

**1 Appendix 3.G, Geotechnical Exploration Plan – Phase 2**

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# GEOTECHNICAL EXPLORATION PLAN- PHASE 2

Delta Habitat Conservation and Conveyance Program

Revision 3

Date: June 2014



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ATTACHMENT A– PROPOSED EXPLORATION MAPS

ATTACHMENT B–EXPLORATION METHODS and EQUIPMENT

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ASTM	American Society of Testing of Materials
CAL/OSHA	California Division of Occupational Safety and Health
CER	Conceptual Engineering Report
CPT	Cone Penetration Testing
DHCCP	Delta Habitat Conservation and Conveyance Program
DSOD	Division of Safety of Dams
DWR	California Department of Water Resources
MPTO	Modified Pipeline/Tunnel Option
SPT	Standard Penetration Test
TBM	Tunnel Boring Machine
EP	Entry Permit
USACE	U. S. Army Corps of Engineers

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## 1.0 INTRODUCTION

This document presents a general geotechnical exploration plan with rationale, investigation methods, and criteria for obtaining subsurface soil information and laboratory test data. Geotechnical data are required to support preliminary engineering and Final design of the Modified Pipeline/Tunnel Option (MPTO) of the Delta Habitat Conservation and Conveyance Program (DHCCP). The proposed subsurface exploration is designed as a two part exploration program (Phase 2a and 2b) to collect geotechnical data. The two part exploration program will allow refinement of the second part of the program to respond to developments in the DHCCP.

The proposed subsurface exploration will focus on geotechnical considerations of the following aspects of the DHCCP.

- Preliminary engineering and Final design
- Site seismic characterization
- Permitting support
- Construction planning

The data obtained during the geotechnical exploration will be used to support the development of an appropriate geologic model, characterize ground conditions, and mitigate the geologic risks associated with the construction of proposed facilities.

An initial phase of subsurface exploration was completed in four parts during 2009, 2010, 2011, and 2012.

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## 2.0 RATIONALE

Subsurface materials will be explored, representative samples will be collected from selected locations along the MPTO alignment and the associated appurtenant facilities, and the collected samples will be subject to laboratory tests to support engineering activities. The distance from Intake 2 (northern end) of the MPTO to the Clifton Court forebay (southern end) is approximately 39 miles. The associated appurtenant facilities include river intakes, conveyance pipelines, sedimentation basins, intake pumping plants, transition structures, forebays, construction and vent shafts, and tunnels. The proposed subsurface exploration will primarily consist of both field tests and laboratory soil sample testing. The field tests will consist of soil borings, cone penetration testing (CPT), seismic profiling, pressure meter testing, excavation of test pits, installation of piezometers and groundwater extraction wells, dissolved gas sampling, and conducting bore-hole permeability tests. The field exploration program will be planned to evaluate soil characteristics and collect samples for laboratory testing, which will include soil index properties, strength, compressibility, permeability, and specialty testing to support tunnel boring machine (TBM) selection and performance specification.

This document is prepared for planning purpose and based on the conceptual engineering completed to date and the available information. As the engineering is advanced, this document should be updated to reflect changes. The type, number, depth, and location of the proposed explorations are preliminary and will be revised as the engineering is advanced and access to the project sites becomes available to verify existing conditions (utility locations, access roads, land use, etc).

Major considerations of the proposed subsurface exploration plan include the following.

### 1. Engineering Considerations.

These considerations consist of evaluation of site-specific geotechnical conditions along the alignment of the MPTO and at all of the proposed conveyance facility locations. The engineering considerations and the facilities include:

- intake structures on the Sacramento River,
- structures with significant embedment depths (e.g. sedimentation basins, pumping plants),
- various types of foundation support (e.g. forebays on natural subgrade or improved foundation soils, river intakes supported by deep foundations),
- structures having unique design features with respect to vertical depth and lateral extent of the installations (i.e. shafts, tunnels, and pipelines).
- access roads and barge unloading facilities

The design features and locations of the structures will have different requirements and considerations as to the depth of soil borings, elevations where samples need to be collected, and type of laboratory tests required to better define the strength, permeability, and compressibility characteristics of the supporting foundation soils or ground surrounding the tunnel and shafts.

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## 2. Construction-related Considerations.

The construction-related considerations include:

- dewatering requirements (i.e. intake structure and its related facilities, pumping plants, forebays, and construction and vent shafts),
- ground support methods for the deep excavations (i.e. construction and vent shafts, intakes, pumping plants),
- definition of ground characteristics required for the TBM; the identification of additional design provisions and mitigation needed due to the potential presence of dissolved gas along the planned tunnel alignment,
- the need for subsoil improvements for the built-up platforms around tunnel construction shafts, access roads, and intake and pumping plant foundations.
- the delineation of the subsurface soil profile to address design consideration and construction needs for unsuitable subsoils removal and foundation soil treatment for conveyance pipelines and forebay foundations, and the sources and the compatibility of the construction materials for the forebay embankments,
- the geotechnical information required to support the construction planning, design, and installations for the marine barge unloading facilities to transport the heavy equipment (i.e. TBMs, pumps for intake and pumping plants, construction equipment, etc.) and construction materials (i.e. tunnel liner segments, backfill, cement, reinforcing steel, etc.).

## 3. Permitting and Other Requirements.

These requirements may include subsurface characteristics and groundwater information that need to be collected to support the USACE 404 and 408 permits for:

- river intakes design and construction including existing levee realignment,
- sedimentation basin excavation and dewatering,
- design of the deep foundations to support the intakes and pumping plants,
- design requirements for new perimeter berms to protect the affected areas prior to any alternations resulting from new construction adjacent to the project levees;
- CAL/OHSA classification requirements for the tunnel construction that may include the stability of the sub-grade materials immediately adjacent to the tunnel excavation and mitigation needs due to the potential release of dissolved gas during the tunnel excavation,
- proposed forebay embankment foundation conditions and the strength properties of the embankment materials meeting the DSOD requirements and regulations.

It is noted that the planning and preparation of the USACE 408 permit application demands a specific analysis and design requirements using site specific geotechnical data meeting the USACE regulation (ER 1110-2-150). This in-turn will require significant amount of lead time and effort to support the data collection.

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#### 4. Seismic Characterization Considerations and Seismic Refraction/Reflection Profiling.

The project site is located adjacent to a region of high seismic activity and strong seismic shaking that could impact various project elements. Site seismic characterization is one of the main objectives of the investigation program, as was highlighted by the Independent Review Committee (IRC) who reviewed the Conceptual Engineering Reports (CERs) prepared by DHCCP for the conveyance options including East, West, All Tunnel, and Dual. Site characterizations such as:

- Representative vertical subsoil profiles, in terms of material characteristics based on the static and seismic properties of its components, need to be collected and established to assist in the site seismic response analysis.
- Project-specific dynamic property profiles, represented by seismic wave velocities and moduli, have been measured and collected using the suspension wave measurement method.
- Measurement of seismic property profiles have been performed in five drilled holes ranging from 200 to 500 feet deep. These holes were located in the north, central, and southern portions of the Delta in the vicinity of the planned conveyance alignments, so that the basic geological settings of the Delta and project site features can best be represented.
- Additional downhole geophysical logging will be performed during future field exploration programs.
- Seismic Refraction/Reflection Profiling will be used to define and delineate both the vertical and lateral extents of the stratum having similar characteristics and strength properties based on the measured material velocities. The seismic refraction/reflection profiling will help to fill in the missing information between the bore holes along the tunnel segments of the MPTO alignment and other locations of the planned facilities.

As discussed in Section 1.0, the proposed subsurface exploration has been structured into two major individual components, namely Phase 2a and 2b proposed subsurface exploration. The elements of Phase 2a and 2b have been defined to support various phases of engineering activities. The scope of work for these two exploration phases is provided below.

Phase 2a Geotechnical Exploration: Phase 2a exploration will focus mainly on collecting the data to support the Preliminary engineering. The data to be collected will include both the over-water and land-based soil borings, cone penetration tests (CPT). The over-water explorations are planned to collect the subsurface information to support the design effort for the intake structures, and at the major water crossings along the planned MPTO alignment. The land-based explorations are planned for the new perimeter berms, sedimentation basins, pumping plants, forebay embankments, tunnel construction and vent shafts, and other appurtenant facilities proposed for the MPTO. Approximately 550 boring and CPT locations are proposed for the Phase 2a exploration.

For the proposed MPTO tunnels, the Phase 2a work would consist of advancing soil borings on approximate 2000-ft spacing along the tunnel alignment and advancing CPT's on approximate 2000-ft spacing placed mid-way between the borings. A few additional overwater boreholes are planned to be in the San Joaquin River. All of the land-based boreholes will be converted into piezometers. There are also CPT's proposed to be co-

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located at every third borehole to enable calibration of the CPT data with the in-situ geology encountered in the boreholes.

For the construction and ventilation shaft sites, six soil borings and four CPT's will be advanced at each planned shaft location. Once drilling is completed at each shaft site, two of the boreholes will be converted into a groundwater extraction wells and the other four boreholes will be converted into piezometers. Maps showing the proposed locations of Phase 2a explorations are included as Attachment A. The exploration locations shown on the maps are approximate and will be revised as the engineering is advanced and access to the project sites becomes available to verify existing conditions (utility locations, access roads, land use, etc).

Phase 2b Geotechnical Exploration: Phase 2b exploration is proposed to collect geotechnical data to support Final design, permitting requirements and planning for procurement and construction related activities. In addition to soil borings and CPTs, test pits would be performed as part of Phase 2b exploration. Additional confirmatory explorations may also be carried out before construction to affirm the validity of the data collected during the design phase. The Phase 2b subsurface exploration will aim to collect geotechnical data from the project site areas and facility locations that have received the system optimizations and verification from additional value engineering studies and Preliminary engineering. Approximately 830 boring, CPT, and test pit locations are proposed for the Phase 2b exploration.

For the proposed MPTO tunnels, the Phase 2b exploration would consist of advancing soil borings near the CPT locations from the Phase 2a work, so a borehole would be located at approximately 1000-ft spacing across the entire tunnel alignment. CPT's would be advanced mid-way between the boreholes. This would provide for a land-based exploratory location (borehole or CPT) spacings of approximately 500-ft along the tunnel alignment, which generally conforms to the design efforts for tunnels with the magnitude of DHCCP.

The exploration proposed for the construction and ventilation shaft sites in Phase 2a would be expanded to include the "safe haven" locations in Phase 2b. Maps showing the proposed Phase 2b explorations are included as Attachment A.

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### 3.0 EXPLORATION METHODS

The primary exploration methods include soil borings and CPTs (conventional piezocones and seismic cones). Soil borings utilizing the Standard Penetration Test will be performed at planned locations for the land-based facilities, in-water structures (e.g. river intakes, tunnel crossings, and siphons) and along the MPTO alignment. Truck-mounted and track-mounted CPT and drill rigs will be used at selected land-based locations for exploration. Geophysical surveys, seismic profiling, pressuremeter, and permeability tests will also be performed to support the data collection for physical and strength properties of the subsoils and the dewatering requirements in areas where deep excavations are anticipated.

Sampling for gas within soils and groundwater will be performed at selected locations. Dissolved gas sampling will be performed using direct push groundwater sampling method, and passive diffusion bags sampling method. The former sampling method will be carried out with the assistance of a CPT machine, while the latter method will be conducted by placing the diffusion bags at the sampling depths for approximately 14 days to allow the diffusion effect to take place and dissolved gas, if any, will be collected within the diffusion bags.

A long reach backhoe will be mobilized to the sites for test pit excavation to allow for visual observation of the near surface profile and sample collections. All affected areas will be backfilled with excavated material and restored to a similar condition. Over-water borings for the intake structures and river crossings for tunnels will be carried out by a drill ship and barge-mounted drill rigs. Sampling for gas within soils and groundwater will be performed at selected locations.

Prior to actual drilling and sampling, each planned boring/CPT location will require field reconnaissance, marking or staking the exploration site, and calling the Underground Service Alert (USA) for utility clearance.

Accurate and consistent classification criteria and guidelines for describing the subsoil conditions will be performed in accordance with the developed Phase I Geotechnical Investigation Work Plan. Environmental screening criteria and guidelines to determine the presence or absence of dissolved gases that may have resulted from man-made or natural activities will also be carried out. Man-made sources could include industry and gas field related activities, while the natural sources could include the decomposition of peats and other organic materials that are native to the Delta geologic setting.

Suspension P-S velocity logging method has been used to collect both compression and shear wave velocity down to a depth of 500 feet to seismically characterize the site. Five deep drill holes situated at the northern, central and southern portion of the PTO alignment have been performed and more are anticipated. Seismic reflection profiling will also be performed to map horizontal profiles along the selected areas of MPTO alignment and other structure locations as required.

The number of drill rigs to be mobilized will depend upon the terms and conditions of the Entry Permits (EP), existing ground conditions, weather, and the number of available days for geotechnical exploration within each parcel. The geotechnical exploration sequencing is expected to gradually ramp up from a few drilling/CPT rigs to multiple rigs operating concurrently. Where practical, CPTs will be performed in advance of borings at the same

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locations. Where required, real-time methane and hydrogen sulfide screening of borings and CPTs will also be conducted by the field staff. Field description/logging will be submitted after completion of each boring for input into the gINT database. There will be close coordination with the DWR Survey office to ensure that the location, elevation, and coordinates of all completed soil borings and CPT holes and test pits are accurately recorded.

It is anticipated that the actual number of borings may change due to availability of land access and the evolving needs to support the focused analysis and related engineering activities for the DHCCP.

Technical oversight on each boring/CPT will be provided by the integrated resources of the Department of Water Resource (DWR) and the Consultant geologist/geotechnical engineers who are knowledgeable of the Delta geological setting and experienced in field exploration work. In addition, a senior geologist/geotechnical engineer will be assigned to provide the oversight and review of the field logs against the collected soil and test pit samples. They will also be working/coordinating with the field staff to verify that project goals with respect to subsurface information collection, soil sampling, and testing are met.

Additional details needed for environmental documents regarding exploration methods, equipment, and estimated duration are included as Attachment B.

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#### 4.0 LABORATORY TESTING

Collected soil samples will be transported to laboratories for analysis and testing. The laboratory testing program will be designed to support the engineering design and construction. Laboratory quality control and assurance will be implemented to ensure the accuracy of the test results.

In addition to the conventional soil physical and strength properties determinations, evaluating soil mineralogy and the testing and analysis of soil abrasivity will also be undertaken. These types of special testing are essential to help identify the potential clogging of the TBM due to the mineral composition of clayey soils and the abrasivity of granular soils. Clayey and sandy soils are commonly encountered within the soil profiles of the Sacramento-San Joaquin Delta. The mineral composition, and the abrasiveness of granular soils will be determined to support the selection of TBMs, since these material properties could potentially reduce the tunneling advance rate and increase the wear of the TBM cutting heads.

Additional laboratory tests are necessary to determine strength properties and compressibility of peaty soil that exist along the MPTO alignment and within areas of planned facilities. The strength properties will be used in the evaluation of the long term foundation stability of the planned facilities and the physical properties will be used to evaluate potential construction impacts.

Below are the anticipated tests that will be performed on selected samples. Test assignments will be determined by geotechnical engineers based on the nature of the materials and the requirements of the Preliminary engineering and Final design. The actual number and type of laboratory tests may be modified according to the number of samples collected and other special needs to support the engineering analysis and procurement activities.

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**Proposed Laboratory Testing Program**  
**Physical and Strength Properties**

Type of Tests	Test Method	Type of Facility Application
Grain Size Analysis	ASTM D422	All
Grain Size Analysis with Hydrometer	ASTM D422	All
Moisture Content/Unit Weight	ASTM D2216/2937	All
Unit Weight	ASTM D2974	All
Atterberg Limits	ASTM D4318	All
Specific Gravity	ASTM D854	All
Corrosivity of Soils, including sulfate and chloride content	Caltrans: CTMs 417, 422, 643	All
Organic Content	ASTM D2947	All
Standard Proctor Density	ASTM D698	Embankments
Modified Proctor Density	ASTM D1557	Embankments
Permeability Test for Granular Soils	ASTM D2434	All
Permeability Test for Clayey Soils Using Triaxial Apparatus	ASTM D5084	All
Consolidation	ASTM D2435	All
Unconsolidated Undrained Triaxial Shear	ASTM D2850	All
Consolidated Undrained Triaxial Shear with Pore Pressure Measurements	ASTM D4767	All
Pin Hole Dispersion	ASTM D4647	Embankments
Soil Mineralogy Analysis	X-ray diffraction analysis	Tunnels
Swell/Expansion	ASTM D4546/4829	Tunnels/Shafts
Abrasivity of Soils	NTNU Soil Abrasion Test (SAT)	Tunnels
Slurry Abrasivity Test	ASTM G-75	Tunnels

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## 5.0 CRITERIA

Geotechnical considerations for the MPTO alignment include the design and construction considerations of intake facilities, providing the necessary subsurface information and technical support for safe excavation of large diameter soft ground tunnels and deep construction and vent shafts necessary to construct the tunnels, design of forebay embankments including an evaluation of the liquefaction susceptibility and potential settlement of a Delta soils (i.e. loose saturated sands and soft clayey soils), and the dewatering requirements of deep excavations for construction of the sedimentation basins and pumping plants.

The depth and thickness of existing peat and organic soils along the MPTO alignment, location of the groundwater table, the suitability of excavated soils to be considered as engineered fill, and the river under-crossings were considered in establishing the criteria for the Phase 2 exploration.

The criteria for the Phase 2a and 2b explorations are briefly summarized below:

1. Boring and CPT locations are chosen to focus on the footprints of the planned facilities such as the intakes, sedimentation basins, pumping plants, river crossings, forebays, tunnel construction and vent shafts, and at the selected locations along the tunnel alignment. The borings and CPTs for the intake structures, the sedimentation basins, and pumping plants will be extended to a depth of approximately 140 feet; 100 feet deep borings are planned for landside berms and forebays; and 220 to 300 feet borings are planned for MPTO tunnel alignment and shafts.
2. Borings and CPTs are planned at intervals of approximately 1,000 feet along the MPTO alignment to support the Preliminary engineering and at intervals of approximately 500 feet for the final design. This spacing criterion is compatible with the level of detail required for different phases of engineering and permitting activities. The actual spacing, with addition of borings and CPTs for a closer spacing arrangement, may be required based on field investigation results and design needs. It is anticipated that additional borings and CPTs will also be required during the construction phase of the project to address the need for construction support for barge unloading facilities, construction laydown, access roads and warehouses for equipment and material storage.
3. CPTs will be performed in accordance with ASTM D5778.
4. Soil boring (Standard penetration tests, SPT) will be performed at approximately 5-foot intervals and at each change of strata, in accordance with ASTM D1586 and D6066. One exception to this plan is that at the lower depths of the deep seismic borings, the SPT sampling interval may be increased in areas where the change of subsoil strata is minimal.
5. For the tunnel alignment, boreholes would be advanced to collect soil samples, alternating between SPT sampler and Cal-mod sampler (or, as needed, other types of undisturbed soil sampling), at a minimum of 5-ft intervals from the top of the borehole to minus-30 feet msl. Continuous core sampling would be done from minus-30 feet msl to bottom of borehole. Upon completion of the drilling, downhole

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testing consisting of pressure meter and measurements of P- and S-wave velocities would be performed. Gas monitoring would also be conducted.

6. For the tunnel shaft locations, boreholes would be advanced to collect soil samples at a minimum of 5-ft intervals from the top of the borehole to minus-30 feet msl. Continuous core sampling would be done from -30-ft msl to bottom of borehole. Upon completion of the drilling, downhole testing would be done, consisting of pressure meter, measurement of P-and S-wave velocities, and E-log that includes spontaneous potential and resistivity, natural gamma, and a caliper log. Gas monitoring would also be conducted.
7. Undisturbed soil sampling will be performed in accordance with ASTM D1587 in selected strata to determine index and strength properties of the soil.
8. Classification of the subsurface soils will be in accordance with ASTM D2487 and D2488.
9. Temporary groundwater piezometers will be installed at selected locations to monitor the fluctuation of groundwater levels for areas where deep excavation and tunneling are anticipated.
10. Once drilling of each borehole is completed, the borehole will be converted into a piezometer or groundwater extraction well, as discussed in Section 2, Phase 2a and 2b Explorations. Along the tunnel alignment, the initial plan at each borehole site is to install one single-level piezometer. However, if the geology encountered in the borehole suggests the likelihood of distinct aquifer units, a multi-level piezometer may be considered. Ideally, the piezometers would be the open-hole type, consisting of a standpipe. However, if conditions are not favorable for an open-standpipe piezometer, buried VW transducers could be utilized.
11. For each shaft site, two boreholes would be converted into groundwater extraction wells and the other four boreholes would be converted into piezometers. This will enable pumping tests to be done in order to characterize the aquifer(s) at each shaft location site. It is envisioned that the piezometers may have up to three distinct monitoring intervals.
12. After well construction is completed at each shaft site, aquifer testing will be performed. It is envisioned that three types of aquifer tests be performed: (1) a step-drawdown test, (2) a constant-rate pumping test, and (3) an aquifer recovery test. For the step-drawdown test, the rates and duration of each step will be determined after results of the drilling have been evaluated, but for planning purposes each step-drawdown test should take about one day to complete. The results from the step-drawdown test will be used to determine the appropriate pumping rate for the constant-rate pumping test.
13. After the step-drawdown test, the aquifer will be allowed to recover and then a constant-rate pumping test will be done which will last up to 120 hours. After the constant-rate test, an aquifer recovery test will be done, likely lasting up to a couple of days.
14. Sampling for soils and groundwater will be performed and tested in accordance with criteria developed for the DHCCP.

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15. Excavation of test pits will be performed within the footprint of proposed forebays, reusable tunnel material areas, and potential borrow areas to evaluate the subsoil profile and enable the collection of soil samples for laboratory testing. The soil samples will be tested to support Preliminary engineering and construction planning, such as the determination of the suitability of the materials to be considered for the embankment construction.
16. Methane and hydrogen sulfide will be monitored in accordance with the need as identified by the on-site environmental screening using direct reading instruments at the collar of the drill hole and with gas monitoring meter at the breathing zone during field investigations for selected borings.

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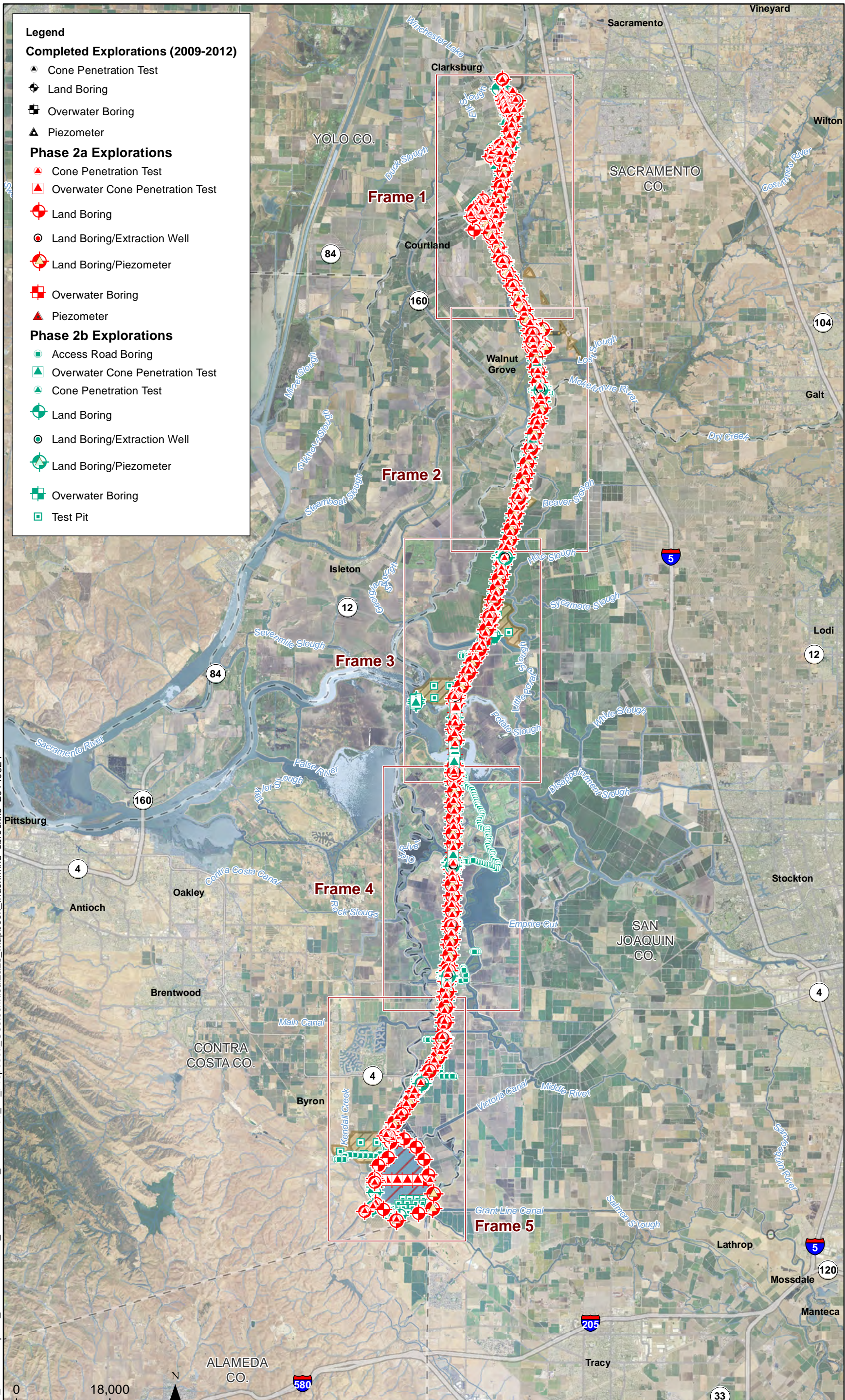
**6.0 SCHEDULE**

The estimated duration to complete the proposed Phase 2a and 2b explorations is about 42 months assuming four drill rigs operate concurrently. The exploration duration will vary depending on the availability of site access, drilling contractors and equipment, permitting conditions, and weather. The proposed explorations are planned to be performed between year 2015 and 2018. This proposed schedule would be refined as the engineering is advanced and access to project sites becomes available.

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**Attachment A**  
**Proposed Exploration Maps**

- Legend**
- Completed Explorations (2009-2012)**
- ▲ Cone Penetration Test
  - ⊕ Land Boring
  - ⊕ Overwater Boring
  - ▲ Piezometer
- Phase 2a Explorations**
- ▲ Cone Penetration Test
  - ▲ Overwater Cone Penetration Test
  - ⊕ Land Boring
  - ⊕ Land Boring/Extraction Well
  - ⊕ Land Boring/Piezometer
  - ⊕ Overwater Boring
  - ▲ Piezometer
- Phase 2b Explorations**
- ⊕ Access Road Boring
  - ▲ Overwater Cone Penetration Test
  - ▲ Cone Penetration Test
  - ⊕ Land Boring
  - ⊕ Land Boring/Extraction Well
  - ⊕ Land Boring/Piezometer
  - ⊕ Overwater Boring
  - ⊕ Test Pit



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**DHCCP - Geotechnical**  
**DWR - Internal Only**  
**WORKING DRAFT-Subject to Change**  
**04-04-800-9723**

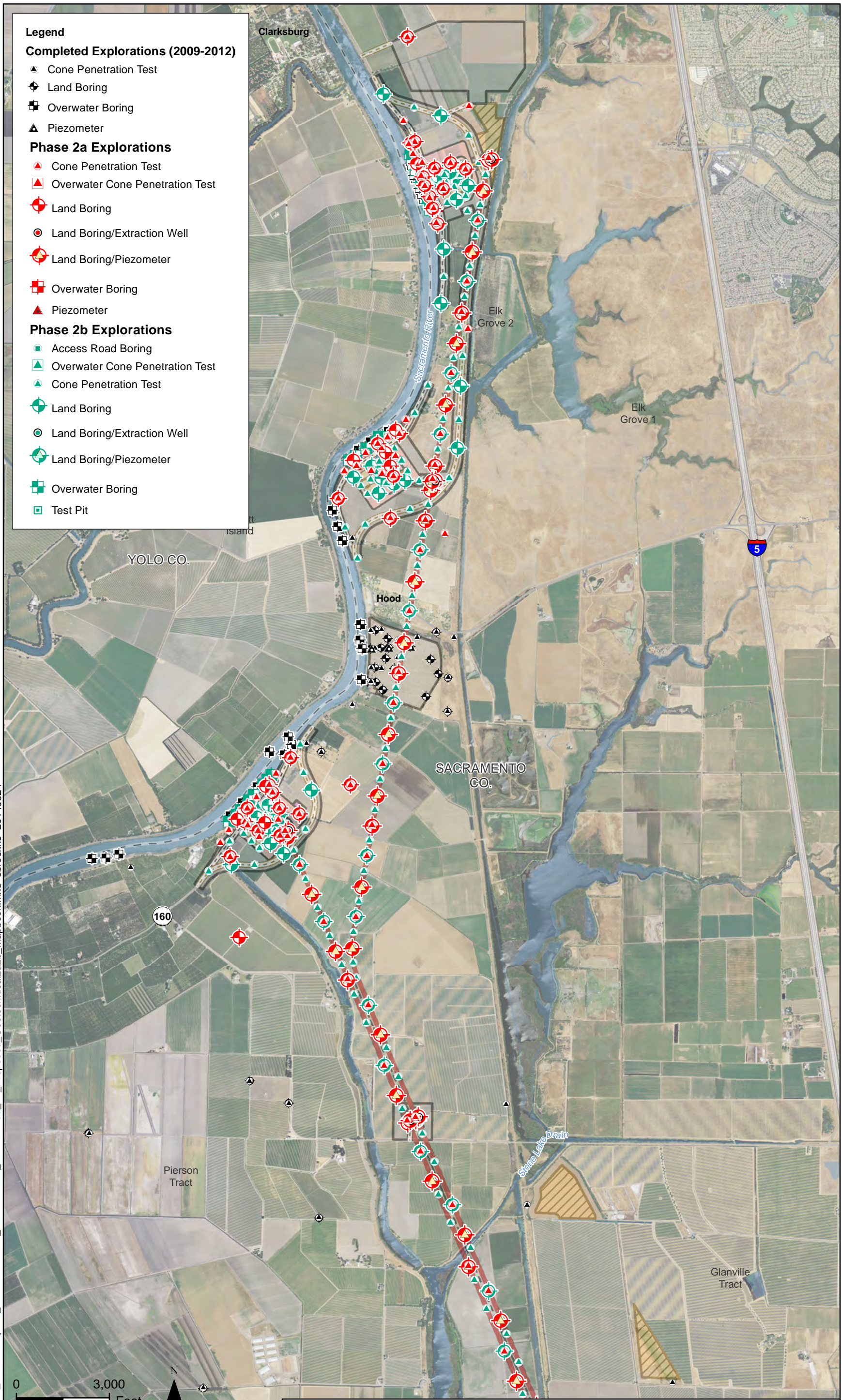
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**Proposed Geotechnical Exploration Locations Mapbook - Index**

Boring locations are preliminary and are subject to move when site access becomes available.

Source: MPTO rev2c

- Legend**
- Completed Explorations (2009-2012)**
- ▲ Cone Penetration Test
  - ⊕ Land Boring
  - ⊞ Overwater Boring
  - ▲ Piezometer
- Phase 2a Explorations**
- ▲ Cone Penetration Test
  - ▲ Overwater Cone Penetration Test
  - ⊕ Land Boring
  - ⊙ Land Boring/Extraction Well
  - ⊕ Land Boring/Piezometer
  - ⊞ Overwater Boring
  - ▲ Piezometer
- Phase 2b Explorations**
- ⊕ Access Road Boring
  - ▲ Overwater Cone Penetration Test
  - ▲ Cone Penetration Test
  - ⊕ Land Boring
  - ⊙ Land Boring/Extraction Well
  - ⊕ Land Boring/Piezometer
  - ⊞ Overwater Boring
  - ⊞ Test Pit



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**DHCCP - Geotechnical**  
**DWR - Internal Only**  
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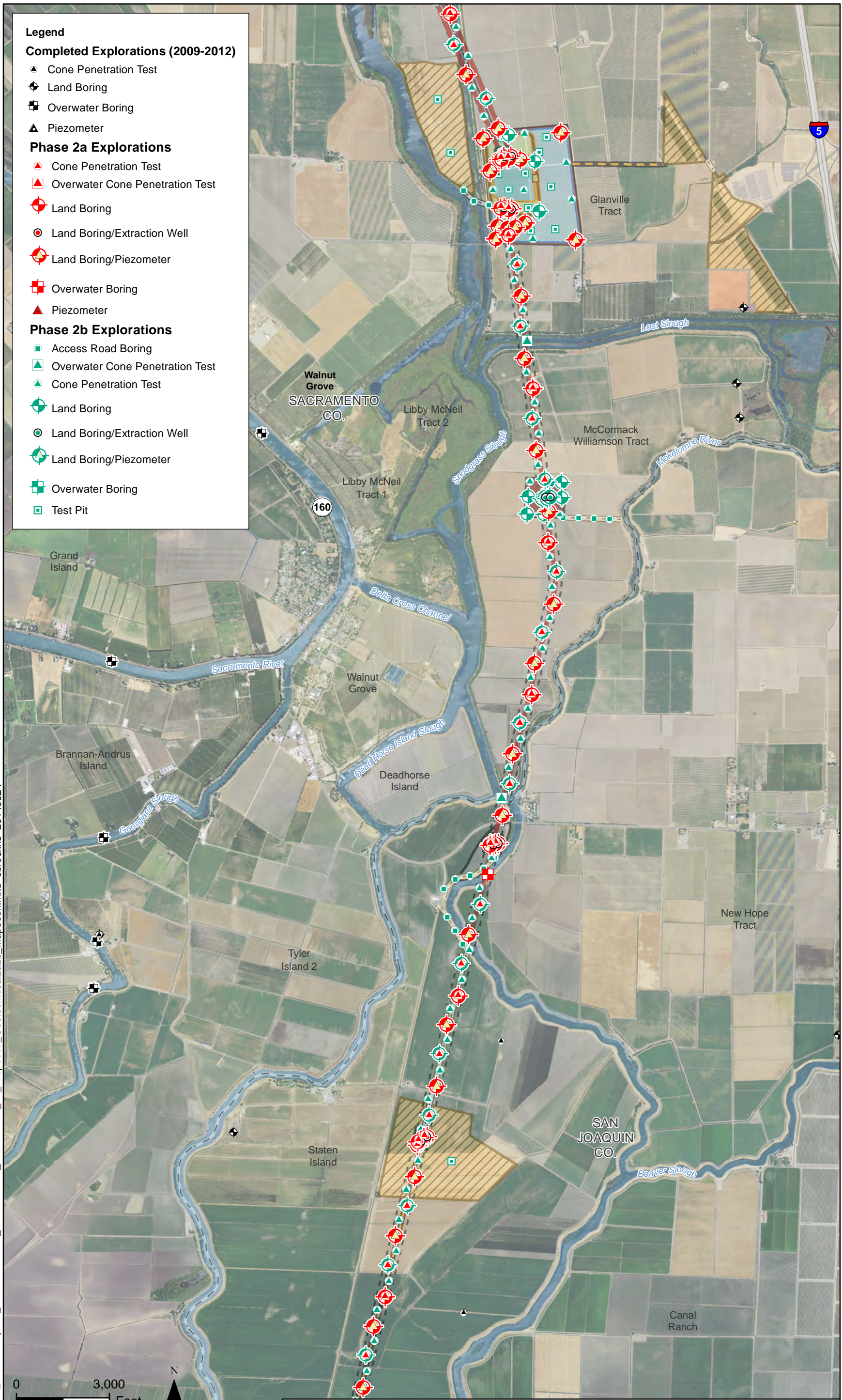
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**Proposed Geotechnical Exploration  
 Locations Mapbook - Frame #1**

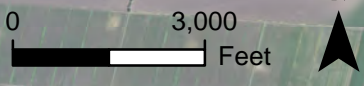
Boring locations are preliminary and are subject to move when site access becomes available.

Source: MPTO rev2c

- Legend**
- Completed Explorations (2009-2012)**
- ▲ Cone Penetration Test
  - ⊕ Land Boring
  - ⊕ Overwater Boring
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- ▲ Cone Penetration Test
  - ▲ Overwater Cone Penetration Test
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  - ⊕ Land Boring/Extraction Well
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  - ▲ Piezometer
- Phase 2b Explorations**
- ⊕ Access Road Boring
  - ▲ Overwater Cone Penetration Test
  - ▲ Cone Penetration Test
  - ⊕ Land Boring
  - ⊕ Land Boring/Extraction Well
  - ⊕ Land Boring/Piezometer
  - ⊕ Overwater Boring
  - ⊕ Test Pit



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**DHCCP - Geotechnical**  
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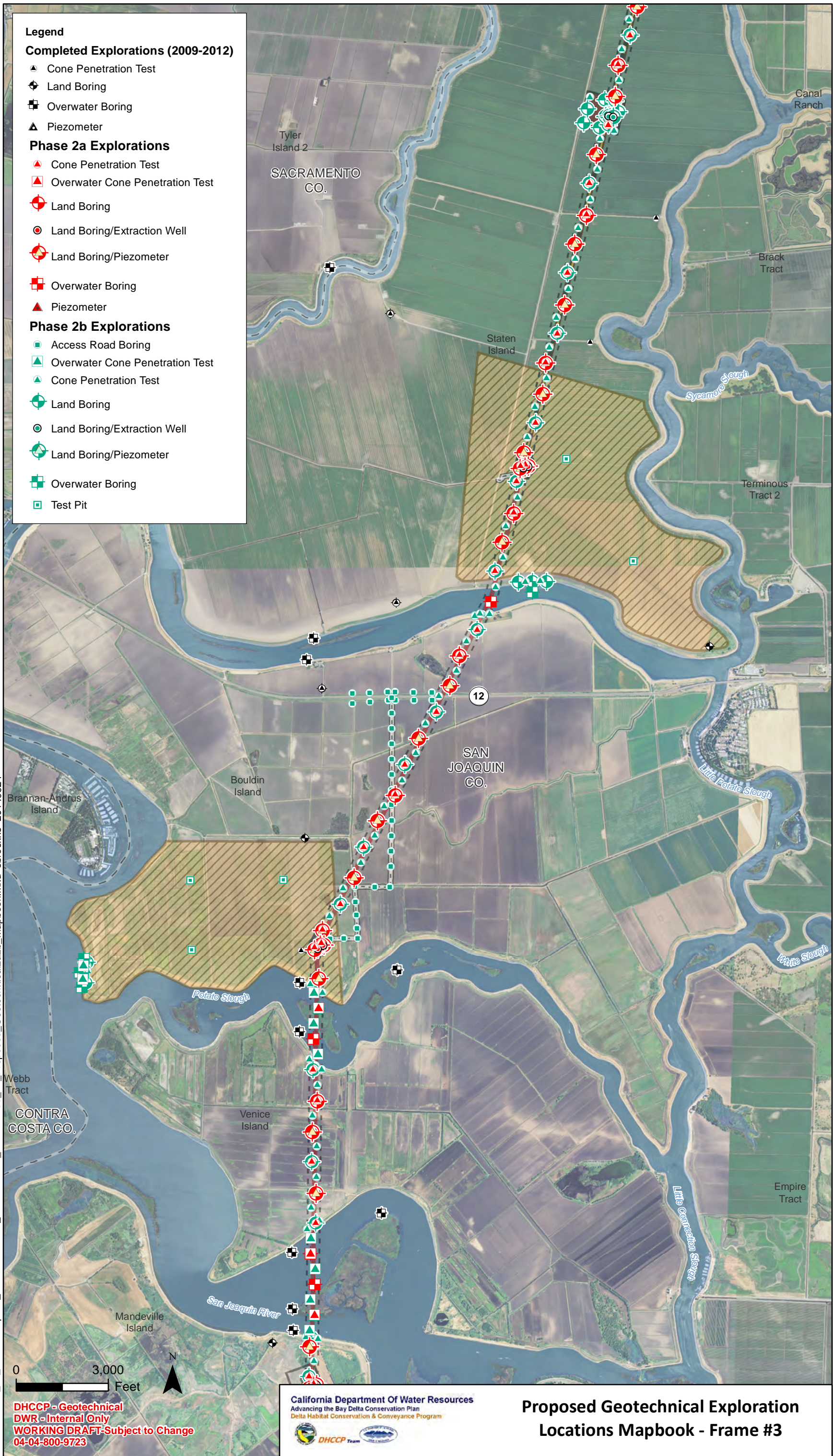
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**Proposed Geotechnical Exploration  
 Locations Mapbook - Frame #2**

Boring locations are preliminary and are subject to move when site access becomes available.

Source: MPTO rev2c

- Legend**
- Completed Explorations (2009-2012)**
- ▲ Cone Penetration Test
  - ⊕ Land Boring
  - ⊕ Overwater Boring
  - ▲ Piezometer
- Phase 2a Explorations**
- ▲ Cone Penetration Test
  - ▲ Overwater Cone Penetration Test
  - ⊕ Land Boring
  - ⊕ Land Boring/Extraction Well
  - ⊕ Land Boring/Piezometer
  - ⊕ Overwater Boring
  - ▲ Piezometer
- Phase 2b Explorations**
- ⊕ Access Road Boring
  - ▲ Overwater Cone Penetration Test
  - ▲ Cone Penetration Test
  - ⊕ Land Boring
  - ⊕ Land Boring/Extraction Well
  - ⊕ Land Boring/Piezometer
  - ⊕ Overwater Boring
  - ⊕ Test Pit



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**DHCCP - Geotechnical**  
**DWR - Internal Only**  
**WORKING DRAFT-Subject to Change**  
**04-04-800-9723**

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**Proposed Geotechnical Exploration  
 Locations Mapbook - Frame #3**

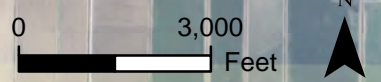
Boring locations are preliminary and are subject to move when site access becomes available.

Source: MPTO rev2c

- Legend**
- Completed Explorations (2009-2012)**
- ▲ Cone Penetration Test
  - ⊕ Land Boring
  - ⊕ Overwater Boring
  - ▲ Piezometer
- Phase 2a Explorations**
- ▲ Cone Penetration Test
  - ▲ Overwater Cone Penetration Test
  - ⊕ Land Boring
  - ⊕ Land Boring/Extraction Well
  - ⊕ Land Boring/Piezometer
  - ⊕ Overwater Boring
  - ▲ Piezometer
- Phase 2b Explorations**
- ⊕ Access Road Boring
  - ▲ Overwater Cone Penetration Test
  - ▲ Cone Penetration Test
  - ⊕ Land Boring
  - ⊕ Land Boring/Extraction Well
  - ⊕ Land Boring/Piezometer
  - ⊕ Overwater Boring
  - ⊕ Test Pit



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**Proposed Geotechnical Exploration  
 Locations Mapbook - Frame #4**

Boring locations are preliminary and are subject to move when site access becomes available.

Source: MPTO rev2c

- Legend**
- Completed Explorations (2009-2012)**
- ▲ Cone Penetration Test
  - ⊕ Land Boring
  - ⊕ Overwater Boring
  - ▲ Piezometer
- Phase 2a Explorations**
- ▲ Cone Penetration Test
  - ▲ Overwater Cone Penetration Test
  - ⊕ Land Boring
  - ⊕ Land Boring/Extraction Well
  - ⊕ Land Boring/Piezometer
  - ⊕ Overwater Boring
  - ▲ Piezometer
- Phase 2b Explorations**
- ⊕ Access Road Boring
  - ▲ Overwater Cone Penetration Test
  - ▲ Cone Penetration Test
  - ⊕ Land Boring
  - ⊕ Land Boring/Extraction Well
  - ⊕ Land Boring/Piezometer
  - ⊕ Overwater Boring
  - ⊕ Test Pit



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**Proposed Geotechnical Exploration  
 Locations Mapbook - Frame #5**

Boring locations are preliminary and are subject to move when site access becomes available.

Source: MPTO rev2c



**Attachment B**

**Exploration Methods and Equipment**

## Exploration Methods and Equipment

Field activities for on-land and overwater explorations are described below:

### On-land Exploration

The proposed Phase 2a and 2b exploration on land will consist of approximately 1,350 to 1,400 exploration locations including drilling boreholes and performing cone penetration tests (CPT); as well as conducting approximately 50 shallow test pit excavations (typically 4 feet wide x 12 feet long X 12 feet deep) in soils to evaluate bearing capacity, physical properties of the sediments, location of the groundwater table, and other typical geologic and geotechnical parameters. Cone penetration testing consists of pushing a cone connected to a series of rods into the ground at a constant rate, allowing continuous measurements of resistance to penetration both at the cone tip and the sleeve behind the cone tip. The resulting information correlates to the nature and sequence of subsurface soil strata, groundwater conditions, and physical and mechanical properties of soils.

Temporary pumping wells may be installed at intake, forebay, and tunnel shaft sites to investigate soil permeability and to allow sampling of dissolved gases in the groundwater. Small test pit excavations will be excavated to obtain near-surface soil samples for laboratory analysis. Drilling will take place at project sites that are readily accessible by truck or track mounted drill rigs.

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After each site is explored, the boring, cone penetration tests and/or well holes will be backfilled with cement-bentonite grout in accordance with California regulations and industry standards (Water Well Standards, DWR 74-81 and 74-90). Test pits will be backfilled with the excavated material on the same day as they are excavated with the stockpiled topsoil placed at the surface and the area restored as close as possible to its original condition.

Exploration activities may consist of auger and mud-rotary drilling with soils sampling using a standard penetration test (SPT) barrel (split spoon sampler) and Shelby tubes; cone penetrometer testing; temporary well installation; test pits; and electrical resistivity and other geophysical surveys. All exploration methods will require a drill rig and support vehicle for the drillers and vehicles for the Geologists and Environmental Scientists. The Department of Water Resources will implement best management practices that include measures for air quality, noise, greenhouse gases, and water quality. The different exploration methods may last from a few hours to several days and are described in the following paragraphs.

1) Drilling activities will generally be performed using a rotary drill rig with auger capabilities. A schematic layout of a typical drilling site is included as Figure B-1. Auger techniques will drill an approximate 6.5- to 8-inch-diameter boring and will be used only for shallow depths. Mud-rotary drilling and sampling will generate 4- to 6-inch-diameter borings, unless casing is required, which will increase the boring diameter to 6 to 8 inches. Depths of test holes will generally vary from about 10 to 225 feet. Drilling time estimated for each drill hole is approximately 3 work days for drill holes less than 100 feet deep, approximately 5 work days for drill holes to 225 feet deep, and up to 10 work days or more for deeper drill holes. Upon completion of soil sampling and testing, holes will be sealed using cement-bentonite grout in accordance with California regulations and industry standards (Water Well Standards, DWR 74-81 and 74-90). Drilling boreholes usually requires a truck or track-mounted drill rig typically powered by a 100 to 200 horsepower diesel engine. A drill rig tender vehicle and tool truck generally accompany the drill rig. Track-mounted rigs will be used only if needed to minimize access impacts over soft ground. Trailers will carry track-mounted equipment to

the site. Cuttings and excess drilling fluid will be contained in drums, large containers, or vacuum truck and disposed of offsite at an appropriate landfill.

2) Exploration to a depth of about 300 feet (rather than 225 feet) is required to evaluate soil properties for the proposed tunnel shafts and safe heaven areas. Exploration time estimated for the 300-ft deep boreholes is about 10 days. Work will be conducted within the established work windows.

3) Additional tests will be performed to collect geophysical data along the MPTO alignment including various structures. Downhole geophysical methods are necessary to characterize the soils, liquefaction potential, and to determine shear wave velocities for seismic stability analysis.

4) The cone penetrometer test sounding usually requires a truck-mounted, 15- to 30-ton push-capacity cone apparatus. The apparatus is typically powered by a 400- to 500-horsepower diesel engine. A drill rig tender vehicle and tool truck generally accompany the cone penetrometer test rig.

5) Select geotechnical drill holes may be completed as groundwater monitoring wells (piezometers) and pumping wells for aquifer testing. A schematic cross section of a typical piezometer is included as Figure B-2. An additional day or two added to the total drilling time may be required for the completion of each well. The wells will be completed in accordance with California regulations and industry standards (Water Well Standards, DWR 74-81 and 74-90). After well tests and monitoring are completed, the well material will be drilled out and the hole will be backfilled with cement-bentonite grout using a tremie pipe.

6) Shallow test pits (typically 4 feet wide x 12 feet long X 12 feet deep) may be excavated at limited locations to obtain near-surface soil samples for laboratory analysis. Test pits will not be excavated on any levees or in any sensitive habitats. During test pit excavation, topsoils will be separated from other material removed from the pit. Test pits will be backfilled with the excavated material on the same day as they are excavated, with the stockpiled topsoil placed at the surface and the area restored as close as possible to its original condition.

7) Non-invasive geophysical surveys may be employed to determine the near surface characteristics of the soil. The electrical resistivity surveys consist of driving four steel probes, each one-half inch in diameter, about 12 inches into the ground and measuring the resistance between different pairs of electrodes. The electrode spacing may vary depending upon the depth of investigation. The survey method is considered safe because low amperage currents (usually less than 0.5 amp) are involved. Therefore, the method does not present a danger to fauna. In addition, the duration of applied current is extremely short; just long enough to take a voltmeter reading. The process takes about 30 minutes, and at the completion, the probes and equipment are removed. Other on-land or airborne geophysical surveys use similar types of non-destructive equipment that measure parameters such as electrical currents, seismic waves, magnetic fields, or radar reflections on the ground.

8) Along the tunnel alignment, all the proposed borings of Phase 2a spaced at approximately 2,000 feet would be converted into piezometers. The initial plan at each borehole site is to install one single-level piezometer. However, if the geology encountered in the borehole suggests the likelihood of distinct aquifer units, a multi-level piezometer may be considered. Ideally, the piezometers would be the open-hole type, consisting of a standpipe. However, if conditions are not favorable for an open-standpipe piezometer, buried VW transducers could be utilized.

9) For each tunnel shaft site, two boreholes would be converted into groundwater extraction wells (pumping wells) and the other four boreholes be converted into piezometers. A schematic layout and cross section of a typical aquifer test is included as Figure B-3. This will enable pumping tests to be done in order to characterize the aquifer(s) at each shaft location site. After well construction is completed at each shaft site, aquifer testing will be performed. Three types of aquifer tests are planned: (1) a step-drawdown test, (2) a constant-rate pumping test, and (3) an aquifer recovery test. For the step-drawdown test, the rates and duration of each step will be determined after results of the drilling have been evaluated, but for planning purposes each step-drawdown test should take about one day to complete. The results from the step-drawdown test will be used to determine the appropriate pumping rate for the constant-rate pumping test. After the step-drawdown test, the aquifer will be allowed to recover and then a constant-rate pumping test will be done which will last up to 120 hours. After the constant-rate test, an aquifer recovery test will be done, likely lasting up to a couple of days.

### Overwater Exploration

Approximately 75 to 90 overwater geotechnical borings and CPTs are proposed to be drilled in the Delta waterways between 2015 and 2018. These include approximately 25 to 30 overwater geotechnical borings and CPTs in the Sacramento River to obtain geotechnical data for the proposed intake structures. Approximately 25 to 30 overwater borings and CPTs are planned at the major water crossings along the planned MPTO alignment. An additional 25 to 30 overwater geotechnical borings and CPTs are proposed for the barge unloading facilities and Clifton Court forebay modifications. The depths of borings and CPTs are planned to range between 100 and 200 feet below the mud line (i.e., river bottom).

The Department of Water Resources plans to conduct overwater drilling only during the time period from August 1 until October 31 between the hours of sunrise and sunset. This period is the recognized window of opportunity to avoid and/or minimize disturbance for sensitive environmental resources. Duration of drilling at each location will vary depending on the number and depth of the holes at each location, drill rate, and weather conditions, but are not expected to exceed 60 days at any one location.

The overwater geotechnical borings are proposed to be conducted in the following areas:

- At the proposed intake structures (intakes 2, 3 and 5) located on the Sacramento River between Courtland and the Clarksburg area, approximately 6 to 10 borings and CPTs at each site.
- Where the MPTO alignment would intersect major waterways, including:
  - North Mokelumne River
  - South Mokelumne River
  - Potato Slough
  - San Joaquin River
  - Connection Slough (east of Youngs Slough)
  - The Santa Fe Cut between Woodward and Bacon Island, if barge access possible
  - Woodward Canal, a.k.a. North Victoria Canal
  - Old River
  - Italian Slough
- Clifton Court Forebay

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The drilling will be conducted with a rotary drilling rig mounted on a shallow-draft barge or ship. Multiple barges and/or ships may be operated concurrently. The barge or ship will be anchored into the bottom of the channel with two to four spuds to prevent the vessel from drifting while the work is being performed. The spuds are steel pipes mechanically lowered into the channel bottom. The barge or ship will be mobilized from an established marina and will be anchored either at the drill sites or at Coast Guard established anchorage points. Personnel will access the barge and/or ship via a support boat from an established marina. When a drill rig remains on a boring location for more than one day, the drill apparatus and casing will remain in the water column and drill hole to minimize sediment disturbance of the river bottom. The drill apparatus consists of a 6- to 8-inch-diameter conductor casing that extends from the barge deck, through the water column, and into the soft sediments of the river bottom. The casing is smaller than most piers and would not impede water flow or migration patterns of fish. All of the drilling rods, samplers, and other down-hole equipment pass through the inside of the casing, which effectively separates them from the water. There are no loose items or netting on the casing that would entrap or snag fish.

The borings will be advanced using mud rotary method and will be drilled and sampled to a maximum depth of approximately 200 feet below the bottom of the slough or river. In this case, the term "mud" refers to the use of bentonite clay added to the boring to allow removal of drill cuttings and to stabilize the boring. Initially, the boring will be advanced by pushing an approximate 6- to 8-inch-diameter conductor casing, which will extend from the top of the barge or drill ship deck, an approximate depth of 10 to 15 feet or more below the mud line of the slough or river channel. The conductor casing will be used to confine the drill fluid and cuttings within the drill hole and operating deck of the barge or drill ship and prevent any inadvertent spillage into the water. Soil samples will be collected from within the conductor casing. The drill hole below the conductor casing will be approximately 3.5 to 5.5 inches in diameter.

Only water will be circulated through the pumps and conductor casing when drilling and sampling within 15 to 20 feet of the slough or river mud line. For deeper drilling, the drilling fluid, consisting of a mixture of circulating water and bentonite clay, will be introduced into the conductor casing via the drill string to create a more viscous drilling fluid (also called drilling mud). The drilling fluid will pass down the center of the drill rod to the cutting face in the formation being drilled and will return up the drilled hole with the suspended cuttings. The drilling fluids and cuttings will be confined by the borehole walls and the conductor casing. Return drill fluids will pass through the conductor casing to the barge or ship deck and then through a tee connection at the head of the conductor casing into the drilling fluid recirculation tank.

With the conductor casing in place, the drilling fluids will be kept in the closed system formed by the conductor casing and a tank at the top of the hole on the barge deck and a precautionary provision of a heavy plastic sleeve over the conductor casing which drapes into an external mud tank. This system will provide a reliable seal and prevent significant spillage of the drilling fluid into the water. The drill rod and sample rod connections will be disconnected either directly over the conductor casing or the recirculation tank. Furthermore, positive barriers consisting of hay waddles and/or other suitable type of spill-stoppage materials will be placed around the work area on the barge and ship decks.

Drill cuttings that settle out in the recirculation tank will be collected into 55-gallon storage drums. Good work practices will be observed and maintained in containing the drilling fluid, including taking care when transferring drill cuttings from the recirculation tank to the

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drums. The drums will be placed adjacent to the recirculation tank. If drilling fluid or drill cuttings material accidentally spill onto the barge deck outside of the containment area, they will be immediately picked up with a flat blade shovel and placed either into the recirculation tank or a storage drum, and the affected area will then be cleaned and mopped. Discarded soil samples will also be placed in the storage drums.

Samples will be obtained using a combination of split spoon samples, thin-walled tubes (Shelby tubes or piston samplers), and soil coring techniques. Standard penetration tests, a process of conducting split spoon sampling, will be taken in the sandy and clayey soils, and Shelby and piston tube (push) undisturbed soil samples will be taken in soft clay soils. Standard penetration tests are performed by dropping a 140 pound automatic hammer on the drill string to drive a sampler about 1.5 feet. This is a test conducted in short durations (a few minutes for each test) using a relatively small energy source. Vibrations from the test are minimal. The Shelby tube samples would be collected by pushing on the drill string with the weight of the drill rig and piston samplers would be collected using hydraulic fluid pressure. No vibrations are produced from pushing tube samples. A punch core or similar soil coring technique will be utilized to retain disturbed soil samples in an inner core barrel within the drill string.

Upon completion of each hole, the borings will be grouted from the bottom of the borehole to within approximately 10 to 15 feet of the top with 5 percent (by weight) bentonite and 95 percent (by weight) cement grout. Water will first be introduced inside the drilled hole and circulated within the conductor casing to clear out any remaining drilling mud prior to grouting. Grouting of the drilled hole will be accomplished by the tremie method from the bottom upward to a depth of approximately 10 feet below the bottom of the river based on a calculated grout take volume to prevent grout migration into the river water. At the completion of the grouting, the conductor casing will then be pulled out of the channel bottom to complete the overwater boring operation.

An Environmental Scientist stationed on the barge or ship will observe the drilling operation to ensure that all drilling fluid and cuttings are kept and confined within the recirculation tanks and storage drums. The Environmental Scientist will pay special attention to the river water for the presence of colored or increasingly opaque plumes when drilling, grouting, and pulling casing. All personnel on the barge or ship will report any observations of colored plumes in the water or leaking of the drilling fluids to the Environmental Scientist. Colored plumes are an indication that material may be leaking into the water. If an unauthorized discharge is discovered by any of the personnel on board the barge or ship, drilling activities will cease until appropriate corrective measures have been completed. Cuttings and excess drilling fluid will be contained in drums or bins, periodically off-loaded to a land-based staging area, and disposed of at a State-approved landfill site. The overwater borings will be supervised by a licensed drilling contractor under the direction of Department of Water Resources' personnel or its Contractor. An Engineering Geologist or an engineer will be on site at the drill rig to supervise activities at all times during the operation. An environmental scientist will be on-site during all active drilling work to monitor activities.

Cone penetration testing will be performed with a rig mounted on a shallow-draft barge or ship. The barge or ship will be anchored into the bottom of the channel with two to four spuds to prevent the vessel from drifting while the work is being performed. The spuds are steel pipes mechanically lowered into the channel bottom. The barge or ship will be mobilized from an established marina and will be anchored either at the drill sites or at Coast Guard established anchorage points. Personnel will access the barge and/or ship via a support boat from an established marina. Cone penetration testing consists of pushing a

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cone connected to a series of rods (about 1.75 inch in diameter) from the barge deck, through the water column, and into the soft sediments of the river bottom at a constant rate, allowing continuous measurements of resistance to penetration both at the cone tip and the sleeve behind the cone tip. There are no loose items or netting on the CPT rods that would entrap or snag fish.

Equipment

Based on the previous exploration completed, details on anticipated equipment with fuel consumption rate and estimated operation hours are provided below to analyze environmental impacts:

On-land Exploration:

<b>Equipment</b>	<b>Estimated Total Operation Days</b>	<b>Total Operation Hours<sup>1</sup></b>	<b>Fuel Consumption Per Hour<sup>2</sup></b>	<b>Total Fuel Consumption (gal. diesel)</b>
Backhoe	24	200	3	600
Drill Rig	2,700	27,000	4	108,000
CPT Rig	250	2,500	7	17,500
Drill Support Truck	2,700	5,400	6	32,400
Backhoe Transport	24	48	8	384
Drill Rig Transport	130	520	8	4,160
CPT Rig Transport	250	1,000	8	8,000
Generator-Pumping Test	350	8,400	6	50,400

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Overwater Exploration:

<b>Equipment</b>	<b>Estimated Total Operation Days</b>	<b>Total Operation Hours<sup>1</sup></b>	<b>Fuel Consumption Per Hour<sup>2</sup></b>	<b>Total Fuel Consumption (gal. diesel)</b>
Drill Rig	500	5,000	4	20,000
CPT Rig	25	250	7	1,750
Drill Rig Mobilization	20	200	7	1,400
CPT Rig Mobilization	6	60	7	420

<sup>1</sup> A 12-hour workday is assumed (2 hours each day for travel and 10 hours for drilling)

<sup>2</sup> Drilling Contractor Estimation (Gregg Drilling, Inc, Tim Boyd 5/18/2009)

Workforce Transportation:

Details on anticipated number of workers and the estimated average distance workers are summarized below:

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<b>Number of workers/Day</b>	<b>Total Number of Workdays</b>	<b>Average Distance Travelled (round trip)</b>	<b>Total Miles Travelled</b>	<b>Fuel Efficiency<sup>3</sup></b>
<b>On-land Exploration</b>				
3 (passenger vehicle)	3,350	70	703,500	21
<b>Overwater Exploration</b>				
4 (passenger vehicle)	550	120	66,000	20.8
Speed Boat	525	15	7,875	4

<sup>3</sup> US Environmental Protection Agency, Light-Duty Automotive Technology and Fuel Economy Trends: 1975 through 2008



**Legend**

- Drill Hole
- ==== Temporary 10' Wide Access Road
- Temporary Construction Area (Approx. 10,000 sq ft)



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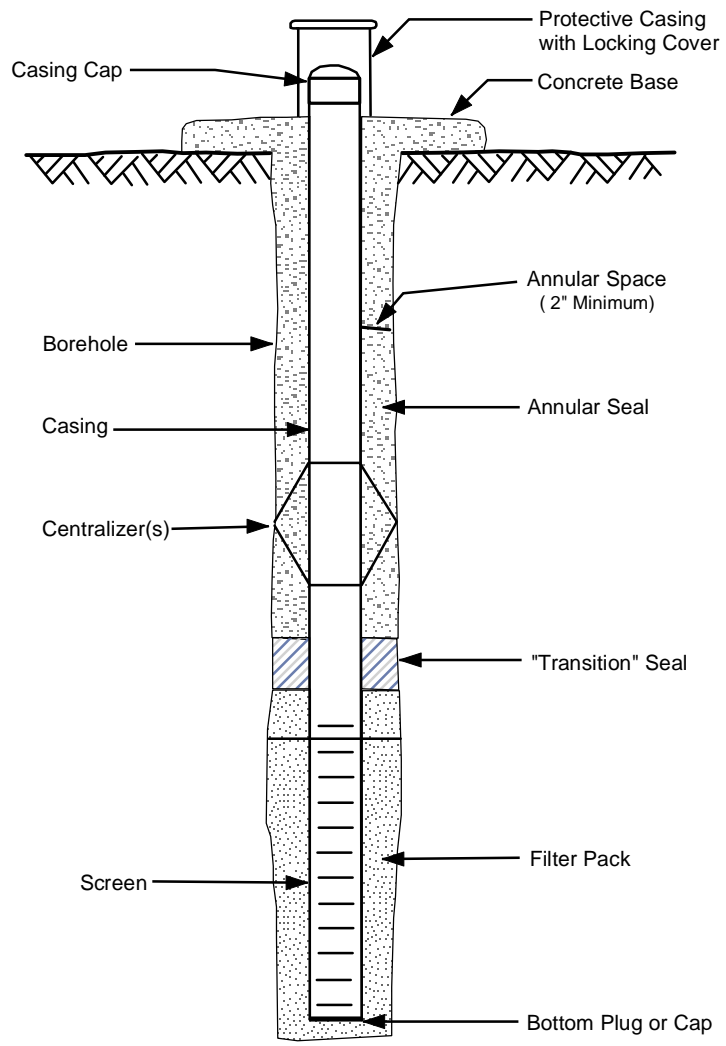


GEOTECHNICAL EXPLORATION PLAN - PHASE 2  
MODIFIED PIPELINE/TUNNEL OPTION

**Typical Drilling Site Layout**  
(Schematic, not to scale)

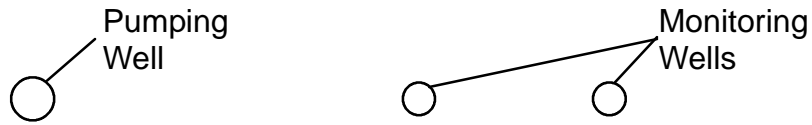
FIGURE

**B-1**

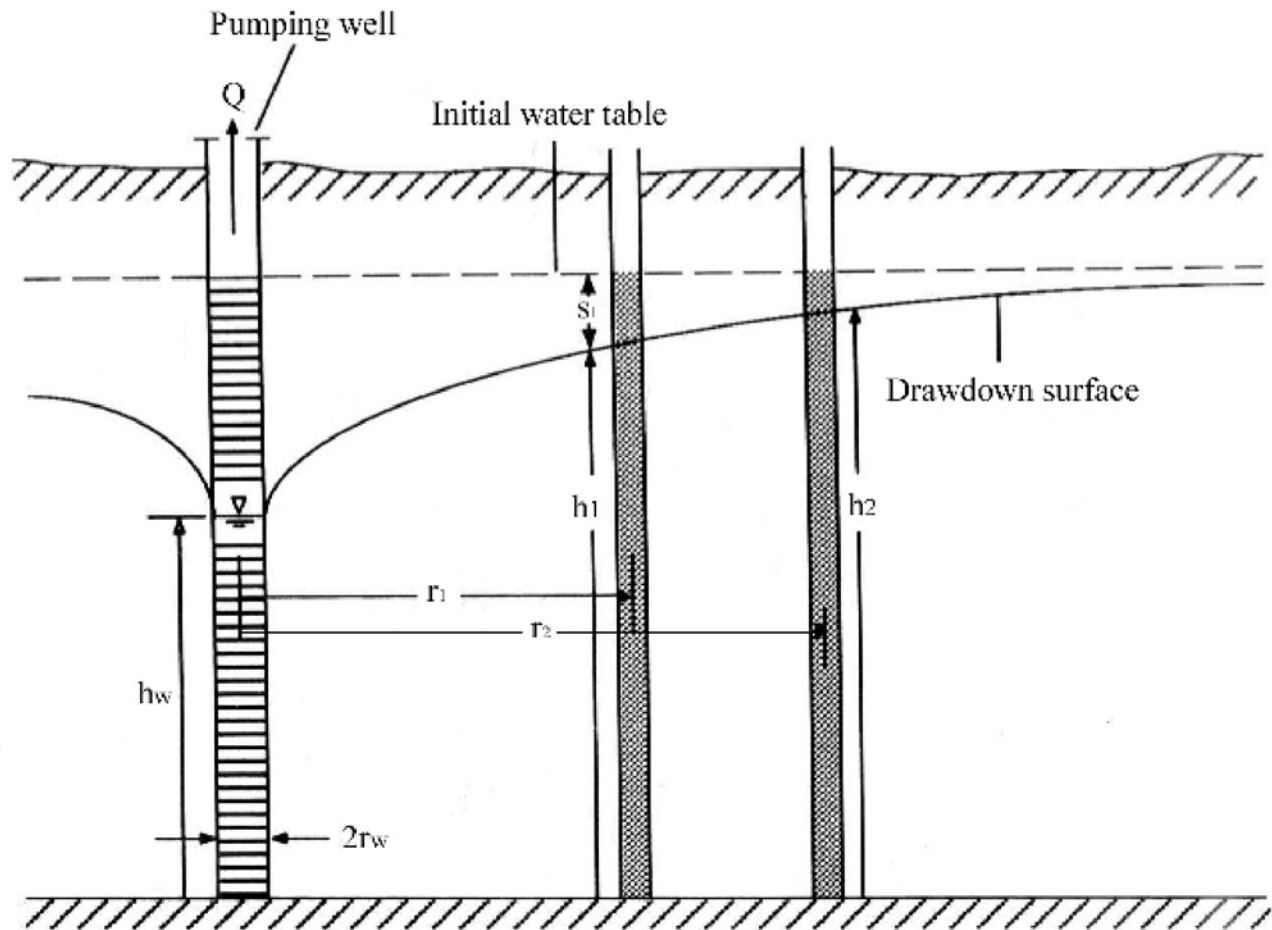


Source: DWR Bulletin 74-90

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**Plan**



**Cross Section**

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GEOTECHNICAL EXPLORATION PLAN - PHASE 2  
 MODIFIED PIPELINE/TUNNEL OPTION

**Typical Aquifer Test Layout and Cross Section  
 (Schematic, not to scale)**

FIGURE  
**B-3**