | 12-60 | Loam, very fine sandy loam. | ML, CL-ML | A-4 | 0 | 95-100 | 85-95 | 70-80 | 55-65 | 15-25 | NP-10 |

See footnote at end of table.

TABLE 11.--ENGINEERING INDEX PROPERTIES--Continued

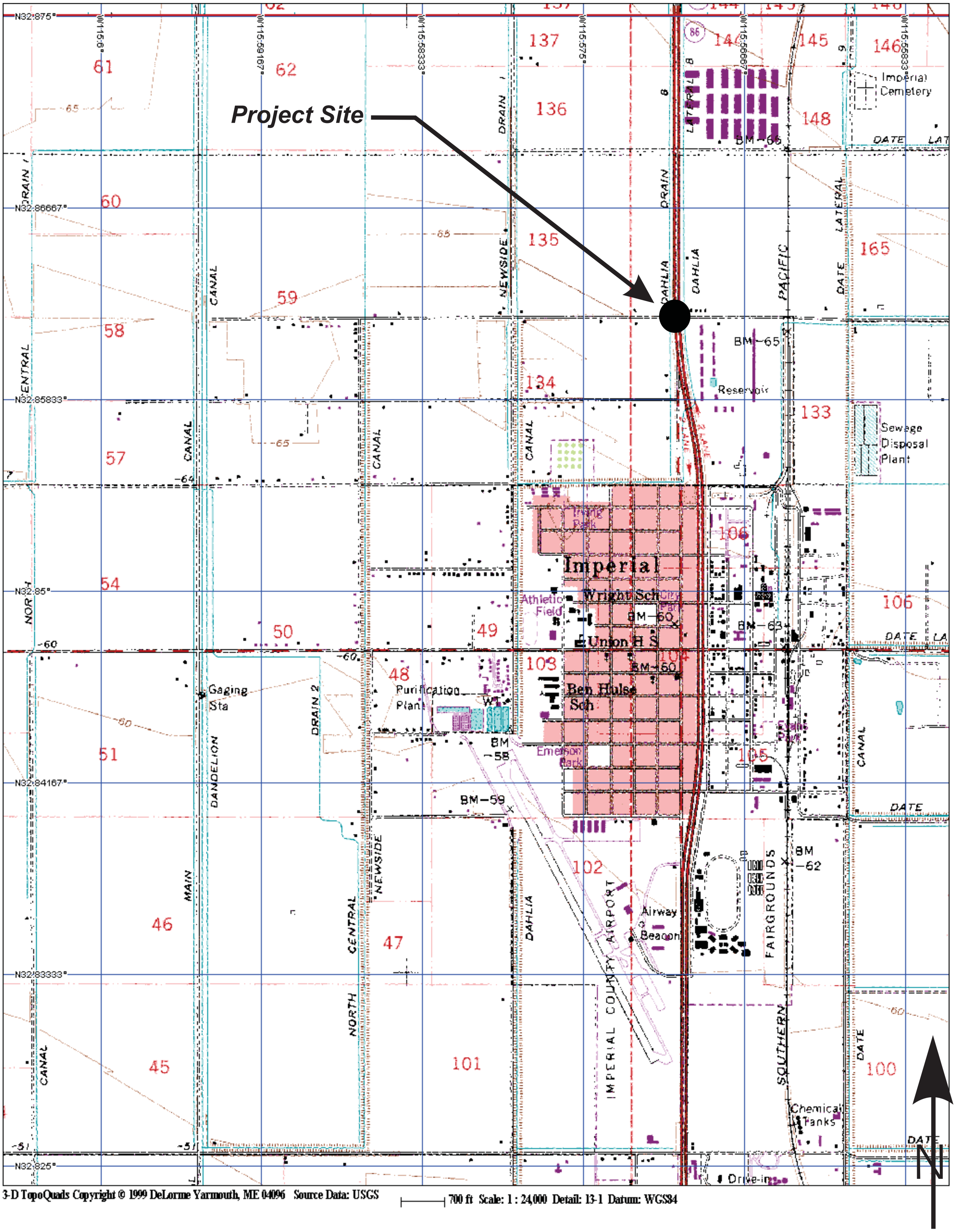
| Soil name and map symbol | Depth | USDA texture | Classification | | Frag-ments > 3 inches | Percentage passing sieve number-- | | | | Liquid limit | Plas-ticity index |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Unified | AASHTO | | 4 | 10 | 40 | 200 | | |
| | In | | | | Pct | | | | | Pct | |
| 121----------------- Meloland | 0-12 | Fine sand------- | SM, SP-SM | A-2, A-3 | 0 | 95-100 | 90-100 | 75-100 | 5-30 | --- | NP |
| | 12-26 | Stratified loamy fine sand to silt loam. | ML | A-4 | 0 | 100 | 100 | 90-100 | 50-65 | 25-35 | NP-10 |
| | 26-71 | Clay, silty clay, silty clay loam. | CL, CH | A-7 | 0 | 100 | 100 | 95-100 | 85-95 | 40-65 | 20-40 |
| 122----------------- Meloland | 0-12 | Very fine sandy loam. | ML | A-4 | 0 | 95-100 | 95-100 | 95-100 | 55-85 | 25-35 | NP-10 |
| | 12-26 | Stratified loamy fine sand to silt loam. | ML | A-4 | 0 | 100 | 100 | 90-100 | 50-70 | 25-35 | NP-10 |
| | 26-71 | Clay, silty clay, silty clay loam. | CH, CL | A-7 | 0 | 100 | 100 | 95-100 | 85-95 | 40-65 | 20-40 |
| 123*: | | | | | | | | | | | |
| Meloland---------- | 0-12 | Loam------------ | ML | A-4 | 0 | 95-100 | 95-100 | 95-100 | 55-85 | 25-35 | NP-10 |
| | 12-26 | Stratified loamy fine sand to silt loam. | ML | A-4 | 0 | 100 | 100 | 90-100 | 50-70 | 25-35 | NP-10 |
| | 26-38 | Clay, silty clay, silty clay loam. | CH, CL | A-7 | 0 | 100 | 100 | 95-100 | 85-95 | 40-65 | 20-40 |
| | 38-60 | Stratified silt loam to loamy fine sand. | SM, ML | A-4 | 0 | 100 | 100 | 75-100 | 35-55 | 25-35 | NP-10 |
| Holtville--------- | 0-12 | Loam------------ | ML | A-4 | 0 | 100 | 100 | 85-100 | 55-95 | 25-35 | NP-10 |
| | 12-24 | Clay, silty clay | CH, CL | A-7 | 0 | 100 | 100 | 95-100 | 85-95 | 40-65 | 20-35 |
| | 24-36 | Silt loam, very fine sandy loam. | ML | A-4 | 0 | 100 | 100 | 95-100 | 55-85 | 25-35 | NP-10 |
| | 36-60 | Loamy very fine sand, loamy fine sand. | SM, ML | A-2, A-4 | 0 | 100 | 100 | 75-100 | 20-55 | --- | NP |
| 124, 125----------- Niland | 0-23 | Gravelly sand--- | SM, SP-SM | A-2, A-3 | 0 | 90-100 | 70-95 | 50-65 | 5-25 | --- | NP |
| | 23-60 | Silty clay, clay, clay loam. | CL, CH | A-7 | 0 | 100 | 100 | 85-100 | 80-95 | 40-65 | 20-40 |
| 126----------------- Niland | 0-23 | Fine sand------- | SM, SP-SM | A-2, A-3 | 0 | 90-100 | 90-100 | 50-65 | 5-25 | --- | NP |
| | 23-60 | Silty clay------ | CL, CH | A-7 | 0 | 100 | 100 | 85-100 | 80-95 | 40-65 | 20-40 |
| 127----------------- Niland | 0-23 | Loamy fine sand | SM | A-2 | 0 | 90-100 | 90-100 | 50-65 | 15-30 | --- | NP |
| | 23-60 | Silty clay------ | CL, CH | A-7 | 0 | 100 | 100 | 85-100 | 80-95 | 40-65 | 20-40 |
| 128*: | | | | | | | | | | | |
| Niland------------ | 0-23 | Gravelly sand--- | SM, SP-SM | A-2, A-3 | 0 | 90-100 | 70-95 | 50-65 | 5-25 | --- | NP |
| | 23-60 | Silty clay, clay, clay loam. | CL, CH | A-7 | 0 | 100 | 100 | 85-100 | 80-100 | 40-65 | 20-40 |
| Imperial---------- | 0-12 | Silty clay------ | CH | A-7 | 0 | 100 | 100 | 100 | 85-95 | 50-70 | 25-45 |
| | 12-60 | Silty clay loam, silty clay, clay. | CH | A-7 | 0 | 100 | 100 | 100 | 85-95 | 50-70 | 25-45 |
| 129*: Pits | | | | | | | | | | | |
| 130, 131----------- Rositas | 0-27 | Sand------------ | SP-SM | A-3, A-1, A-2 | 0 | 100 | 80-100 | 40-70 | 5-15 | --- | NP |
| | 27-60 | Sand, fine sand, loamy sand. | SM, SP-SM | A-3, A-2, A-1 | 0 | 100 | 80-100 | 40-85 | 5-30 | --- | NP |

See footnote at end of table.

TABLE 11.--ENGINEERING INDEX PROPERTIES--Continued

| Soil name and map symbol | Depth | USDA texture | Classification: Unified | Classification: AASHTO | Fragments > 3 inches | Percentage passing sieve number-- 4 | 10 | 40 | 200 | Liquid limit | Plasticity index |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | In | | | | Pct | | | | | Pct | |
| 132, 133, 134, 135-- Rositas | 0-9 | Fine sand | SM | A-3, A-2 | 0 | 100 | 80-100 | 50-80 | 10-25 | --- | NP |
| | 9-60 | Sand, fine sand, loamy sand. | SM, SP-SM | A-3, A-2, A-1 | 0 | 100 | 80-100 | 40-85 | 5-30 | --- | NP |
| 136 Rositas | 0-4 | Loamy fine sand | SM | A-1, A-2 | 0 | 100 | 80-100 | 40-85 | 10-35 | --- | NP |
| | 4-60 | Sand, fine sand, loamy sand. | SM, SP-SM | A-3, A-2, A-1 | 0 | 100 | 80-100 | 40-85 | 5-30 | --- | NP |
| 137 Rositas | 0-12 | Silt loam | ML | A-4 | 0 | 100 | 100 | 90-100 | 70-90 | 20-30 | NP-5 |
| | 12-60 | Sand, fine sand, loamy sand. | SM, SP-SM | A-3, A-2, A-1 | 0 | 100 | 80-100 | 40-85 | 5-30 | --- | NP |
| 138*: | | | | | | | | | | | |
| Rositas | 0-4 | Loamy fine sand | SM | A-1, A-2 | 0 | 100 | 80-100 | 40-85 | 10-35 | --- | NP |
| | 4-60 | Sand, fine sand, loamy sand. | SM, SP-SM | A-3, A-2, A-1 | 0 | 100 | 80-100 | 40-85 | 5-30 | --- | NP |
| Superstition | 0-6 | Loamy fine sand | SM | A-2 | 0 | 100 | 95-100 | 70-85 | 15-25 | --- | NP |
| | 6-60 | Loamy fine sand, fine sand, sand. | SM | A-2 | 0 | 100 | 95-100 | 70-85 | 15-25 | --- | NP |
| 139 Superstition | 0-6 | Loamy fine sand | SM | A-2 | 0 | 100 | 95-100 | 70-85 | 15-25 | --- | NP |
| | 6-60 | Loamy fine sand, fine sand, sand. | SM | A-2 | 0 | 100 | 95-100 | 70-85 | 15-25 | --- | NP |
| 140*: | | | | | | | | | | | |
| Torriorthents | | | | | | | | | | | |
| Rock outcrop | | | | | | | | | | | |
| 141*: | | | | | | | | | | | |
| Torriorthents | | | | | | | | | | | |
| Orthids | | | | | | | | | | | |
| 142 Vint | 0-10 | Loamy very fine sand. | SM, ML | A-4 | 0 | 100 | 100 | 85-95 | 40-65 | 15-25 | NP-5 |
| | 10-60 | Loamy fine sand | SM | A-2 | 0 | 95-100 | 95-100 | 70-80 | 20-30 | --- | NP |
| 143 Vint | 0-12 | Fine sandy loam | ML, CL-ML, SM, SM-SC | A-4 | 0 | 100 | 100 | 75-85 | 45-55 | 15-25 | NP-5 |
| | 12-60 | Loamy sand, loamy fine sand. | SM | A-2 | 0 | 95-100 | 95-100 | 70-80 | 20-30 | --- | NP |
| 144*: | | | | | | | | | | | |
| Vint | 0-10 | Very fine sandy loam. | SM, ML | A-4 | 0 | 100 | 100 | 85-95 | 40-65 | 15-25 | NP-5 |
| | 10-40 | Loamy fine sand | SM | A-2 | 0 | 95-100 | 95-100 | 70-80 | 20-30 | --- | NP |
| | 40-60 | Silty clay | CL, CH | A-7 | 0 | 100 | 100 | 95-100 | 85-95 | 40-65 | 20-35 |
| Indio | 0-12 | Very fine sandy loam. | ML | A-4 | 0 | 95-100 | 95-100 | 85-100 | 75-90 | 20-30 | NP-5 |
| | 12-40 | Stratified loamy very fine sand to silt loam. | ML | A-4 | 0 | 95-100 | 95-100 | 85-100 | 75-90 | 20-30 | NP-5 |
| | 40-72 | Silty clay | CL, CH | A-7 | 0 | 100 | 100 | 95-100 | 85-95 | 40-65 | 20-35 |

* See description of the map unit for composition and behavior characteristics of the map unit.




LANDMARK
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Project No.: LE15112

Topographic Map

Plate A-4

# APPENDIX B

# LOG OF BORING No. B-1

SHEET 1 OF 1

| DEPTH | BLOW COUNT | POCKET PEN. (tsf) | DESCRIPTION OF MATERIAL | DRY DENSITY (pcf) | MOISTURE CONTENT (% dry wt.) | OTHER TESTS |
|---|---|---|---|---|---|---|
| | | | CLAYEY SILT (ML): Lt. brown, moist, medium dense | | | |
| 5 | 9 | | | 103.9 | 11.1 | |
| | | | SILTY CLAY (CL): Brown, moist, stiff, medium plasticity | | | |
| 10 | 12 | | | | 27.5 | LL=43% PI=25% |
| | | | CLAYEY SANDY SILT (ML): Brown, saturated, loose, fine to very fine grained sand | | | |
| 15 | 7 | | | 95.1 | 28.7 | LL=29% PI=14% Passing #200 = 78.1% c=0.34 tsf Φ=26° |
| 20 | 12 | 3.0 | SILTY CLAY (CL): Brown, wet, very stiff, medium plasticity | | | |
| 25 | 23 | 2.5 | | | | |
| 30 | | | | | | |
| 35 | | | | | | |
| 40 | | | | | | |
| 45 | | | | | | |
| 50 | | | | | | |
| 55 | | | Total Depth = 25.5'<br>20' Piezometer Installed<br>Backfilled with excavated soil | | | |
| 60 | | | | | | |

DATE DRILLED: 7/9/15
LOGGED BY: P. LaBrucherie
SURFACE ELEVATION: Approximately -60'

TOTAL DEPTH: 26.5 Feet
TYPE OF BIT: Hollow Stem Auger
HAMMER WT.: 140 lbs.

DEPTH TO WATER: 10.8 ft.
DIAMETER: 8 in.
DROP: 30 in.

PROJECT NO. LE15112

LANDMARK Geo-Engineers and Geologists

PLATE B-1

# LOG OF BORING No. B-2

SHEET 1 OF 1

| DEPTH | FIELD: BLOW COUNT | FIELD: POCKET PEN. (tsf) | DESCRIPTION OF MATERIAL | LABORATORY: DRY DENSITY (pcf) | LABORATORY: MOISTURE CONTENT (% dry wt.) | LABORATORY: OTHER TESTS |
|---|---|---|---|---|---|---|
| | | | CLAYEY SILT (ML): Lt. brown, moist, medium dense | | | |
| 5 | 4 | 1.0 | | | | |
| 10 | 20 | 4.0 | SILTY CLAY (CL): Brown, moist, stiff, medium plasticity | 99.3 | 24.9 | LL=43% PI=25% c=1.21 tsf |
| 15 | 3 | | CLAYEY SANDY SILT (ML): Brown, saturated, loose, fine to very fine grained sand | | 27.5 | LL=35% PI=18% Passing #200 = 76.4% |
| 20 | 26 | 3.0 | SILTY CLAY (CL): Brown, wet, very stiff, medium plasticity | 101.4 | 24.3 | c=0.55 tsf |
| 25 | 11 | 3.5 | | | | |

Total Depth = 25.5'
20' Piezometer Installed
Backfilled with excavated soil

DATE DRILLED: 7/9/15
LOGGED BY: P. LaBrucherie
SURFACE ELEVATION: Approximately -60'
TOTAL DEPTH: 26.5 Feet
TYPE OF BIT: Hollow Stem Auger
HAMMER WT.: 140 lbs.
DEPTH TO WATER: 9.8 ft.
DIAMETER: 8 in.
DROP: 30 in.

PROJECT NO. LE15112

LANDMARK Geo-Engineers and Geologists

PLATE B-2

# DEFINITION OF TERMS

| PRIMARY DIVISIONS | | | SYMBOLS | | SECONDARY DIVISIONS |
|---|---|---|---|---|---|
| Coarse grained soils More than half of material is larger that No. 200 sieve | Gravels: More than half of coarse fraction is larger than No. 4 sieve | Clean gravels (less than 5% fines) | | GW | Well graded gravels, gravel-sand mixtures, little or no fines |
| | | | | GP | Poorly graded gravels, or gravel-sand mixtures, little or no fines |
| | | Gravel with fines | | GM | Silty gravels, gravel-sand-silt mixtures, non-plastic fines |
| | | | | GC | Clayey gravels, gravel-sand-clay mixtures, plastic fines |
| | Sands: More than half of coarse fraction is smaller than No. 4 sieve | Clean sands (less than 5% fines) | | SW | Well graded sands, gravelly sands, little or no fines |
| | | | | SP | Poorly graded sands or gravelly sands, little or no fines |
| | | Sands with fines | | SM | Silty sands, sand-silt mixtures, non-plastic fines |
| | | | | SC | Clayey sands, sand-clay mixtures, plastic fines |
| Fine grained soils More than half of material is smaller than No. 200 sieve | Silts and clays: Liquid limit is less than 50% | | | ML | Inorganic silts, clayey silts with slight plasticity |
| | | | | CL | Inorganic clays of low to medium plasticity, gravely, sandy, or lean clays |
| | | | | OL | Organic silts and organic clays of low plasticity |
| | Silts and clays: Liquid limit is more than 50% | | | MH | Inorganic silts, micaceous or diatomaceous silty soils, elastic silts |
| | | | | CH | Inorganic clays of high plasticity, fat clays |
| | | | | OH | Organic clays of medium to high plasticity, organic silts |
| Highly organic soils | | | | PT | Peat and other highly organic soils |

## GRAIN SIZES

| Silts and Clays | Sand | | | Gravel | | Cobbles | Boulders |
|---|---|---|---|---|---|---|---|
| | Fine | Medium | Coarse | Fine | Coarse | | |

200 40 10 4 3/4" 3" 12"

US Standard Series Sieve — Clear Square Openings

| Sands, Gravels, etc. | Blows/ft. * |
|---|---|
| Very Loose | 0-4 |
| Loose | 4-10 |
| Medium Dense | 10-30 |
| Dense | 30-50 |
| Very Dense | Over 50 |

| Clays & Plastic Silts | Strength ** | Blows/ft. * |
|---|---|---|
| Very Soft | 0-0.25 | 0-2 |
| Soft | 0.25-0.5 | 2-4 |
| Firm | 0.5-1.0 | 4-8 |
| Stiff | 1.0-2.0 | 8-16 |
| Very Stiff | 2.0-4.0 | 16-32 |
| Hard | Over 4.0 | Over 32 |

* Number of blows of 140 lb. hammer falling 30 inches to drive a 2 inch O.D. (1 3/8 in. I.D.) split spoon (ASTM D1586).

** Unconfined compressive strength in tons/s.f. as determined by laboratory testing or approximated by the Standard Penetration Test (ASTM D1586), Pocket Penetrometer, Torvane, or visual observation.

**Type of Samples:**

Ring Sample — Standard Penetration Test — Shelby Tube — Bulk (Bag) Sample

**Drilling Notes:**

1. Sampling and Blow Counts
   - Ring Sampler - Number of blows per foot of a 140 lb. hammer falling 30 inches.
   - Standard Penetration Test - Number of blows per foot.
   - Shelby Tube - Three (3) inch nominal diameter tube hydraulically pushed.
2. P. P. = Pocket Penetrometer (tons/s.f.).
3. NR = No recovery.
4. GWT = Ground Water Table observed @ specified time.

LANDMARK Geo-Engineers and Geologists

**Project No. LE15112** | **Key to Logs** | **Plate B-3**

# APPENDIX C

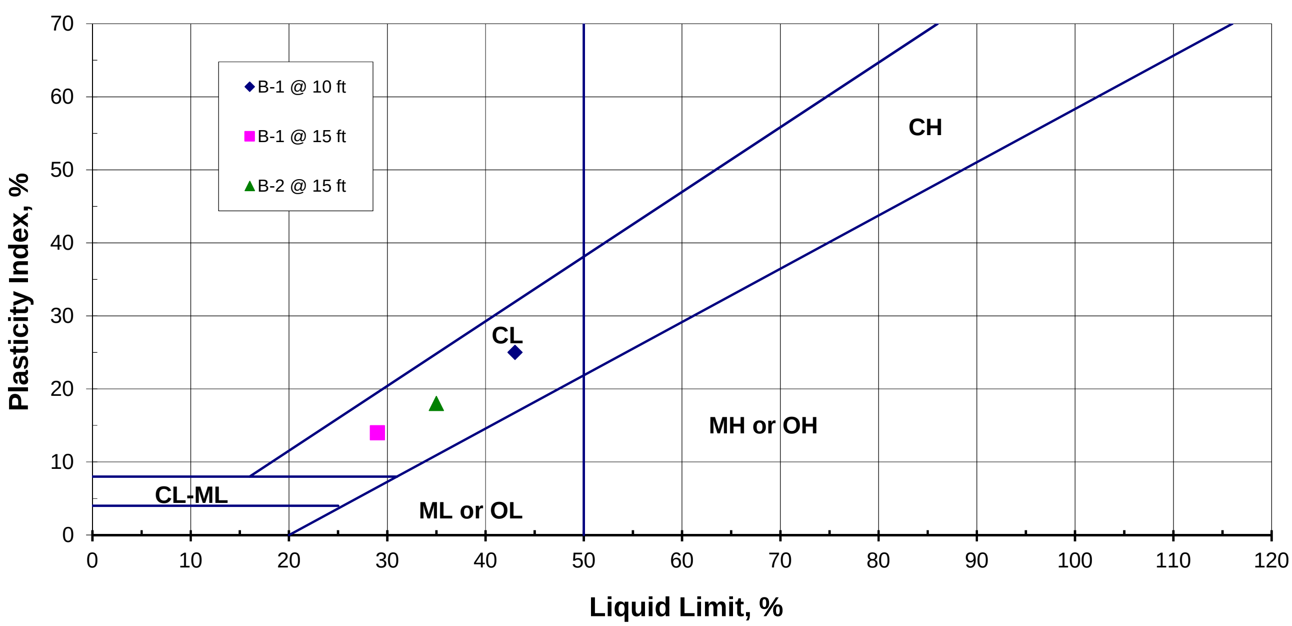
# LANDMARK CONSULTANTS, INC.

**CLIENT:** Webb Associates
**PROJECT:** Neckel Road Utility Crossing -- Imperial, CA
**JOB No.:** LE15112
**DATE:** 07/23/15

## ATTERBERG LIMITS (ASTM D4318)

| Sample Location | Sample Depth (ft) | Liquid Limit (LL) | Plastic Limit (PL) | Plasticity Index (PI) | USCS Classification |
|---|---|---|---|---|---|
| B-1 | 10 | 43 | 18 | 25 | CL |
| B-1 | 15 | 29 | 15 | 14 | CL |
| B-2 | 15 | 35 | 17 | 18 | CL |

## PLASTICITY CHART



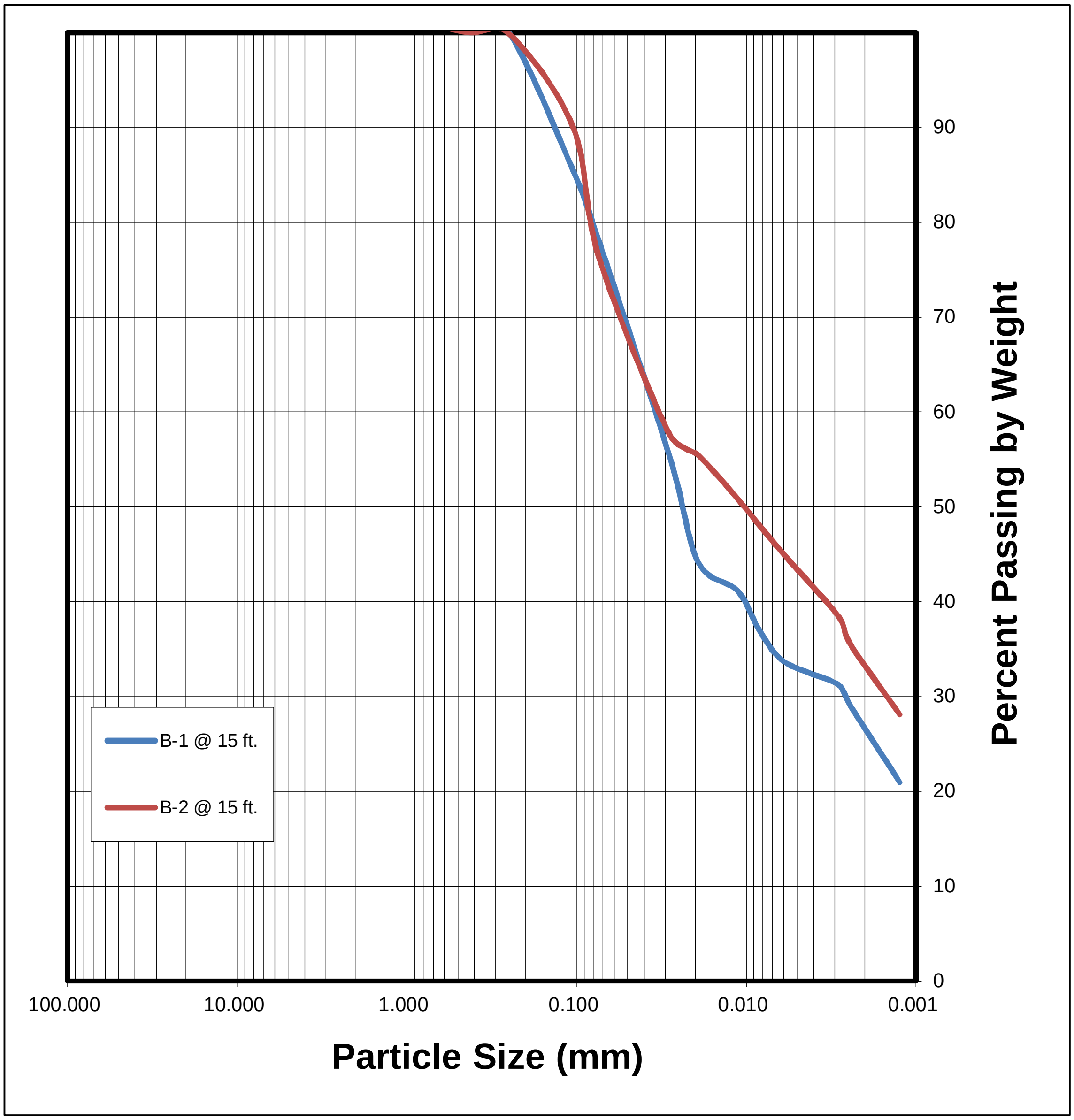

LANDMARK
Geo-Engineers and Geologists

**Project No.: LE15112**

**Atterberg Limits Test Results**

**Plate C-1**

| SIEVE ANALYSIS | | | | | HYDROMETER ANALYSIS |
|---|---|---|---|---|---|
| Gravel | | Sand | | | Silt and Clay Fraction |
| Coarse | Fine | Coarse | Medium | Fine | |




LANDMARK Geo-Engineers and Geologists

**Project No.: LE15112**

**Grain Size Analysis**

**Plate C-2**

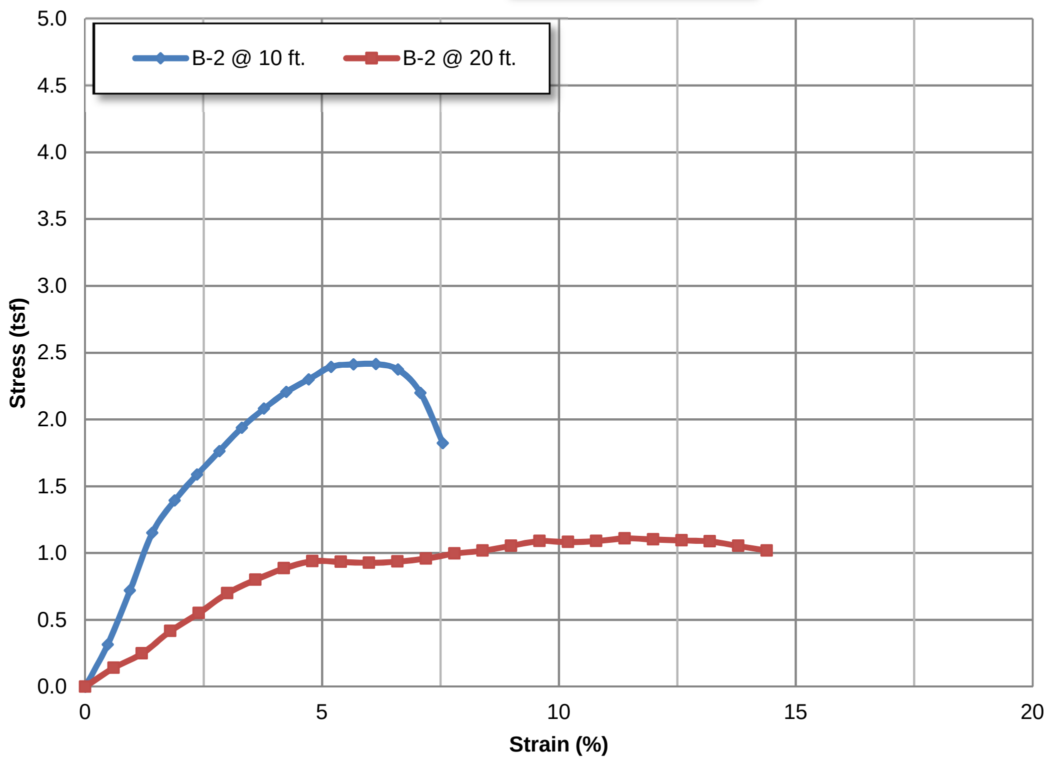
**LANDMARK CONSULTANTS, INC.**

**CLIENT:** Webb Associates
**PROJECT:** Neckel Road Utility Crossing -- Imperial, CA
**JOB NO:** LE15112
**DATE:** 7/23/2015

**UNCONFINED COMPRESSION TEST (ASTM D2166)**

| Boring No. | Sample Depth (ft) | Natural Moisture Content (%) | Unit Dry Weight (pcf) | Maximum Compressive Strength (tsf) | Cohesion (tsf) | Failure Strain (%) |
|---|---|---|---|---|---|---|
| B-2 | 10 | 24.9 | 99.3 | 2.41 | 1.21 | 6.1 |
| B-2 | 20 | 24.3 | 101.4 | 1.11 | 0.55 | 11.4 |

**Stress - Strain Plot**




Geo-Engineers and Geologists
**Project No.: LE15112**

**Unconfined Compression Test Results**

**Plate C-3**

# LANDMARK CONSULTANTS, INC.

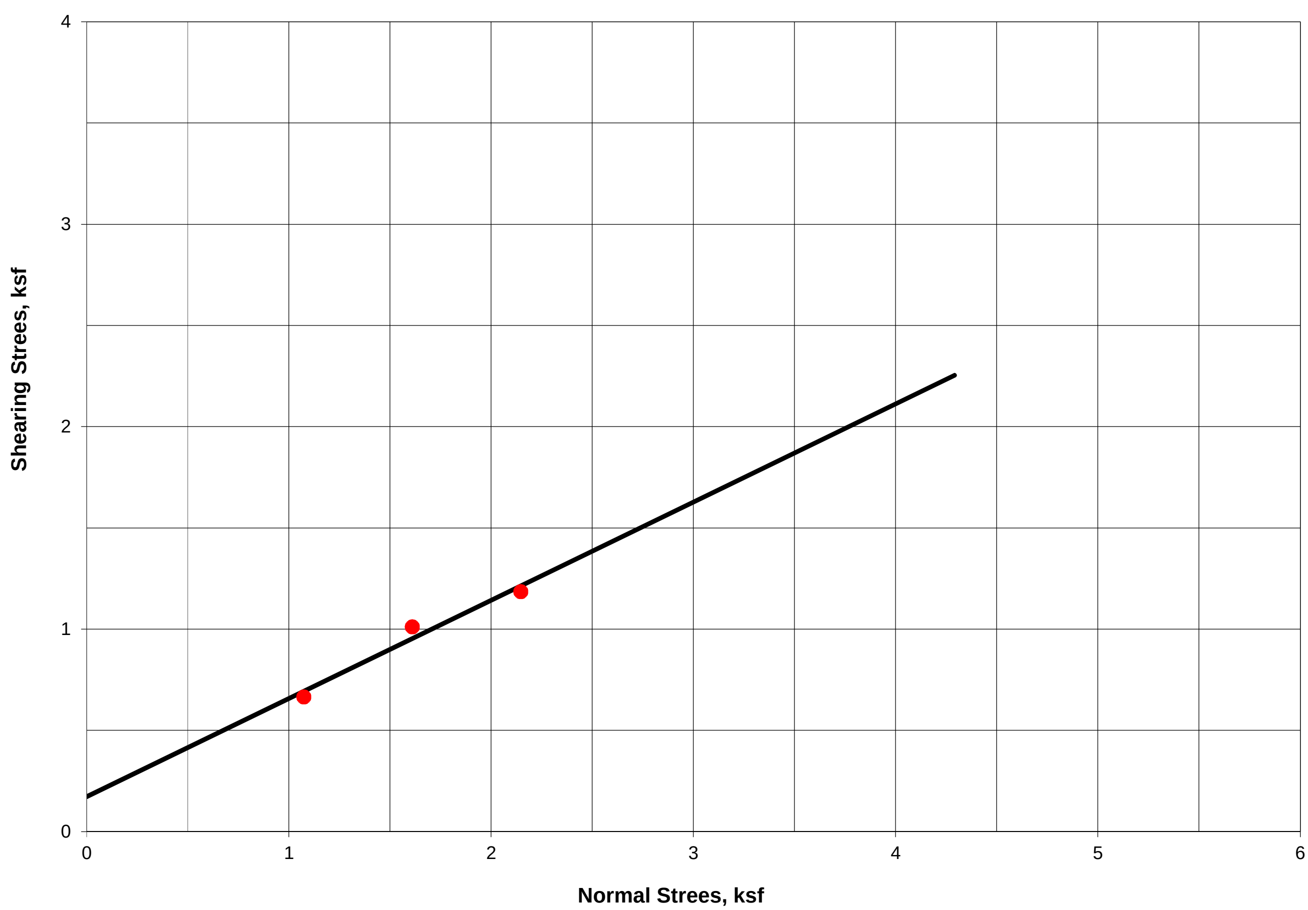
**CLIENT:** Webb Associates
**PROJECT:** Neckel Road Utility Crossing -- Imperial, CA
**PROJECT No:** LE15112 **DATE:** 7/16/2015

## DIRECT SHEAR TEST - INSITU (ASTM D3080)

**SAMPLE LOCATION:** B-1 @ 15 ft
**SAMPLE DESCRIPTION:** Silty Clay/Clayey Silt (CL-ML)

| | | | |
|---|---|---|---|
| **Angle of Internal Friction:** | **26º** | **Initial Dry Density:** | **95.1 pcf** |
| **Cohesion:** | **0.17 ksf** | **Initial Moisture Content:** | **28.7%** |

## DIRECT SHEAR TEST RESULTS




LANDMARK Geo-Engineers and Geologists

**PROJECT No: LE15112**

**Direct Shear Test Results**

**Plate C-4**

# LANDMARK CONSULTANTS, INC.

**CLIENT:** Webb Associates
**PROJECT:** Neckel Road Utility Crossing -- Imperial, CA
**JOB No.:** LE15112
**DATE:** 07/23/15

## CHEMICAL ANALYSIS

| | | Caltrans Method |
|---|---|---|
| **Boring:** | B-2 | |
| **Sample Depth, ft:** | 15 | |
| **pH:** | 8.4 | 643 |
| **Electrical Conductivity (mmhos):** | 0.63 | 424 |
| **Resistivity (ohm-cm):** | -- | 643 |
| **Chloride (Cl), ppm:** | 330 | 422 |
| **Sulfate (SO4), ppm:** | 444 | 417 |

General Guidelines for Soil Corrosivity

| Material Affected | Chemical Agent | Amount in Soil (ppm) | Degree of Corrosivity |
|---|---|---|---|
| Concrete | Soluble Sulfates | 0 - 1,000 | Low |
| | | 1,000 - 2,000 | Moderate |
| | | 2,000 - 20,000 | Severe |
| | | > 20,000 | Very Severe |
| Normal Grade Steel | Soluble Chlorides | 0 - 200 | Low |
| | | 200 - 700 | Moderate |
| | | 700 - 1,500 | Severe |
| | | > 1,500 | Very Severe |
| Normal Grade Steel | Resistivity | 1 - 1,000 | Very Severe |
| | | 1,000 - 2,000 | Severe |
| | | 2,000 - 10,000 | Moderate |
| | | > 10,000 | Low |

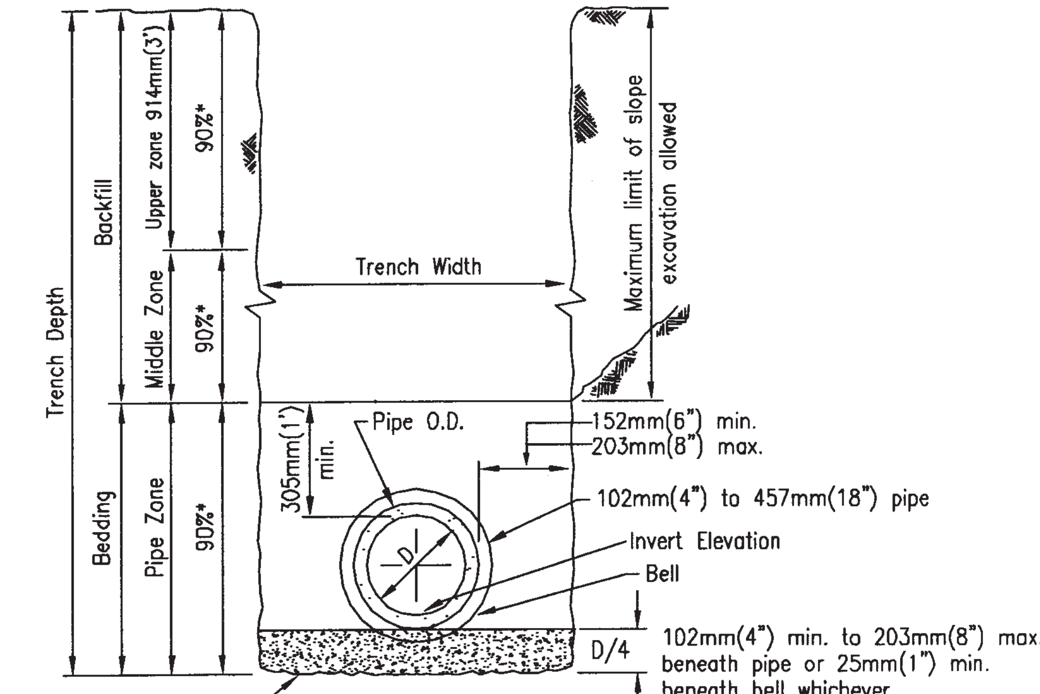
LANDMARK
Geo-Engineers and Geologists

**Project No.: LE15112**

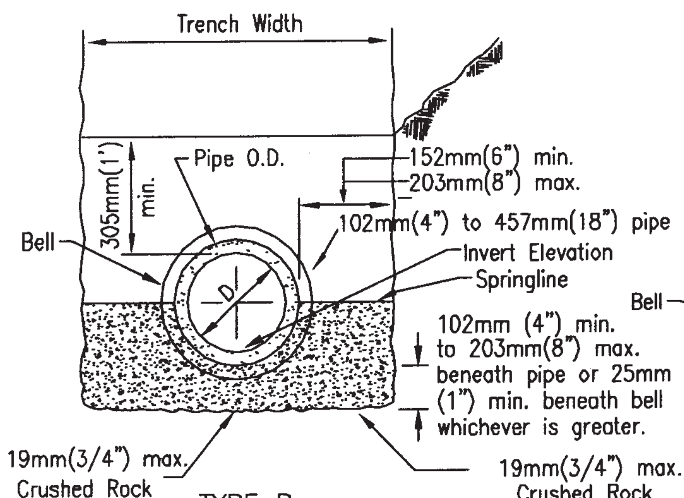
**Selected Chemical Test Results**

**Plate C-5**

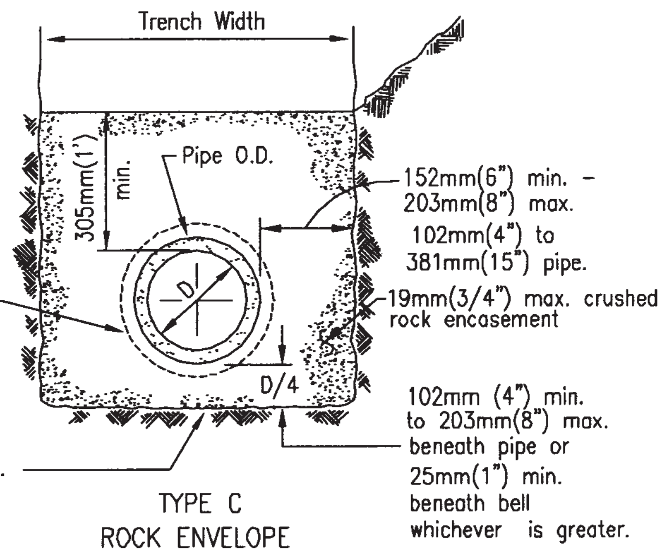
# APPENDIX D




TYPE A
STANDARD INSTALLATION




TYPE B
ROCK TO SPRINGLINE



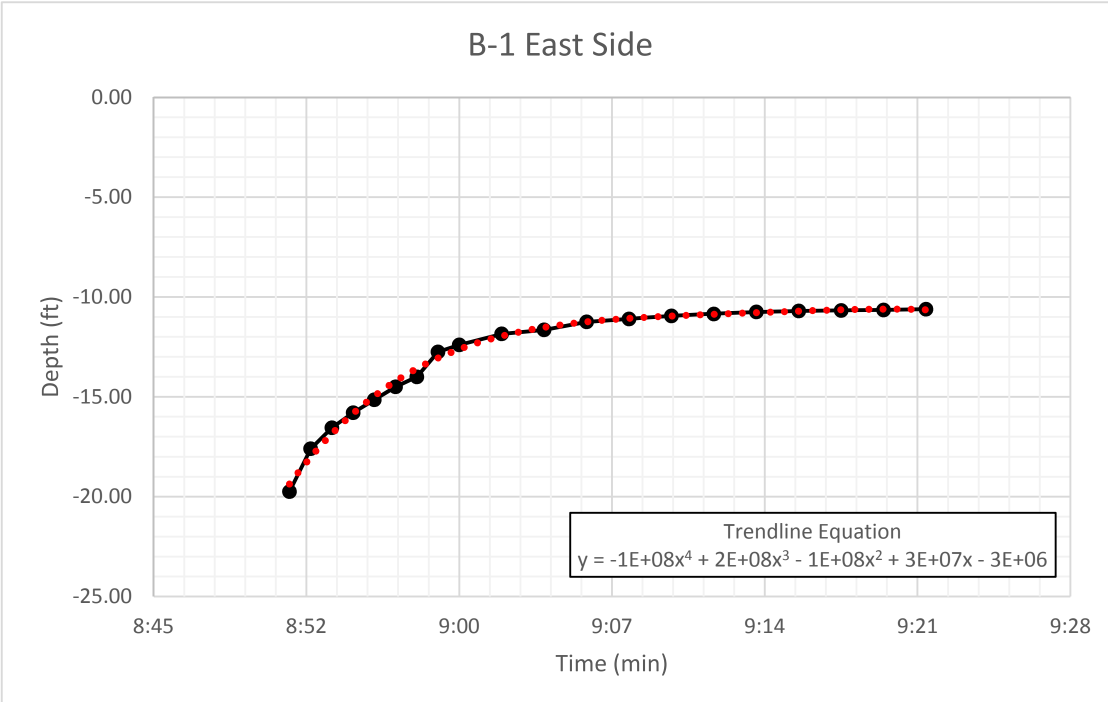

TYPE C
ROCK ENVELOPE

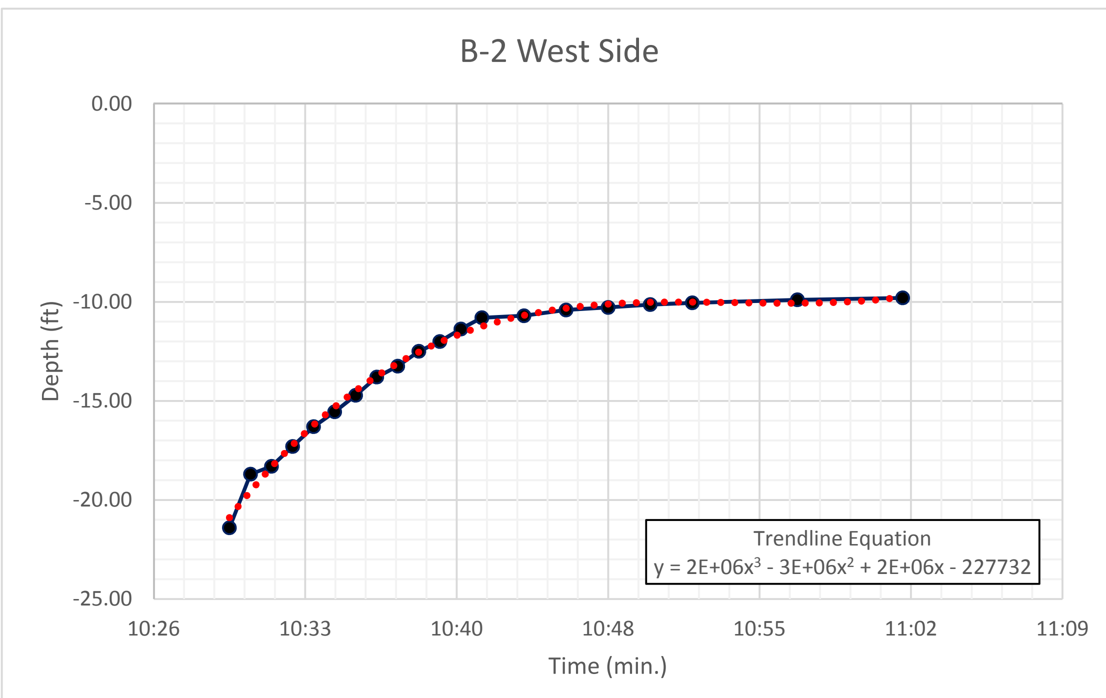
NOTES

1. For trenching in improved streets, see Standard Drawings G-24 or G-25 for trench resurfacing.
2. (*) indicates minimum relative compaction.
3. Minimum depth of cover from the top of pipe to finish grade for all sanitary sewer installations shall be 914mm(3') For cover less tnan 914mm(3'), see Standard Drawing S-7 for concrete encasement.
4. See Type A installation for details not shown for Types B and C.

| | | |
|---|---|---|
| LANDMARK<br>Geo-Engineers and Geologists<br>**Project No.: LE15112** | **Pipe Bedding and Trench Backfill Recommendations** | **Plate**<br>**D-1** |

# APPENDIX E




**LANDMARK**
Geo-Engineers and Geologists

**Project No.: LE15112**

**Grain Size Analysis**

**Plate**
**E-1**

# APPENDIX F

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