DRAFT PHASE II GEOTECHNICAL INVESTIGATION – OVER-WATER GEOTECHNICAL DATA REPORT – PIPELINE / TUNNEL OPTION

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ASTM	ASTM International
ATO	All Tunnel Option (name changed to Pipeline/Tunnel Option)
BDCP	Bay Delta Conservation Plan
bgs	below ground surface
BTF	Byron Tract Forebay
CAM 17	California Administration Manual Title 22 Environmental Health listing of 17 heavy metals
CCF	Clifton Court Forebay
CEQA	California Environmental Quality Act
CER	Conceptual Engineering Report
CH_4	methane
cm/sec	centimeter per second
cm^2	square centimeters
COC	chain-of-custody
CO	carbon monoxide
CPT	cone penetrometer test
CVFPB	Central Valley Flood Protection Board
CVP	Central Valley Project
DCC	Delta Cross Channel
Delta	Sacramento River-San Joaquin River Delta
DHCCP	Delta Habitat Conservation and Conveyance Program
DOT	California Department of Transportation
DWR	California Department of Water Resources
EL	elevation
fps	feet per second
gINT	gINT Geotechnical and Geoenvironmental database and graphics presentation software, produced by Bentley Systems, Inc., Exton, PA
GPS	global positioning system
Gregg Drilling	Gregg Drilling & Testing, Inc.
H_2S	hydrogen sulfide
ICF	Isolated Conveyance Facility
ICF East	Isolated Conveyance Facility - East Option
ICF West	Isolated Conveyance Facility - West Option
ID	inside diameter
IF	Intermediate Forebay
LiDAR	Light Detection And Ranging
mg/L	milligrams per liter
mg/kg	milligrams per kilogram
mg/m^3	milligrams per cubic meter

mm	millimeter
MND	Mitigated Negative Declaration
Mod Cal	modified California split-spoon sampler
ND	not detected
NOE	Notice of Exemption
NS	not sampled
OD	outside diameter
O_2	oxygen
PID	photoionization detector
PTO	Pipeline/Tunnel Option
PVC	polyvinyl chloride
QA	quality assurance
QC	quality control
RD	Reclamation District
SLC	State Lands Commission
SPT	standard penetration test
SLR	sea level rise
SWP	State Water Project
TDF	Through-Delta Facility
TEP	temporary entry permit
TPH	total petroleum hydrocarbons
µg/kg	microgram/kilogram
µg/L	microgram/liter
URS	URS Corporation
USA	Underground Service Alert
USACE	U.S. Army Corps of Engineers
USCS	Unified Soil Classification System
VOC	volatile organic compound
WGI	Washington Group International

EXECUTIVE SUMMARY

This report presents the data collected during the 2010 Phase II Geotechnical Investigation of the Delta Habitat Conservation and Conveyance Program. The main purpose of the Phase II Geotechnical Investigation is to collect and provide relevant subsurface information along the four proposed water conveyance option alignments and appurtenant facilities in support of the preparation of the environmental impact report and environmental impact statement. The water conveyance options are part of the improvement alternatives to the Sacramento River-San Joaquin River Delta (Delta) outlined by former Governor Schwarzenegger in his letter to Senators Don Perata, Darrell Steinberg, and Mike Machado, dated February 28, 2008.

The proposed 2010 Phase II Geotechnical Investigation included land-based and over-water field exploration using conventional soil borings and performing laboratory soil testing. To perform the land-based field exploratory work, temporary entry permits (TEPs) for each property would be required. TEPs were not obtained and the land-based field program could not be performed as planned. Only over-water exploration was accomplished for the 2010 Phase II Geotechnical Investigation. The over-water exploration locations drilled were at five proposed intakes and along the Pipeline/Tunnel Option. Table ES-1 summarizes the over-water borings completed under the 2010 Phase II Geotechnical Investigation program. In areas where no field explorations were performed, existing data collected by other investigators may be consulted. Section 1.5 identifies the sources of existing data that were collected by past investigations for other Delta-related projects.

This report includes six sections:
Section 1.0 provides a brief introduction of the overall project and background information
Section 2.0 provides a detailed description for investigation methods.
Section 3.0 presents results found in this investigation.
Section 4.0 provides recommendations for additional work to support future engineering activities.
Section 5.0 includes a list of publications cited in this report.
Section 6.0 includes a list of staff responsible for preparing this report.

This data report provides the findings from field exploration and results from laboratory testing. No interpretation and analysis of the findings and test results are provided in this Geotechnical Data Report.

Table ES-1 Summary of 2010 Phase II Exploration

Feature/Option	CPTs	Land-Based Borings	Over-Water Borings	Piezometers
Intakes	0	0	15	0
ICF East	0	0	0	0
ICF West	0	0	0	0
TDF	0	0	0	0
PTO	0	0	11	0
Total	**0**	**0**	**26**	**0**
Total Footage	**0**	**0**	**4,376.5**	**0**

CPT = cone penetrometer test
ICF = Isolated Conveyance Facility
TDF = Through-Delta Facility
PTO = Pipeline/Tunnel Option

1.0 INTRODUCTION

1.1 Purpose

This geotechnical data report presents the data acquired during the 2010 Phase II Geotechnical Investigation Program performed for the Proposed Intakes and the Isolated Conveyance Facility - Pipeline/Tunnel Option (PTO), of the Delta Habitat Conservation and Conveyance Program (DHCCP). These data were collected to support the development of the environmental impact report and the environmental impact statement for the Bay Delta Conservation Plan (BDCP). This report provides geotechnical data and is not intended as a comprehensive, interpretative report to support the preliminary engineering design process of the DHCCP. However, it provides a widely spaced overview of the geologic and geotechnical conditions of the proposed intakes and PTO.

1.2 Scope

This report presents field and laboratory test data obtained during the 2010 Phase II Geotechnical Investigations, as well as the methods used for data acquisition. This report is prepared for the Proposed Intakes and PTO conveyance alignment. The Proposed Intakes and PTO alignment were previously named the All Tunnel Option (ATO) in reports written before July 1, 2010. All the investigation locations specific to the Pipeline/Tunnel Option and intakes are designated DCRA and DCR (followed by a numeral designating which intake), respectively. In some cases, the data collected during the 2010 Phase II Geotechnical Investigation is applicable to more than one alternative. This report highlights information obtained for this specific option and the Proposed Intakes. The appendices contain all the data collected during the 2010 Phase II Geotechnical Investigations.

1.3 Project Background

1.3.1 Overall Project

Currently, the State Water Project (SWP) and the Central Valley Project (CVP) divert water primarily from the Sacramento and San Joaquin Rivers for use by cities and farms in the Central Valley, San Francisco Bay Area, Central Coast, and Southern California. The current method for conveying water to the SWP and the CVP is based solely upon the existing rivers, channels, and sloughs of the Sacramento River-San Joaquin River Delta (Delta). The SWP and CVP facilities include reservoirs on the Sacramento and the San Joaquin Rivers. The rivers themselves are used as conveyance channels. The Delta Cross Channel (DCC), near Walnut Grove, controls the flow of Sacramento River water into the eastern Delta. Internal Delta channels are used to convey water from the DCC through the central Delta to the pumping and fish salvage facilities of the SWP and CVP in the southern Delta, near the town of Tracy.

In his letter dated February 28, 2008, Governor Schwarzenegger requested that four different conveyance options to move surface water from the North Delta to the South Delta be investigated as solutions to help reduce the deteriorating conditions in the Delta. Geotechnical field investigations were undertaken to acquire data that could be used to support the preparation of the environmental documentation necessary to evaluate each option. The results of the 2010 Phase II geotechnical field investigation are presented here.

1.3.2 Summary of Option

The PTO provides a new isolated conveyance for Sacramento River water diverted through multiple fish-screened intakes located near Freeport and Hood and conveyed by a series of tunnels to an Intermediate Forebay (IF) protected from flood, earthquake, and sea level rise (SLR). The intakes are common to all proposed options with the exception of the western alignment option. This option proposes a few intakes on the right bank of the Sacramento River. Water collected in the forebay would flow by gravity or pumping through a two-bore tunnel system to a new forebay, the Byron Tract Forebay (BTF), located adjacent to and south of the Clifton Court Forebay (CCF). Water would then be conveyed to the existing pumping plants serving the State Water Project and Central Valley Project.

The system includes:

- Intake facilities equipped with fish screens, sedimentation basins, pumping plants, and pipelines
- Tunnels to convey flow to the IF
- IF with pumping plant
- Tunnels to convey flow to the south
- A new forebay at CCF

1.4 Geologic Setting

The alignment options, which extend from the City of Sacramento in the north to CCF in the south, all begin in the alluvial flood plain of the Central Valley's Sacramento River and cross the Delta. The Delta represents the arm of the San Francisco Bay estuary that extends into the Central Valley geomorphic province of California and the waters are all influenced by tidal actions. The Delta is bordered on the west by the Coast Ranges, on the north by the Sacramento River floodplain, on the south by the San Joaquin River floodplain, and transitions into California's Central Valley towards the east. The Central Valley province is a sedimentary basin approximately 430 miles long and up to 65 miles wide, which lies between the primarily granitic mountain ranges of the Sierra Nevada province to the east and the primarily marine and volcanic Franciscan Complex rocks of the Coast Ranges province to the west. The Central Valley province is characterized by a large northwest-trending asymmetrical synclinal trough filled with a prism of upper Mesozoic-age (approximately 135 million years old) through recent sediments up to 30,000 feet thick (Bartow, 1991).

The geomorphology and surficial geology of the Delta have been shaped by the landward spread of tidal environments resulting from sea level rise (SLR) since the last glacial period. During that period, approximately 15,000 years ago, the Pacific Coast was at least 6 miles west of its present position and the relative sea level was approximately 300 feet lower than present-day sea level. During the last glacial period, the location of the present-day Delta formed part of the arid alluvial floodplain. As a consequence, alluvial and eolian sand deposits underlie most of the late Holocene Delta soils. Between 10,000 and 5,000 years ago, relative SLR was rapid, out-stripping the rate of deposition of flood-borne sediments supplied by the river systems (Byrne et al., 2001). This action resulted in the landward transgression of the ocean through the Carquinez Strait and into the Central Valley, forming the Suisun Bay and the Delta. This period saw the widespread deposition of organic silt and clay across the alluvial floodplain surface. Approximately 5,000 years ago, relative SLR slowed, halting landward transgression of the tidal wetlands. At this time, the Deltaic environment remained in approximately its present position, with slow relative SLR balanced by vertical marsh growth through biomass accumulation and sediment deposition (Atwater et al., 1979).

The natural topography of the valley in the vicinity of the alignment options is subdued, with little relief. An extensive manmade levee system has been developed along the lower reaches of both the Sacramento and San Joaquin River systems and throughout the Delta area.

Geologic units mapped in the area of the alignment options are dominated by marsh and tidal estuary deposits associated with the Delta and by alluvium deposited by the Sacramento and San Joaquin Rivers and their tributaries (Gorman and Wells, 2000). These units are lithologically diverse and exhibit complex interfingering typical of a deltaic depositional environment.

The Sacramento and San Joaquin Rivers and their tributaries drain approximately 80 percent of the Central Valley watershed through the Delta into San Francisco Bay. Before construction of modern flood control features, such as dams and levees, these river systems provided floodwater and sediment to much of the valley floor (Simenstad et al., 2000). During low flow, these rivers were confined to channels by natural levees. Natural levees consist of overbank deposits that form low ridges parallel to the river that are built of sandy and silty sediment. These ridges slope gently away from the river toward the flood basins. During floods, the river would overtop these levees depositing water and sediment onto the adjacent flood plains. As the flood waters spread out from the rivers, losing velocity, the heavier portions of the sediment load settled out, depositing first sand, then silt, and lastly clay on the adjacent flood basin. Over time, some of these river channels migrated across the valley floor leaving abandoned and buried channel and over-bank deposits within the flood basin deposits.

Throughout the Delta, the Sacramento and San Joaquin River systems are “losing” rivers, meaning that surface water in the Sacramento and San Joaquin Rivers seeps from these rivers into the subsurface and becomes groundwater. Groundwater over much of the area of the conveyance alignments is controlled by farming activities, including irrigation and pumping, to maintain groundwater levels below the root zones of cultivated crops. In general, groundwater is approximately 5 feet below the surface throughout the Delta, except in areas immediately adjacent to a riverbank where groundwater elevations typically rise to within 1 or 2 feet of the surface (California Department of Water Resources [DWR], 2009).

During the past century, large quantities of groundwater have been pumped from islands in the Delta to create arable land suitable for agriculture. The decline in groundwater levels has led to oxidation and desiccation of peat deposits (Atwater, 1982). These factors, coupled with levee construction to manage floodwaters, have led to land subsidence throughout much of the Delta.

1.5 Historical Data

Until property access is obtained for site-specific investigations, historical boring data continue to provide the most widespread information on the geologic and geotechnical conditions expected at the project. Two electronic databases of boring logs are available to the DHCCP project through the project's geographic information systems. One was provided from the Delta Risk Management Strategy project and one was provided from DWR internal records. Most of the existing data is concentrated along levees and highways and is limited to the upper 50 feet of the subsurface. Of particular note are borings from the original SWP investigations of the peripheral canal and various investigations in the vicinity of the CCF. Data quality is variable. The data were acquired between the late 1950s and the mid-2000s. These data sources included the following investigations:

- Salinity Control Barrier Investigation. DWR, 1957-1958.
- Third Mokelumne Aqueduct Investigation. East Bay Municipal Utility District, December, 1960.
- Peripheral Canal Investigation, Delta Facilities. DWR, 1968.
- Alternative Studies, East Central Delta Canal. DWR, June 1976.
- Suspension P- and S_H-Wave Velocity Measurements on the Bacon Island Levee, Webb Tract, Sherman Island, and Clifton Court Forebay Levees. Prepared by Agbabian Associates for DWR, July 13; May 13; August 5, 24, 29; and October 18, 1993.
- South Delta Seepage Study, Old River Monitoring Wells. DWR, September 1997.
- Engineering Geology Report, Clifton Court Forebay. Proposed New Intake-Italian Slough. DWR, February 2011.
- Engineering Geology Report, Grant Line Barrier, South Delta Improvement. DWR, October 2002.
- West Sacramento Levee System Problem Identification and Alternatives Analysis, Solano and Yolo Counties, California. Prepared by Kleinfelder, September 2007.

2.0 INVESTIGATION METHODS

The 2010 Phase II Geotechnical Investigations included over-water soil borings and laboratory testing. The completed explorations represent only a portion of the planned investigation. On-land borings and cone penetration testing at other locations along the various proposed alignments are proposed as part of future exploration. Locations of the borings are depicted in Figure 2-1. This section describes the pre-field activities and permits required for the Phase II Geotechnical Investigations, as well as details of the equipment, procedures, and quality control (QC) measures employed during the investigation.

2.1 Site Access and Permits

2.1.1 Overview

Multiple permits, clearances, and authorizations were obtained for access to the 2010 Phase II Geotechnical Investigation over-water exploration locations. These included notifying local levee reclamation districts (RDs) and a project-wide Mitigated Negative Declaration (MND) under the California Environmental Quality Act (CEQA), including permits and consultation with federal, state, and local agencies as discussed below. Pre-investigation field inspections and surveys were performed to evaluate environmental, biological, and cultural resources, and utility clearances.

The final location of each investigation site was an iterative process, as the originally planned location could be modified by environmental, utility, and site-access concerns. Where practical, all the pre-investigation field inspections and surveys were combined into one visit, in which the geographic coordinates of the proposed exploration location, which may have been modified as part of the survey, was recorded with global positioning system devices; the nearest on-bank location was then marked with a stake, white spray paint, and flagging.

2.1.2 Temporary Entry Permits

While land parcels require a temporary entry permit (TEP), including parcels owned by DWR, all 2010 Phase II exploration was conducted from the water in rivers and sloughs, where TEPs are not required. However, land exploration was proposed for Phase II, and the TEP process was employed to conduct environmental, utility, and geotechnical site assessments for proposed land exploration locations that are now delayed until 2011 and 2012. The TEP allows project staff to enter a parcel to conduct ground and aerial surveys, engineering, biological, geological, archeological, floral and faunal studies, environmental site assessments, and other incidental purposes. Acquisition of TEPs from owners willing to grant temporary access for subsequent phases of investigation in the project is ongoing. On April 8, 2011, the San Joaquin Superior Court declined to order temporary access to parcels in Sacramento, Solano, Yolo, Contra Costa, and San Joaquin Counties whose owners are unwilling to allow geotechnical exploration on their land.

Entry to individual parcels with a signed TEP was limited to a total of 60 days for all disciplines including environmental, cultural, survey, engineering, and geotechnical. Over-water drilling was restricted to hours between sunrise and sunset to comply with environmental restrictions.

Each crew was required to have a signed copy of the TEP at all times. A DHCCP environmental monitor accompanied the geotechnical crew during all investigation activities.

2.1.3 Levee Reclamation District Notification

Levee RDs were notified by DHCCP Public Relations of proposed exploration locations when drilling was planned adjacent to their levees. All borings adjacent to levees were drilled in accordance with state and industry standards for drilling through levees; emergency procedures, as described in the DHCCP Geotechnical Investigation Work Plan (DHCCP Team, Revision 3, September 20, 2010), were in place in case of incidents.

2.1.4 Mitigated Negative Declaration

The MND prepared under CEQA was accepted by the State Clearinghouse in June 2010 and updated in September 2010. The MND allows geotechnical exploration through December 2012 to prepare a draft environmental document but requires site-specific inspections of the proposed exploration locations before geotechnical field work is performed. The site inspections evaluate access and potential environmental restrictions or potential project performance concerns, including, but not limited to, potential biological and cultural resources and the locations of underground utilities. Each site inspection involved an environmental scientist, cultural resource specialist, and a geologist who assessed any potential environmental impacts owing to the geologic investigations at the proposed site and the proposed access route. Utility clearances are discussed in more detail in Section 2.1.5.

2.1.5 Utility Clearances

The presence of overhead and underground utilities was evaluated for proposed exploration locations. A minimum distance of 20 feet was maintained between drill rig mast and low-voltage overhead lines (power lines). A minimum distance of 50 feet was maintained between drill rig mast and high-voltage overhead transmission lines.

Proposed over-water exploration locations were documented with a GPS device; where possible, the nearest on-bank location was marked by wood lathe with white flagging. Underground Service Alert (USA) was contacted a minimum of two weeks before performing subsurface explorations. The DWR and DHCCP team contacted representatives from utilities identified by USA to verify utility clearance for the proposed exploration locations. Site visits with the utility representatives were performed at proposed exploration locations where there was an uncertainty about the location of underground utilities or potential conflicts.

2.1.6 Pre-Drilling Site Survey

A pre-drilling site survey for cultural compliance, environmental compliance, utility clearance, and drill-rig access was performed for the exploration locations. Surveys of the proposed exploration locations were performed by a geologist or engineer and documented on a specific form.

2.1.7 Over-Water Drilling Permit and Access Requirements

The waterways where drilling was planned are considered State Lands. The State Lands Commission (SLC) protects waterways in a public trust and has jurisdiction over rivers. Therefore, TEPs are not needed. However, pursuant to the 1979 Memorandum of Understanding between SLC and DWR, formal notification of the proposed work was provided by DWR to the SLC Public Lands Manager.

Multi-agency coordination and several permits were obtained before over-water drilling was performed. Permissions and permits were obtained from:

- California Fish and Game Code Section 1600, Streambed Alteration Agreement;
- U. S. Army Corps of Engineers (USACE), Section 404 of the Clean Water Act, and Section 10 of the Rivers and Harbors Act, Nationwide Permit 6;
- Regional Water Quality Control Board Clean Water Act Section 401;
- Letter of Concurrence from U.S. Fish and Wildlife Service for federal species under the Endangered Species Act under their jurisdiction;
- Letter of Concurrence from National Oceanic and Atmospheric Agency Fisheries Unit for federal species under the Endangered Species Act under their jurisdiction.

The Central Valley Flood Protection Board (CVFPB) was contacted for encroachment permits for over-water borings proposed near Project levees. CVFPB concluded that permits were not required because the DHCCP project is considered part of the SWP conveyance program, therefore, exempt from Board permits. California Water Code 8536 provides that CVFPB has no power, jurisdiction, or authority over the construction, operation, and maintenance of the State Water Project.

The MND, which describes activities to be performed during subsurface exploration and ways to avoid adverse effects on natural habitats, was submitted and accepted at the State Clearinghouse on September 23, 2010.

The various permits and MND imposed the following restrictions on over-water drilling:

- Drilling is limited to the period starting August 15 through October 31 during daylight hours only;
- Presence of an environmental monitor is required at all times during drilling;

- Plans and mitigation to minimize or control spills during drilling activities are required;
- No drilling is permitted at known shipwreck sites; and
- No drilling is permitted on levee slopes.

2.2 Location Surveys

Location surveys were required during the planning and execution of the 2010 Phase II Geotechnical Investigation. Proposed exploration areas were determined in the office using aerial photography overlain by the mapped representations of conveyance alignments. Pre-investigation field inspections and surveys were conducted in the field around the proposed exploration. A revised exploration area based on the results of the investigation field inspections and surveys was delineated and marked for USA clearance on adjacent levees or levee roads.

The final exploration locations were determined in the field at the time of field exploration. A handheld or shipboard GPS was used to locate over-water boring locations. The ship captain, geologist, and environmental monitor modified the location as necessary to ensure safe drilling that avoided levee slopes, environmentally sensitive areas, and utilities by staying in the area cleared by USA. When possible, the DWR survey crew surveyed the location of the borings during drilling. In some locations, the surveyors were not able to board the ship or barge and the GPS device provided the location coordinates. The DWR survey crew did not survey the locations of Borings DCR1-DH-010, DCR2-DH-004, DCR2-DH-006, DCR3-DH-005, DCR3-DH-007, DCR4-DH-004, DCR5-DH-006, and DCRA-DH-010. These borings were surveyed using handheld GPS units or the *RV Quin Delta* shipboard GPS. The horizontal datum used for the project is NAD83 and the North American Vertical Datum of 1988.

2.3 Drilling

2.3.1 Drilling Contractor and Equipment

Gregg Drilling & Testing, Inc., was contracted to provide the over-water drilling equipment and services, which were carried out under the direction of a DWR or DHCCP geologist or engineer. All drilling completed in 2010 Phase II was done in the waterways of the Delta. Three over-water drilling operations, one ship-based and two barge-based, proceeded concurrently for most of the mobilization. Drilling operations consisted of three or four personnel from Gregg Drilling, two DWR or DHCCP geologists, and a DWR environmental monitor. Drilling occurred from September 27 through October 31, 2010. The locations of the over-water borings are shown in Figure 2-1.

The *RV Quin Delta* drill ship was equipped with a Mobile B-80 drill rig. The ship is a self-propelled ocean-going vessel with a shallow draft of 5 feet. It was equipped with two 80-foot-long “spud” anchors, allowing the vessel to be safely anchored over the testing location. The *RV Quin Delta* has twin Detroit 671 engines, and a licensed ship-board captain uses the on-board digital GPS to guide and position the vessel accurately over the selected location. The ship was staffed full time by a captain and a first mate.

The drill crew included the driller and two helpers, along with the first mate, who assisted with the drilling activities. The first mate or driller personnel piloted the support boat, which transported personnel and equipment between the anchored ship and the marina. The location of the marina depended on the location of the boring. The *RV Quin Delta* drill ship mobilized on September 27, 2010, and demobilized on October 31, 2010. A total of eight over-water borings were drilled by the *RV Quin Delta* drill ship, with a total footage of 1,674.0 feet.

The large barge was approximately 35 feet wide by 90 feet long with two anchoring spuds. The barge was equipped with a Mobile B-80 drill rig located in the center of the barge. Next to the drill rig was a mechanical shaker which separated drill cuttings from the drilling fluid. Also on the barge was a large shipping container box used for equipment storage. The area to the stern of the drill rig was occupied by engines used to raise the spud anchors. Open areas around the engines were used for logging samples and storing drill equipment. The drill crew included the driller and two helpers, along with a fourth man, who assisted with the drilling activities and piloted the support boat.

An attached tug boat was used to move the barge into location. A licensed tugboat operator from San Francisco was dispatched to move or relocate the barge to the next hole location. Similar to the *RV Quin Delta*, the large barge was moved into location by the captain who used the onboard GPS. The large barge was mobilized on September 27, 2010, and completed 16 holes, finishing on October 30, 2010, for a total footage of 2,337.5 feet.

The small barge was approximately 20 by 25 feet and was equipped with spuds and a CME-45 drill rig. That drill rig was able to take SPT samples at 5-foot intervals but lacked the ability to drill with punch-core samples between SPTs. The drill crew included the driller and two helpers. The small barge did not mobilize until October 13, 2010, and was out of service for maintenance for part of the drilling period. It completed its second hole on October 31, 2010, for a total footage of 365.0 feet.

Support vessels were used to transport personnel and equipment between the drill sites and the marinas. Locations of marinas depended upon drill locations.

2.3.2 Drilling Methods

Drilling and sampling methods were selected to provide the best technique of achieving useful geotechnical data while acknowledging the sensitivity of soft sediments of the Delta soils and conditions that occur while drilling in a water way. Sampling involved alternating standard-penetration tests (SPTs) with modified California (Mod Cal) split tube samplers, punch-core samplers, and Shelby tube samplers depending on the soil conditions.

2.3.2.1 Hollow-Stem Auger Drilling

As all drilling was performed in waterways in the 2010 Phase II geotechnical exploration, hollow-stem auger drilling was not employed.

2.3.2.2 Mud Rotary Drilling

Mud rotary drilling was used for all over-water soil borings. Borings were advanced using a wire-line punch-core system. The drilling set-up consisted of a 5.5-inch-diameter coring bit and 2-5/8-inch-diameter (NWJ series), flush-jointed drilling rods (N rods). Before drilling, an 8.5-inch flush-jointed steel surface conductor casing was installed to a depth of 10 to 15 feet below the mud line. The conductor casing kept drilling fluid from entering the waterway and helped aid in keeping the hole from collapsing. The surface conductor casing could be pushed deeper when the drill hole needed to be kept from collapsing. On the small barge the conductor casing was 6-inch diameter and the drilling rod was 2-5/8-inch diameter, NWJ rod. Drilling fluid (water with or without additives) was passed through the rotating drill rod and around the drill bit, flushing the cuttings from the borehole to a mud tub on the deck.

Bentonite was used in the drilling fluid mixture for all the over-water borings. Bentonite was not added to the drilling fluid until the casing was set and the sampler was at least 15 feet past the mud line. The bentonite mixture reduces friction, cools the drill bit, and helps to prevent circulation loss into the surrounding material. The drilling fluid was discharged from a collar positioned around the conductor casing and into a deep mud tub, allowing the drill cuttings to settle out and separate from the drilling fluid. A rubber collar was used to direct cuttings and drilling fluid into the mud tub and prevent them from entering the river via the opening in the drill deck. The settled drill cuttings were constantly removed by pumping them into a de-sanding “shaker” system that emptied into 55-gallon drums or shoveled and carefully put into drums. The drilling fluid was then re-circulated down the borehole. Cuttings were monitored as they were discharged from the collar to assess changes in stratigraphy.

2.3.3 In Situ Testing and Sampling

In situ testing conducted during drilling activities consisted of SPTs. In addition to testing and recovery of soil samples using the standard 2-inch split tube SPT sampler, soil samples were recovered using punch-pores, thin-walled (Shelby) tubes, and modified California (Mod Cal) split-tube samplers.

The sample numbering system included a letter designation for the type of sampler and the sampling depth interval. Sample numbers were noted on the field boring log as well as on each sample container. The sample numbering system is included in Appendix A of the DHCCP Geotechnical Investigation Work Plan (DHCCP Team, 2010). The sample number is linked to the boring number for cross-reference in the database. All samples were photographed with a reference scale and a whiteboard specifying the project name, drill hole, date, sample number, and sampling depth interval; for SPT samples the number of blow counts was also recorded on the whiteboard. Multiple photographs were taken, if needed, to document the sample. Chain-of-custody (COC) forms were used to track the samples from the field to their intermediate and final destinations. Sample handling and tracking is further discussed in Section 2.8.3.

Occasionally, sampling was attempted but nothing was recovered. In those cases, “NR” for “No Recovery” was written on the boring log and other documentation for that sample. Equipment was checked and every attempt made to understand why no sample was recovered. Field personnel troubleshot the problems and directed the drillers to drill to the bottom of the attempted sampling interval and remove all disturbed material followed by a fresh sampling attempt. For example, if the recovery problem appeared to be a matter of loose, clean sands or gravel falling out of the sampler, a sand catcher was added to the sampler.

2.3.3.1 Standard Penetration Test

SPTs were performed using a 24-inch long, 2-inch outside diameter (OD), 1 3/8-inch constant inside diameter (ID) split tube sampler. Split tube SPT samplers are described in, and sampling performed in, general accordance with ASTM D1586. An SPT sampler was attached to NWJ (2-5/8-inch-diameter) drill rods and advanced using a 140-pound automatic hammer with a 30-inch drop. Liners were not used in the sample barrel. The sampler was not driven more than 18 inches. Blow counts for each 6-inch increment were noted on the boring logs.

The recovered sample from each drive was logged, photographed, and placed in a re-sealable moisture-proof glass jar and labeled with permanent ink. Obvious slough in the sampler was placed in a 55-gallon California Department of Transportation (DOT)-approved drum for subsequent disposal. SPTs were generally performed at 5-foot intervals resulting in a 3.5-foot-long punch core and 1.5-foot SPT.

Each of the automatic hammers was calibrated to determine the hammer energy for blow-count (N-value) corrections. Corrected blow counts are included in DHCCP soil logs in Appendix A along with uncorrected field blow counts. The hammer energy measurements are detailed in Appendix B.

SPT tests were halted for each 6-inch increment when the:

- Number of blows exceeded 50
- Sampler had not advanced as a result of 10 consecutive blows, as evidenced by the rebound of the rods when encountering hard material.

2.3.3.2 Shelby Tube Samplers

A Shelby tube (thin-walled) sampler was used to obtain relatively undisturbed samples of cohesive soils for laboratory strength and consolidation testing. Shelby tube sample collection was in accordance with ASTM D1587. A Shelby tube is not suited for formations containing gravel, cobbles, very dense sands or hard clays. Three-inch Shelby tubes were employed to provide a better quality sample for laboratory testing use, although they did not fit through the punch core bit. But the desire for better quality data overrode the desire for convenience, and 2.5-inch tubes were not used in Phase II as they were in Phase I because the laboratory reported that samples collected from the 2.5-inch tubes did not provide sufficient material to accommodate the trimming of external irregularities and still retain sufficient material to satisfy ASTM standards for strength and consolidation testing. Therefore, 3-inch OD Shelby tubes were provided for all borings drilled after October 9, 2009.

Samples were labeled in accordance with the DHCCP Geotechnical Investigation Work Plan (DHCCP Team, 2009) and handled in accordance with ASTM D4220 and ASTM D1587. The following information was written on the top half of the tube and on the end cap:

- Project name
- Boring/sample number
- Depth interval
- Vertical (UP) direction

Samples were kept out of direct sunlight and placed in a custom Shelby tube carrier. The entire sample carrier was secured with rope or cable to the body of the transporting vehicle for delivery to a moisture-controlled area and the final testing laboratory.

2.3.3.3 Punch-Core Sampling

Punch-core samplers consist of a wire-line coring system with a 5-foot-long, HWT (4.5 in. OD) core barrel for coring through soil. Land-based drilling in Phase I initially began with the standard 94-mm system, because the smaller borehole size resulted in the generation of a smaller volume of drill cuttings, and allowed smaller diameter casing to be used. However, this system did not allow use of 3-inch ID Shelby tube through the bit. When 3-inch-diameter undisturbed sampling was required, either all of the drill rod assembly was pulled out of the borehole, risking hole collapse and increasing drilling time, or the larger diameter 4.5 in. HWT punch core system was used. Use of the HWT system was universal in the over-water drilling in both Phases I and II to provide for retrieval of 3-inch ID Shelby tubes. Most punch-core sampling included redrilling through the SPT or Shelby tube sample interval and then recovery of the remaining 3 to 3.5 feet of a 5-foot drilling run.

Cored soil samples were retrieved and extruded onto a logging tray. After geologic logging according to ASTM D2488, Standard Practice for Description and Identification of Soils (Visual-Manual Method) and ASTM D2487, Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System [USCS]) and photography, samples were retained from each distinct stratum within each core run. Samples were sealed in moisture-proof glass jars, labeled with a permanent marker and placed in boxes for storage. Punch-core from critical intervals were retained for long-term storage in core boxes, with blocks indicating top and bottom of core runs and locations of removed samples and SPT intervals. Critical intervals for the over-water drilling were determined to be a minimum of 20 feet above and below the planned tunnel crown and invert. Any unusual intervals were retained at the discretion of the field geologist. Non-retained punch-core samples were placed in a 55-gallon DOT-approved drum for subsequent disposal.

2.3.3.4 Modified California Sampler

The Mod Cal sampler consists of a 2.5-inch ID by 18-inch-long split tube sampler, with three, 6-inch-long brass liners inserted in the tube for sample collection. All environmental soil samples were collected using this sampler. The sampler was driven 18 inches through the desired interval using the automatic hammer on the drill rig. Blow counts for each six inches, were noted on the boring logs. Upon retrieval, the brass liners were removed and capped with Teflon tape and plastic caps. Labels were attached to the outside of each liner for laboratory identification, and placed in clear zip-locked plastic bags. The samples then were placed in an ice-cooled ice chest for transportation to a certified laboratory for analysis. In those sampling intervals where a Mod Cal sampler was used in lieu of an SPT sampler (i.e., to improve sample recovery), the soil samples were treated in the same manner as the SPT samples.

2.3.3.5 Groundwater Sampling

No groundwater samples were planned in the over-water borings because of the short permit time for drilling and the relatively long time it takes to obtain a sample using a HydroPunch sampling device. There was also a concern that the groundwater sample could be contaminated by river water.

2.3.4 Environmental Screening

A detailed discussion of the environmental sampling program is provided in the DHCCP report *Environmental Sampling Report – Phase I Geotechnical Investigations* (DHCCP Team, 2010c). Environmental screening involved laboratory testing of soil samples obtained using the Mod Cal sampler described in Section 2.3.3.4. The target sampling zones were sediments immediately below the river bottom and tunnel grade soil samples. For the shallow samples, the planned analyses included CAM 17 metals plus mercury and methyl mercury. Analysis performed from the tunnel grade included CAM 17 metals plus mercury and TPHs.

2.3.5 Piezometer Installation and Abandonment

Piezometers are installed on land to facilitate groundwater data monitoring and collection; consequently no piezometers were installed during Phase II Geotechnical Investigations because drilling occurred in waterways only.

2.3.6 Site Restoration

To restore the site, the borings were backfilled with a grout mix of approximately 95 percent cement and 5 percent bentonite pumped through a tremie pipe from the bottom of the boring up to approximately 15 to 20 feet below ground surface (bgs). This helped ensure that no grout went near or into the waterway.

Clear water with bentonite additives was used to advance exploration borings and remove the drill cuttings from the boreholes. These products are stable, non-toxic, non-hazardous materials manufactured for use as drilling mud. Drilling fluids and cuttings were containerized for off-site disposal at an appropriate facility. At the completion of drilling, equipment, tools, unused materials, and drill-cuttings disposal drums remained on the ship and transported away from the site, to a designated harbor area for off-loading. Trash and drums were properly disposed offsite.

2.3.7 Spill Control

During the drilling operations, spill control measures were applied in accordance with Best Management Practices requirements. A storm-water pollution prevention plan was implemented for all site-disturbing activities to control spills of fluids from drilling activities.

2.3.8 Complications

Several complications arose during the over-water drilling program, which are documented below as a guideline for future over-water activities.

2.3.8.1 River Stage Effects on Depth Measurement

River stage fluctuations introduced inaccuracy to the depth recorded on field logs of over-water borings. During the course of over-water drilling operations, Delta water elevation fluctuated according to releases from storage reservoirs and tidal changes. The depth of drilling recorded on the field boring log references the deck of the drill ship or barge-mounted drill rig as the datum. However, this datum varies in elevation with fluctuation of the river level.

The river can rise or fall up to approximately a quarter of a foot during the course of advancement of a single 5-foot punch core run, and several feet during a day. As a result, punch-core runs are systematically longer or shorter than planned. That is, if the river is rising in elevation during advancement, the punch core reaches the end of the run at a length that is less than anticipated, and vice versa for receding river elevation. Successive punch core runs accumulate a total inaccuracy that may range up to a few feet, depending on the range of river stage at each location.

The final boring logs depict the depth relative to the elevation of the deck of the drill ship or barge-mounted drill rig at the start of drilling. Records from nearby U.S. Geological Survey and DWR gauging stations were used to determine the elevation at the start of drilling. Change in river elevation during driving of samples was assumed to be zero so that the top and bottom of the sample could be completely defined by a single recorded time. While water surface elevations could vary by a few feet during the course of drilling, tidal corrections have not been applied to depths on the logs.

A sample time was estimated if it was not recorded for a specific collected sample. The estimated time was approximated to the nearest 5-minute interval, and was proportioned based on the length of punch-core run immediately above and below the collected sample.

The beginning and ending elevation of punch-core intervals was set equal to the bottom elevation of the preceding collected sample and the top elevation of the following collected sample, respectively.

2.3.8.2 Sample Recovery

While recovery of samples using a thin-walled Shelby tube was generally poor when soft fine-grained soil was sampled in the Phase I program, Shelby recovery was better in Phase II. Several techniques and methods were employed to increase the undisturbed sample recovery. These techniques included allowing the Shelby tubes to rest at the end of tube advancement, then gently rotating the tubes to increase sample recovery. Undisturbed samplings using the Shelby tubes during Phase II generally provided adequate soil sample recovery for a suite of three triaxial tests. If the recovery problems reappear in future exploration phases, it is recommended that alternate sampling methods including the use of a fixed-piston sampler be considered for sampling of soft fine-grained soils.

Recovery of punch-core runs advanced through clean sands and gravels was often poor. In some cases, no recovery or a small amount of recovery, such as only a few pieces of gravel, were reported. In cases of little or no recovery, the field geologist relied on observations of the drill rig, cuttings from the drilling fluid during drilling, and comments from the driller to describe the subsurface materials encountered. Recovery of punch-core samples in sands and gravels was generally improved when a sand catcher was used and the rate of borehole advancement, along with drilling fluid pump pressures, was decreased.

2.3.8.3 Drilling Fluid Releases

After an observance of cloudy water during drilling of the first few over-water soil borings in 2009, numerous precautions were taken for 2010 Phase II geotechnical exploration. On the rare occasion when a possible release was observed, drilling was stopped to correct the problem. Anti-release measures adopted during the 2009 Phase I over-water drilling were continued in 2010: replacement of bolted casing with flush-jointed casing and the fabrication of a rubber sleeve, which was placed over the conductor casing and within the mud tub. The rubber sleeve facilitated the diversion and capture of the drilling fluid in the mud tub, thus preventing the escape of drilling fluid between the through-deck hole and the conductor casing. Additionally, physical barriers were also provided around the working areas of the drill ship and barge-mounted drill rig to prevent drilling fluid from entering the waterway. Drilling fluid that splashed on to the deck was scrupulously cleaned up.

2.3.9 Safety Protocol

Version 3 of the DHCCP Field Safety Plan outlines procedures to prevent hydraulic fluid, motor oil, diesel fuel, and gasoline from entering the water. Those steps include:

- Inspection of equipment and repair of leaks before launching the vessel.
- Daily inspection of equipment for oil leaks or weak hoses; problems are repaired if found.
- Monitoring by an environmental scientist for colored plumes in the water indicating discharge.
- Using a pump or funnel when transferring fuel from cans to equipment.
- Storing of fuel and oil cans in an area where they cannot be knocked overboard.
- Keeping absorbent towels and booms on barges and vessels for oil leaks or hose ruptures.
- Motorized vessels longer than 16 feet shall not be left in the water unattended unless they are equipped with a functioning automatic bilge pump.

Because the Federal Water Pollution Control Act prohibits the discharge of oil or oily waste into any navigable water of the United States, discharges and spills are to be reported immediately. Section 10.2 of the Field Safety Plan details steps to take when a discharge or spill occurs.

2.4 Laboratory Testing

2.4.1 Geotechnical

Laboratory tests were performed on selected samples to aid in soil classification and to determine the physical characteristics of the soil underlying the planned facilities and the conveyance alignments. Tests were performed by Signet Laboratories in Hayward, California. Tests performed included:

- Grain size analysis (ASTM D422)
- Hydrometer analysis (ASTM D422)
- Moisture content (ASTM D2216)

- Atterberg limits (ASTM D4318)
- Specific gravity (ASTM D854)
- Organic content (ASTM D2974)
- Consolidation (ASTM D2435)
- Unconsolidated-Undrained Triaxial Compression (ASTM D-2850)
- Consolidated-Undrained Triaxial Compression with pore pressure measurements (ASTM D4767)

In addition, three specialty tests on selected samples within the tunnel grade of the proposed Pipeline/Tunnel Option were performed. They include the soil abrasivity test, the soil abrasion test and the X-ray test. These tests are further described in Section 2.4.3, Specialized Testing. Geotechnical laboratory test data are presented in Appendix C and the specialized test data are presented in Appendix D.

2.4.2 Environmental

A detailed discussion of the environmental sampling program, including results and interpretation of data can be found in the DHCCP report *Environmental Sampling Report – Phase II Geotechnical Investigations* (DHCCP Team, 2011). Environmental samples were tracked using COC forms and shipped by DWR's partner consultant URS to Test America laboratory, located in West Sacramento, California, and Brooks Rand Labs, located in Seattle, Washington, for testing.

Following is a list of tests performed on environmental samples. Not all tests were performed on each sample.

- SW6010B/SW7470A (CAM 17 metals and mercury in water)
- SW6010B/SW7471A (CAM 17 metals and mercury in soil)
- SW8015G/8015D/8015MO (TPH as gasoline, diesel, and motor oil)
- SW8081A (Organochlorine Pesticides)
- E160.1 (Total Dissolved Solids)
- E300.0 (Salinity as Cl^-)
- RSK-175 (CH_4 and CO_2)
- SM4500 S2 (Dissolved Sulfides)
- SW6020/SW7470A (CAM 17 metals and mercury in water)
- SW6020/SW7471A (CAM 17 metals and mercury in soil)

- SW8015G/8015D/8015MO (TPH as gasoline, diesel, and motor oil)
- SW8260B (benzene, toluene, ethylbenzene, xylenes)

A summary of these results is presented in Table 3-6, and complete listing of these results will be presented in the DHCCP report *Environmental Sampling Report – 2010 Phase II Geotechnical Investigations* (DHCCP Team, 2011).

2.4.3 Specialized Testing

2.4.3.1 X-Ray Diffraction Mineralogy Analyses

X-ray diffraction was used to determine the mineral content of representative clayey soil samples collected from the 2010 Over-Water Geotechnical Investigations along the Pipeline and Tunnel Option alignment. The analyses were performed by the University of Texas at Austin under the supervision of Professor Fulvio Tonon. The results are used to determine the proportion of various clays and silts that compose the fine-grained soils, for the identification of potentially expansive clays.

2.4.3.2 Abrasion Testing

2.4.3.2.1 Soil Abrasion Test

Soil Abrasion Tests (SAT) were performed on selected soil samples collected from the 2010 Over-Water Geotechnical Investigations. The tests were performed by the University of Texas at Austin under the supervision of Professor Fulvio Tonon. The test method follows the new Norwegian Soil Abrasion Test (SAT) procedures.

2.4.3.2.2 Miller Number Testing

Miller Number test or Slurry Abrasivity tests were performed on selected soil samples collected from the 2010 over-water borings drilled along the Pipeline/Tunnel Option alignment. The tests were conducted in general accordance with ASTM G-75, Standard Test Method for Determining of Slurry Abrasivity (Miller Number) and Slurry Abrasion Response of Materials (SAR Number). The procedure and the method used to perform the tests are described in the ASTM G-75.

2.5 Quality Assurance

DHCCP program QA requirements are provided in the DHCCP QA Plan (DHCCP Team, 2010) and were followed for the implementation of the Task Order 14 geotechnical investigation activities and the preparation of this report.

2.6 Quality Control

QC measures were performed in accordance with the Geotechnical Investigation Work Plan (DHCCP Team, Revision 3, 2010) for those portions of the investigation performed by the DHCCP integrated team under Task Order 14. Similar DWR Project Geology standard quality practices were implemented for those portions of the investigation conducted solely by DWR personnel. QC measures included calibration requirements for field equipment, supervision and training of geologic field staff by experienced senior staff, a detailed checking procedure for boring log preparation, sample handling and COC procedures, and QA/QC plan for soil laboratory testing. Lead and management DHCCP geologists and geotechnical engineers visited the field at least weekly to monitor field work.

2.6.1 Field Equipment

2.6.1.1 Drilling – Hammer Energy Tests

Hammer energy tests were performed on all of the reciprocating safety hammers located on the drill rigs. These calibration tests determined the efficiency of the hydraulic system within each hammer. To ensure consistency of data collected from SPTs, each hammer must deliver a minimum of 60% of the system's potential energy. The DWR drilling subcontract required the contractor to provide proof of hammer calibration within 12 months of being used on this project. If the drill rig calibration expired during the program, a hammer calibration test was performed on the first available boring. The DHCCP drilling contract required that a hammer calibration test be provided whenever a new drill rig was brought onto the project.

Hammer calibration testing was performed by the contractor, Gregg Drilling, in the presence of the rig geologist. Hammer calibrations were conducted in accordance with ASTM D4633. Table 2-1 summarizes hammer energy test results for all drill rigs used during the 2009 field season. Complete calibration records are included in Appendix B. The calibrated hammer efficiency is also noted on the first page of each boring log in the remarks area.

Table 2-1 Summary of Hammer Energy Test Results

Drill Rig No.	Drill Model	Average Percent Efficiency	Date Tested
D-29 (Sm. Barge-Mounted)	CME-45	66.4	October 20-21, 2010
D-34, RV Quin Delta	Mobile B-80	78.7	October 19, 2010
D-23 (Lg. Barge-Mounted)	Mobile B-80	78.9	October 18, 2010

2.6.1.2 Field Gas and Water Meters

Field gas meters were required for monitoring field situations where there was a potential for encountering hazardous gases or chemicals. Multiple types of field gas meters were used during the Phase I field investigation in 2009. A Multi Rae Plus meter and a RKI Eagle meter were used to monitor borehole gases such as CH_4 and H_2S, along with the air mixture percentage of O_2 and CO. However, there were problems with instrument calibration in the field in 2009 that could not be resolved at the time of drilling in 2010. As a result, the borehole gas monitoring was not considered reliable and is not included in this report.

2.6.2 Preparation of Boring Logs

Field logs were prepared in accordance with the Geotechnical Investigation Work Plan (DHCCP Team, Revision 3, 2010). Data and observations from drilling, sampling, and in situ testing were recorded on field logs at the time of exploration, and the soil encountered was classified in the field according to Appendix F - Boring Log and Soil Classification Guidelines of the Work Plan.

A first-hand review of the field logs and soil samples was conducted in the office to rectify inconsistencies. The first-hand review comprised field soil classification as well as other details recorded on the field logs (such as blow counts, remarks, and notes). Soil samples were stored in the office with first-hand reviewers, who selectively checked the visual classifications by performing field classification tests a second time.

The results of the first-hand review were incorporated on the draft boring logs. Draft boring logs were prepared using Bentley's gINT Software, a geotechnical database program. Draft borings logs were reviewed for accuracy and revised, if necessary. Completed boring logs are presented in Appendix A.

In some cases, geotechnical laboratory test results justified a different soil classification from those made in the field and first-hand review. Where necessary, geotechnical laboratory test results and revised soil classification were incorporated on the final boring logs.

2.6.3 Sample Handling and Tracking

Samples collected during this field investigation were tracked with a COC form. The field geologist recorded soil and water samples on COC forms. The specific COC form depended on whether samples were collected for geotechnical or chemical (environmental) analysis.

Geotechnical samples were logged on separate COC forms for each boring's jar and core-box samples, with a separate form for Shelby tube samples and a separate form for environmental soil samples. Soil samples and respective COC forms were transported to the DHCCP office in the Paul R. Bonderson Building in downtown Sacramento, California. Bulk or grab samples and plastic core boxes were stored on shelves. Shelby tube samples were padded and remained vertical during transportation to the laboratory. At the laboratory, Shelby tubes were stored vertically in a moisture-controlled room of Signet Testing Laboratory awaiting laboratory testing assignment.

Geotechnical laboratory testing was assigned in the office, and new COC forms were prepared to accompany the samples to the laboratories. Samples not selected for laboratory testing, accompanied by a COC form, were transported to interim storage at DWR's levee program warehouse.

Soil samples collected for chemical (environmental) analysis were packaged in ice-cooled chests, transported to either the DHCCP or the Sacramento URS Corporation (URS) office, and shipped to a certified laboratory for analysis. COCs accompanied the samples to their destinations, with copies retained by the DHCCP team.

Tracking, handling, and record-keeping of the COCs were conducted by the field coordinator. All paper work was passed from the field workers to the coordinator, who kept files for each boring and placed the completed COCs into those files. Original forms will be transferred to the DHCCP files.

2.6.4 Laboratory Testing

Geotechnical laboratory testing was performed by Signet Testing Labs, Inc. All geotechnical laboratory tests were performed in general conformance with ASTM standards. The DHCCP Quality Department conducted a project surveillance audit of the Signet Testing Lab on December 2, 2009. The surveillance confirmed compliance with Project Specification No. 12-004-002 Geotechnical Testing and no unsatisfactory conditions were reported.

Chemical testing of environmental samples was performed by Test America and Brooks Rand Labs under contract to DWR. Test America is certified by the State of California and the National Environmental Laboratory Accreditation Program certificate No. 01119CA for the analyses performed. Brooks Rand is accredited by the National Environmental Laboratory Accreditation Program through the Florida Department Health, Bureau of Laboratories certificate No. E87982. The laboratory QA Program includes control of sample containers, preparation, analyses of blanks, matrix spikes, duplicates, certified check samples, proficiency evaluation and blind check samples, cross-check between different methods, different levels of data reviewing, and archiving of QC data.

3.0 RESULTS

3.1 Drilling

3.1.1 Over-Water Drilling

Over-water drilling was conducted from September 27 through October 31, 2010. A total of 26 borings were completed using a customized drill ship and two barges mounted with drills. As seen in Table 3-1, 11 borings were completed specifically for the PTO. Table 3-2 provides a detailed summary of individual boring information. Boring logs are contained in Appendix A.

Table 3-1 Summary of 2010 Over-Water Drilling

Feature/Option	Borings Drilled	Total Footage
ICF East	0	0
ICF West	0	0
TDF	0	0
PTO	11	2,365.5
Intake[1]	15	2,011.0
Total	**26**	**4,376.5**

[1] Intake borings apply to ICF East, ICF West, and PTO.

PTO = Pipeline/Tunnel Option
ICF = Isolated Conveyance Facility
TDF = Through-Delta Facility

Table 3-2 Over-Water Borings Summary

Boring	Alignment Option	Location		Elevation[1] (ft)	Boring Depth (ft)	Date(s) Drilled	Drill Rig	Waterway
		Northing	Easting					
DCR1-DH-008	Intake[3]	2346437.51	6269546.91	10.4	156.5	9/28-30/2010	Large Barge	Sacramento R.
DCR1-DH-010	Intake[3]	2346363.26	6270237.64	4.4	126.5	10/30-31/2010	Ship	Sacramento R.
DCR1-DH-011	Intake[3]	2346405.66	6269924.04	11.9	156.5	9/30-10/2/2010	Large Barge	Sacramento R.
DCR2-DH-004	Intake[3]	2336341[2]	6270668[2]	10.5	145.0	10/3-4/2010	Large Barge	Sacramento R.
DCR2-DH-006	Intake[3]	2335915.18	6270800.99	11.1	145.0	10/4-6/2010	Large Barge	Sacramento R.
DCR2-DH-007	Intake[3]	2335600.81	6270919.31	10.3	146.5	10/28-30/2010	Large Barge	Sacramento R.
DCR2-DH-008	Intake[3]	2335243.78	6271056.16	10.1	145.0	10/27-28/2010	Large Barge	Sacramento R.
DCR3-DH-003	Intake[3]	2325226.78	6268115.33	9.4	151.5	10/6-7/2010	Large Barge	Sacramento R.
DCR3-DH-005	Intake[3]	2324706[2]	6268293[2]	9.7	150.0	10/25-26/2010	Large Barge	Sacramento R.
DCR3-DH-007	Intake[3]	2324246[2]	6268436[2]	10.5	151.5	10/8-9/2010	Large Barge	Sacramento R.
DCR4-DH-004	Intake[3]	2318611[2]	6266971[2]	10.2	151.5	10/10-11/2010	Large Barge	Sacramento R.
DCR4-DH-006	Intake[3]	2317668.72	6266802.14	10.7	147.0	10/11-12/2010	Large Barge	Sacramento R.
DCR4-DH-008	Intake[3]	2317341.17	6266566.02	10.2	145.0	10/13-14/2010	Large Barge	Sacramento R.
DCR5-DH-006	Intake[3]	2314136[2]	6261226[2]	8.7	110.0	10/15-16/2010	Large Barge	Sacramento R.
DCR5-DH-008	Intake[3]	2314006.96	6260813.10	8.9	140.0	10/17-18/2010	Large Barge	Sacramento R.
DCRA-DH-001	PTO	2287376.20	6263907.05	8.9	231.5	10/19-21/2010	Large Barge	Sacramento R.
DCRA-DH-002	PTO	2275450.28	6263798.87	10.0	221.5	10/22-24/2010	Large Barge	Sacramento R.
DCRA-DH-006	PTO	2243519.95	6261895.00	9.0	223.0	10/25-28/2010	Ship	Mokelumne R. - North Fork
DCRA-DH-008	PTO	2230742.73	6261133.64	5.4	200.0	10/13-23/2010	Small Barge	Mokelumne R.
DCRA-DH-010	PTO	2218616[2]	6260902[2]	6.0	229.0	10/21-24/2010	Ship	Potato Slough
DCRA-DH-011	PTO	2211425.80	6260655.08	5.5	236.5	10/17-20/2010	Ship	San Joaquin R.
DCRA-DH-012	PTO	2209578.63	6260670.24	6.4	212.5	10/13-16/2010	Ship	San Joaquin R.
DCRA-DH-014	PTO	2191500.56	6260959.55	4.7	223.0	10/9-13/2010	Ship	Connection Slough

DCRA-DH-017	PTO	2166660.61	6259999.71	6.2	211.0	10/5-8/2010	Ship	Railroad Cut
DCRA-DH-022	PTO	2156675.09	6259158.57	5.2	212.5	10/1-5/2010	Ship	Woodward Canal
DCRA-DH-024	PTO	2136898.40	6257536.29	3.6	165.0	10/26-30/2010	Small Barge	Old River

[1] Elevation reference is to the ship or barge deck. Elevations of the deck varied with tide and river flow during the process of drilling. Elevations were determined by ground survey, GPS, adjacent river gages or LIDAR data as noted on the boring logs.

[2] Location determined by GPS accurate to the nearest foot, other locations by DWR survey crew.

[3] Intake borings apply to East, West, and Pipeline/Tunnel Options

Ship = Mobile B-80 Rig D-34 mounted on "*RV Quin Delta*"

Large Barge = Mounted Mobile B-80 Rig D-23

Small Barge = Mounted Mobile CME 45 Rig D-29

3.1.2 Drilling Results

A summary graphic presentation of the boring logs and a legend are presented on Figures 3-1 and Plates 1 and 2. Because of the wide spacing between borings, correlation of soil classification units between the borings for engineering purposes is not recommended. For details of each log, see Appendix A. In the following discussion, borings are generally discussed from north to south.

3.1.2.1 Intake Area

Fifteen over-water borings were drilled in the Sacramento River offshore of the proposed on-bank and in-river intake sites from approximately 1.5 miles upstream of Clarksburg to approximately 2.5 miles downstream of Hood. The locations are shown on Figure 2-1 and the graphic summary logs are presented on Plate 1. These borings provide general information on the river subsurface conditions:

- Borings DCR1-DH-008, DCR1-DH-010, and DCR1-DH-011 were located in the vicinity of the Intake 1 options for the ICF East, ICF West, and PTO alternatives.
- Borings DCR2-DH-004, DCR2-DH-006, DCR2-DH-007, and DCR2-DH-008 were located in the vicinity of the Intake 2 options for the ICF East, ICF West, and PTO alternatives.
- Borings DCR3-DH-003, DCR3-DH-005 and DCR3-DH-007 were located in the vicinity of the Intake 3 options for the ICF East, ICF West, and PTO alternatives.
- Borings DCR4-DH-004, DCR4-DH-006 and DCR4-DH-008 provide information in the vicinity of Intake 4 for the ICF West, ICF East and PTO alternatives.
- Borings DCR5-DH-006 and DCR5-DH-008 were located in the vicinity of Intake 5 for the ICF East, IFC West, and PTO Options.

Although the intakes are widely spaced, the following general comments can be made about the geologic conditions encountered at the proposed intake sites.

- Subsurface conditions are not uniform through the reaches or even from the north to south at the same intake location.
- The river bottom sediments at the mud line were difficult to sample. They are logged as very soft clay, sandy clay, and poorly graded loose sand. Where no samples were recovered, the field geologists generally interpreted the material as lean clay based on drilling characteristics.
- The thickness of very loose to loose sands and very soft to soft clays beginning at the mud line (river bottom) varied from 5 to 30 feet. Two exceptions were borings

DCR3-DH-007 and DCR4-DH-004 which had medium dense sands and silty sands at the mud line.

- Density or stiffness of the material expressed as blow counts (N_{60} values) generally increased with depth.

- Soils encountered included lean clay, lean clay with sand, clayey sand, silty sand, poorly graded sand with silt, poorly graded sand with clay, poorly graded sand, well-graded sand, well-graded sand with gravel, well-graded gravel with sand, poorly graded gravel. Minor amounts of fat clay, silt, and silty gravel were also logged.

- Organic material was limited to traces of organic and woody material. Organic material was found in intake locations 1, 2, and 3. Organic materials were found at depth of 58 feet bgs in boring DCR1-DH-008; 37 and 73 feet in boring DCR2-DH-008 and at 45 feet in boring DCR3-DH-005.

- Shells were observed in some shallow river bottom soils.

- Gravels observed within sand, clay, and silt soil units were generally angular to subrounded and less than 1 inch in diameter. Note that the maximum size that could have been recovered was limited to approximately 1 inch in an SPT sampler or 2.5 inches in the punch core sampler. Laboratory tests confirmed the field classification of fine- and course-grained gravels in DCR1-DH-010, DCR1-DH-011, DCR2-DH-006, DCR2-DH-008, DCR3-DH-005, DCR5-DH-006, and DCR5-DH-008. These results are discussed in Section 3.2.1 below.

3.1.2.2 Pipeline/Tunnel Option Alignment

The borings in the vicinity of the PTO alignment (Figure 2-1) are listed in Tables 3-1 and 3-2, and presented graphically on Plate 2. A total of 11 Phase II borings, all over-water, were drilled along the PTO alignment.

Over-water boring results for the PTO alignment are summarized below:

Although the borings are widely spaced, the following general comments can be made about the geologic conditions encountered at the PTO boring sites.

- Subsurface conditions are not uniform from the north to south along the PTO alignment; for example, DCRA-DH-001 in the north contains more coarse-grained soils than DCRA-DH-024 in the south. DCRA-DH-024 has significantly less of the gravels and poorly graded sands present in DCRA-DH-001. When finer-grained layers do appear in DCRA-DH-001, they tend to have a higher sand content than fine-grained layers logged in DCRA-DH-024. The variability of soil types across the delta reflects differences in both the depositional energy levels and provenance. The material for DCRA-DH-001 is derived primarily from the Sierra Nevada Mountains, drained by the Sacramento River, while the material from DCRA-DH-024 is derived from the Sierra Nevada Mountains, drained by the San Joaquin River, and the nearby Coast Ranges, drained by small local streams. For details, please refer to the logs of the two drill holes in Appendix A.

- The river bottom sediments at the mud line were difficult to sample. They are logged as peat, organic, very soft clay, sandy clay, and poorly graded loose sand. Where no samples were recovered, the field geologists generally interpreted the material as lean clay based on drilling characteristics.

- The thickness of very loose to loose sands and very soft to soft clays beginning at the mud line (river bottom) varied from seven to 41 feet.

- Density or stiffness of the material expressed as blow counts (N_{60} values) generally increased with depth but then decreased as the bottom of the hole was reached. But there were notable exceptions and often abrupt changes. High SPT hammer blow counts, blow counts greater than 80, occurred at multiple mid-depth and deep levels in DCRA-DH-022, DCRA-DH-014, DCRA-DH-011, and DCRA-DH-010. High blow counts occurred only at mid-depths in DCRA-DH-024, DCRA-DH-017, and DCRA-DH-008. High blow counts occurred only at great depth in DCRA-DH-006 and DCRA-DH-001.

Comment [m1]: What 's the High blow count number?

Comment [srs2]: I looked at all four of those logs, and 80 seems a good cut-off number. Each of the four holes has at least three instances of N60 values of 80 or greater.

- Soils encountered included lean clay, lean clay with sand, clayey sand, silty sand, poorly graded sand with silt, poorly graded sand with clay, poorly graded sand, well-graded sand, well-graded sand with gravel, well-graded gravel with sand, poorly graded gravel. Minor amounts of fat clay, silt, and silty gravel were also logged.

- Organic material was most prominent in DCRA-DH-017, where it occurred to a depth of more than 12 feet below the mud line, and DCRA-DH-012, where it occurred more than 11 feet below the mud line. Elsewhere, organics were limited to traces of organic and woody material, which were found near the mud line or as deep as 93 and 210 feet in boring DCRA-DH-011. Organic material was also found as deep as, 182.5 feet, 67.5 feet, 77 feet, and 126.5 feet in borings DCRA-DH-010, DCRA-DH-012, DCRA-DH-014, and DCRA-DH-016, respectively.

- Gravels observed within sand, clay, and silt soil units were generally angular to subrounded and less than 1 inch in diameter. Note that the maximum size that could have been recovered was limited to approximately 1 inch in an SPT sampler or 2.5 inches in the punch core sampler. Laboratory tests confirmed the field classification of fine- and course-grained gravels in DCRA-DH-001 and DCRA-DH-002. These results are discussed in Section 3.2.1 below.

3.2 Laboratory Test Data

The scope of the geotechnical soil laboratory testing program is summarized in Table 3-3. Laboratory test results are summarized in a table in Appendix C and included on the boring logs in Appendix A.

A total of 11 over-water borings are associated with the PTO and 15 over-water borings are associated with intake locations.

Table 3-3 Summary of Geotechnical Laboratory Tests

Test	ASTM Method	Number of Tests Performed for Each Alignment					Total
		Intakes	**ICF East**	**ICF West**	**TDF**	**PTO**	
Moisture Content	D2216	32	0	0	0	55	87
Dry Unit Weight	D2216	0	0	0	0	0	0
Grain Size	D422	52	0	0	0	45	97
Hydrometer	D422	48	0	0	0	62	110
Atterberg Limits	D4318	48	0	0	0	61	109
Specific Gravity	D854	0	0	0	0	0	0
Organic Content	D2974	1	0	0	0	3	4
Consolidation	D2435	2	0	0	0	8	10
Unconsolidated-Undrained Triaxial Compression	D2850	2	0	0	0	5	7
Consolidated-Undrained Triaxial Compression with Pore Pressure Measurements	D4767	0	0	0	0	3	3

ASTM = ASTM International
PTO = Pipeline/Tunnel Option
ICF = Isolated Conveyance Facility
TDF = Through-Delta Facility

3.2.1 Index Properties

The soil samples collected from the Phase II Geotechnical Investigations were tested to determine the index properties of the Delta soil encountered during the over-water drilling operations. The tests included grain size analysis, hydrometer, moisture contents, Atterberg limits, unit weight, and specific gravity. The test results are presented in Appendix C and in the boring logs included in Appendix A.

A total of 97 grain size analyses and 110 hydrometer tests were performed to measure the distribution of the particle sizes. One hundred nine Atterberg limits tests were conducted on the fine-grain soils to assess the plasticity characteristics of the Delta sediments. Some of the noteworthy information revealed from the grain size analyses, Atterberg limits tests, and unit weights are highlighted below:

- The data obtained from grain size analysis and hydrometer tests indicated the soil particles and distribution of the particle sizes are consistent with expected Delta sedimentation: coarser sands and gravels in upstream portions of the Sacramento River hydrologic regime, and finer sands, silts, and clays downstream. Atterberg limits can best be represented by the range of distribution for various types of cohesive soils. Plastic indexes in cohesive samples obtained at the proposed intake locations rarely exceed 20. For samples obtained at exploration locations along the proposed Pipeline/Tunnel Option alignment, plastic indexes are more likely to exceed 20, sometimes substantially.

3.2.2 Compressibility of the Subsoils

Ten one-dimensional consolidation tests were performed on collected undisturbed clayey and silty soil samples. The test results are graphically presented in Appendix C. The compressibility of the subsoils may be represented by the compression index (C_c) of material exhibited under loads for the collected soil samples with a range varying from 0.259 to 1.106, while the recompression index ranging from 0.034 to 0.102. The investigation of the compressible nature of the peat and organic soil may need to be performed in the next phase of investigation in accordance with the design features and requirements. Table 3-4 summarizes the consolidation test results with the relevant material properties for the samples tested.

Table 3-4 Summary of Consolidation Test Results

Sample Sources	Sample Depth (feet)	Liquid Limit	Plastic-ity Index	Classifi-cation	Initial Void Ratio e_o	Com-pression Index	Recom-pression Index
DCR2-DH-006	112.5 - 114.5	44	16	ML	0.933	0.327	0.0457
DCR4-DH-006	92.5 – 94.5	38	10	ML	0.892	0.597	0.102
DCRA-DH-008	80.0 – 82.0	42	11	ML	1.378	0.730	0.059
DCRA-DH-010	97.5 – 99.5	43	12	ML	1.235	0.371	0.035
DCRA-DH-012	107.5 – 109.5	43	14	ML	0.801	0.359	0.060
DCRA-DH-014	109.5 - 111.5	60	19	MH	1.379	1.106	0.095
DCRA-DH-017	139.5 – 141.5	61	18	MH	1.559	0.632	0.084
DCRA-DH-022	120.0 - 121.0	37	15	CL	0.816	0.259	0.042
DCRA-DH-022	136.0 – 138.0	65	27	MH	1.379	0.643	0.054
DCRA-DH-024	112.5 – 114.5	41	16	CL	0.793	0.292	0.034

3.2.3 Strength Characteristics of the Subsoils

Seven unconsolidated-undrained triaxial shear tests and three isotropically consolidated-undrained (ICU) triaxial shear tests with pore water pressure measurements were performed on the collected soil samples. ICU triaxial tests were backpressure saturated to a B-value of at least 0.95 before testing. The shear strength properties may be represented by the total stress or the effective stress concept compatible with the design conditions. The triaxial test results are graphically presented, in terms of Mohr circles, in Appendix C, and are summarized in Table 3-5.

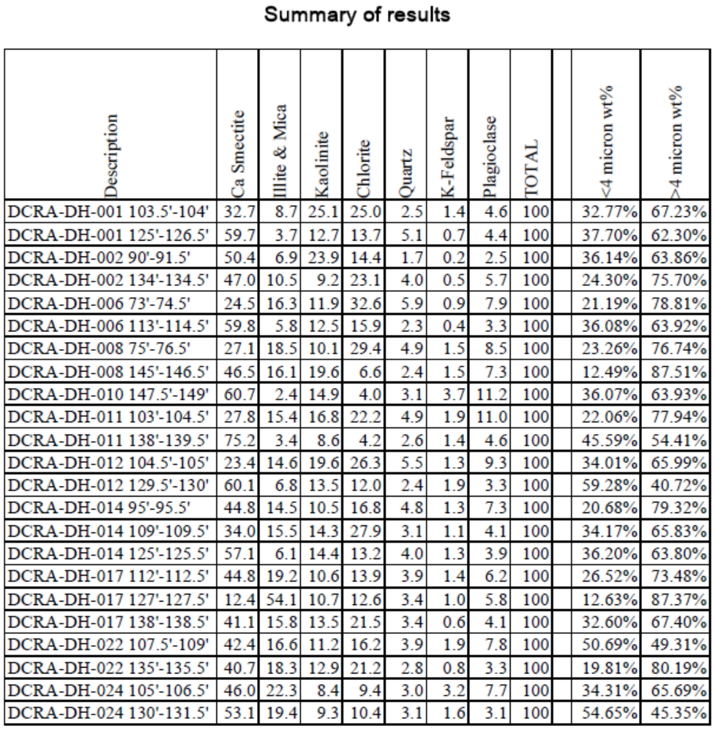
Table 3-5 Summary of Triaxial Test Results

Sample Source	Sample Depth (feet)	Liquid Limit,	Plastic Index	Classification	Confining Pressure σ_3, psf	Total Stress		Effective Stress		Remarks
						C, psf	Φ, degree	C′, psf	Φ′, degree	
DCR2-DH-006	112.5-114.5	44	16	ML	6000, 9000, 12000	1000	-	-	-	UU test
DCR4-DH-006	92.5-94.5	38	10	ML	5000, 7000, 10000	2000	-	-	-	UU test
DCRA-DH-008	80-82	42	11	ML	4500, 6000, 9000	1500	-	-	-	UU test
DCRA-DH-010	97.5-99.5	43	12	ML	5500, 8000, 11000	850	-	-	-	UU test
DCRA-DH-012	107.5-109.5	43	14	ML	6000, 9000, 12000	2800	-	-	-	UU test
DCRA-DH-014	109.5-111.5	60	19	MH	6000, 9000, 12000	3300	-	1000	17	CU test
DCRA-DH-017	139.5-141.5	61	18	MH	8000,12000, 16000	3550	-	600	27	CU test
DCRA-DH-022	120-121	37	15	CL	7000, 10500	900	-	-	-	UU test
DCRA-DH-022	136-138	65	27	MH	7500, 11000, 15000	3200	-	600	26	CU test
DCRA-DH-024	112.5-114.5	41	16	CL	6000, 9000, 12000	2000	-	-	-	UU test

3.3 Specialty Testing

3.3.1 X-Ray Diffraction Mineralogy Analyses

X-ray diffraction was used to determine the mineralogy of representative clayey soil samples collected from the 2010 Over-Water Geotechnical Investigation along the proposed Pipeline/Tunnel Option alignment. The analyses were performed by the University of Texas at Austin under the supervision of Professor Fulvio Tonon. The results are used to determine the proportion of various clays and silts that compose the fine-grained soils, for the identification of potentially expansive clays. The summary results of the X-ray diffraction analyses are provided below and the data report of X-ray analyses is provided in Appendix D.



Summary of results

Description	Ca Smectite	Illite & Mica	Kaolinite	Chlorite	Quartz	K-Feldspar	Plagioclase	TOTAL		<4 micron wt%	>4 micron wt%
DCRA-DH-001 103.5'-104'	32.7	8.7	25.1	25.0	2.5	1.4	4.6	100		32.77%	67.23%
DCRA-DH-001 125'-126.5'	59.7	3.7	12.7	13.7	5.1	0.7	4.4	100		37.70%	62.30%
DCRA-DH-002 90'-91.5'	50.4	6.9	23.9	14.4	1.7	0.2	2.5	100		36.14%	63.86%
DCRA-DH-002 134'-134.5'	47.0	10.5	9.2	23.1	4.0	0.5	5.7	100		24.30%	75.70%
DCRA-DH-006 73'-74.5'	24.5	16.3	11.9	32.6	5.9	0.9	7.9	100		21.19%	78.81%
DCRA-DH-006 113'-114.5'	59.8	5.8	12.5	15.9	2.3	0.4	3.3	100		36.08%	63.92%
DCRA-DH-008 75'-76.5'	27.1	18.5	10.1	29.4	4.9	1.5	8.5	100		23.26%	76.74%
DCRA-DH-008 145'-146.5'	46.5	16.1	19.6	6.6	2.4	1.5	7.3	100		12.49%	87.51%
DCRA-DH-010 147.5'-149'	60.7	2.4	14.9	4.0	3.1	3.7	11.2	100		36.07%	63.93%
DCRA-DH-011 103'-104.5'	27.8	15.4	16.8	22.2	4.9	1.9	11.0	100		22.06%	77.94%
DCRA-DH-011 138'-139.5'	75.2	3.4	8.6	4.2	2.6	1.4	4.6	100		45.59%	54.41%
DCRA-DH-012 104.5'-105'	23.4	14.6	19.6	26.3	5.5	1.3	9.3	100		34.01%	65.99%
DCRA-DH-012 129.5'-130'	60.1	6.8	13.5	12.0	2.4	1.9	3.3	100		59.28%	40.72%
DCRA-DH-014 95'-95.5'	44.8	14.5	10.5	16.8	4.8	1.3	7.3	100		20.68%	79.32%
DCRA-DH-014 109'-109.5'	34.0	15.5	14.3	27.9	3.1	1.1	4.1	100		34.17%	65.83%
DCRA-DH-014 125'-125.5'	57.1	6.1	14.4	13.2	4.0	1.3	3.9	100		36.20%	63.80%
DCRA-DH-017 112'-112.5'	44.8	19.2	10.6	13.9	3.9	1.4	6.2	100		26.52%	73.48%
DCRA-DH-017 127'-127.5'	12.4	54.1	10.7	12.6	3.4	1.0	5.8	100		12.63%	87.37%
DCRA-DH-017 138'-138.5'	41.1	15.8	13.5	21.5	3.4	0.6	4.1	100		32.60%	67.40%
DCRA-DH-022 107.5'-109'	42.4	16.6	11.2	16.2	3.9	1.9	7.8	100		50.69%	49.31%
DCRA-DH-022 135'-135.5'	40.7	18.3	12.9	21.2	2.8	0.8	3.3	100		19.81%	80.19%
DCRA-DH-024 105'-106.5'	46.0	22.3	8.4	9.4	3.0	3.2	7.7	100		34.31%	65.69%
DCRA-DH-024 130'-131.5'	53.1	19.4	9.3	10.4	3.1	1.6	3.1	100		54.65%	45.35%

3.3.2 Abrasion Testing

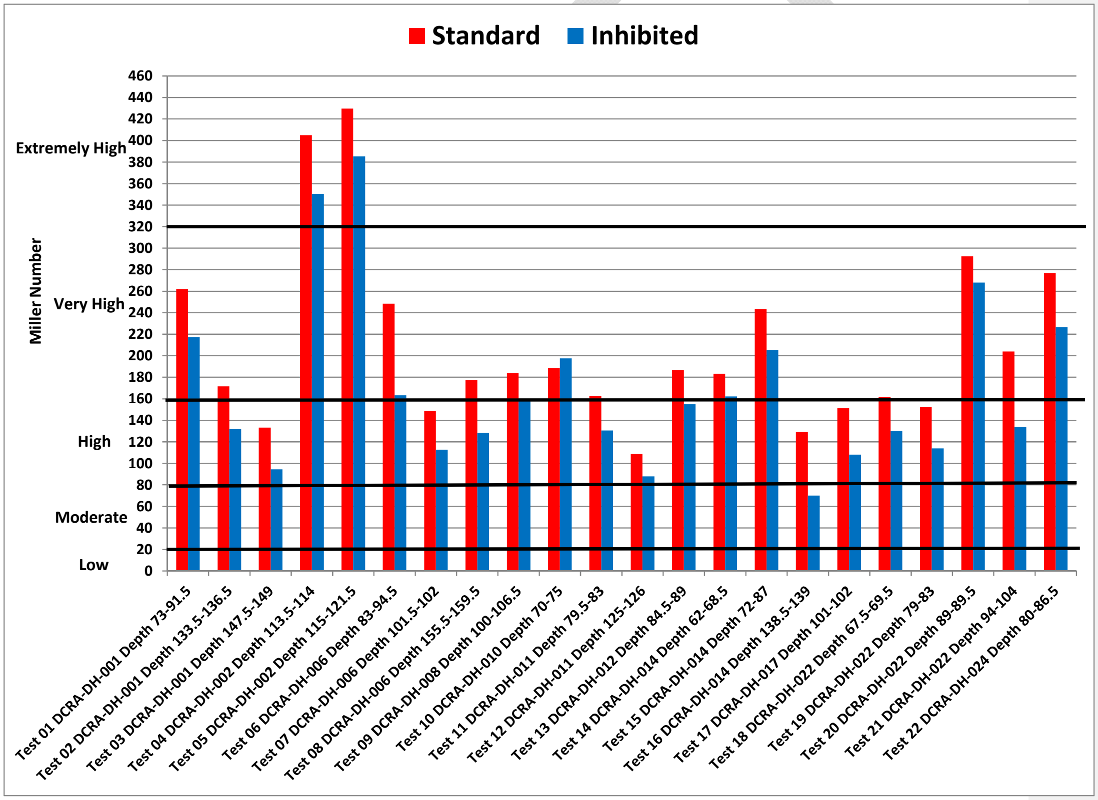
3.3.2.1 Soil Abrasion Test

Soil abrasion tests were performed on selected soil samples collected from the 2010 Over-Water Geotechnical Investigations. The tests were performed by the University of Texas at Austin under the supervision of Professor Fulvio Tonon. The test method follows the new Norwegian Soil Abrasion Test procedures. Details of the test procedures and photographs of test samples and results are provided in Appendix D. Below are the summary results of the soil abrasion test performed on the representative soil samples collected from the depths of 75 to 179 feet along the proposed Pipeline/Tunnel Option alignment.

Boring Name	Sample No.	Depth (ft)	Test 1	Test 2	AVS
DCRA-DH-002	1	75-77.5	50	53	51.5
	2	81.5-83	37	42	39.5
DCRA-DH-006	3	140-141	36	38	37
	4	148-151	37	42	39.5
DCRA-DH-010	5	172.5-179	22	27	24.5
DCRA-DH-011	6	118-120	32	28	30
	7	125-126	62	57	59.5
DCRA-DH-012	8	77.5-84	39	43	41
	9	144.5-145.5	46	50	48
DCRA-DH-014	10	139-140	51	55	53
	11	148.5-153.5	39	43	41
DCRA-DH-017	12	76.5-81.5	45	48	46.5
DCRA-DH-022	13	121-127.5	42	44	43

3.3.2.2 Miller Number Test

The Miller Number Test or slurry abrasivity tests were performed by White Rock Engineering Services of Frisco, Texas, on selected soil samples collected from the 2010 over-water borings drilled along the Pipeline/Tunnel Option alignment. The tests were conducted in general accordance with ASTM G-75, Standard Test Method for Determining of Slurry Abrasivity (Miller Number) and Slurry Abrasion Response of Materials (SAR Number). The procedure and the method used to perform the tests are described in the ASTM G-75. The photographs of the test samples and the test results are provided in Appendix D. Below are the summary results of the slurry abrasivity tests performed on the representative soil samples collected from the depths of 62 to 159 feet along the planned Pipeline/Tunnel Option alignment.



3.4 Environmental

All environmental samples were analyzed by TestAmerica and Brooks Rand Labs. Twenty-six locations (borings) were sampled at potential intake sites and along the proposed PTO alignment. Of the 43 discrete samples collected, 11 apply to the PTO alignment and were collected at possible tunnel grade. Fifteen explorations were at the proposed intake sites and more than one sample was collected at some of the exploration sites. Table 3-6 summarizes the analytical results of the environmental sampling.

Material samples were collected to evaluate disposal requirements.

A detailed discussion of the environmental sampling program, including results and interpretation of data, will be available in the DHCCP report *Environmental Sampling Report – Phase II Geotechnical Investigations*, 2011.

Table 3-6 Environmental Sample Results

Method	SW7471	SW6010B - Metals																8015G		8015D/MO			SW8081A	E1630
Analyte	**Mercury**	**Silver**	**Arsenic**	**Barium**	**Beryllium**	**Cadmium**	**Cobalt**	**Chromium**	**Copper**	**Molybdenum**	**Nickel**	**Lead**	**Antimony**	**Selenium**	**Thallium**	**Vanadium**	**Zinc**	**Gas**	**Unknown**	**Diesel**	**Motor Oil**	**Unknown**	**Pesticides**	**Methyl Mercury**
Units	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**	**ug/kg**	**ug/kg**	**mg/kg**	**mg/kg**	**mg/kg**	**ug/kg**	**ng/g**
10X STLC Limit	2	50	50	1,000	7.5	10	800	5600 (50)	250	3,500	200	50	150	10	70	240	2,500							
TTLC Limit	20	500	500	10,000	75	100	8,000	2,500	2,500	3,500	2,000	1,000	500	100	700	2,400	5,000							
DCR1-DH-010-38	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	<0.008
DCR1-DH-010-43.5	0.028 J	<0.59	4.70	116.00	0.36	<0.24	12.30	**56.20**	65.70	<2.4	69.80	4.00	<2.4	<2.4	<2.4	60.00	194.00	<320	NA	<1.2	<6.0	<6.0	All ND	NS
DCR1-DH-011-01-041	0.013 J	<0.64	6.90	40.80	0.17 J	<0.26	9.10	44.10	9.80	<2.6	62.60	3.30	<2.6	<2.6	<2.6	27.50	35.50	<640	<640	<1.3	<6.3	<1.3	All ND	NS
DCR1-DH-011-01D-041 (FD)	<0.052	<0.65	5.70	41.70	0.18 J	<0.06	10.00	51.80	9.10	<2.6	63.40	3.10	<2.6	<2.6	<2.6	27.50	34.70	<650	<650	<1.3	<6.5	<1.3	All ND	NS
DCR1-DH-011-01-038	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	<0.010
DCR1-DH-011-01D-038 (FD)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	<0.009
DCR1-DH-008-01-041	0.023 J	0.70	5.10	39.20	0.16 J	<0.28	9.20	33.20	33.60	<2.8	48.60	3.10	<2.8	<2.8	<2.8	24.80	46.90	<690	<690	<1.4	<7.0	<1.4	All ND	0.018 J
DCR2-DH-004-01-27	0.021 J	<0.66	4.60	46.70	0.18 J	<0.26	9.40	35.50	13.00	<2.6	47.70	3.40	<2.6	<2.6	<2.6	27.60	49.00	<660	<660	<6.7	210	<6.7	All ND	0.017 J
DCR2-DH-006-01-27.5	0.011 J	<0.51	4.80	44.30	0.17 J	<0.21	8.40	30.00	11.90	<2.1	42.50	2.90	<2.1	<2.1	<2.1	27.10	43.70	<510	<510	<1.0	<5.2	<1.0	All ND	NS
DCR2-DH-006-01-26	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	0.17
DCR2-DH-007-01	0.016 J	<0.62	4.30	60.70	0.20 J	<0.25	8.70	30.00	17.00	<2.5	46.80	3.20	<2.5	<2.5	<2.5	25.30	44.80	<290	NA	<1.3	<6.3	<6.3	All ND	0.066
DCR2-DH-007-01D (FD)	0.017 J	<0.62	4.90	52.10	0.19 J	<0.25	8.40	30.90	23.60	0.99 J	39.80	2.70	<2.5	<2.5	<2.5	25.30	53.10	<300	NA	<1.2	9.20	<1.2	All ND	NS
DCR2-DH-008-01-10.5	0.030 J	<0.63	<2.5	46.70	0.15 J	0.049 J	8.30	26.50	16.20	<2.5	37.50	2.40	<2.5	<2.5	<2.5	23.00	26.70	NS	NS	<1.2	<6.2	<6.2	All ND	NS
DCR2-DH-008-01-11	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
DCR2-DH-008-01	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	<320	NA	NS	NS	NS	NS	NS
DCR2-DH-008-01-12	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	<0.010
DCR2-DH-008-01-12 (FD)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	<0.010
DCR3-DH-003-01-(no depth on COC)	0.011 J	<0.59	5.50	39.60	0.17 J	<0.24	8.70	34.60	11.80	<2.4	47.10	3.20	<2.4	<2.4	<2.4	27.40	41.50	<590	<590	<1.2	9.40	<1.2	All ND	0.015 J
DCR3-DH-005-01-40.0	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	0.04
DCR3-DH-005-01	0.13	<0.71	6.20	122.00	0.45	<0.28	16.70	**56.60**	29.50	<2.8	59.20	5.30	<2.8	<2.8	<2.8	61.70	49.30	<710	<710	<1.4	<6.9	<6.9	All ND	NS
DCR3-DH-007-01-(no depth on COC)	0.020 J	<0.61	5.60	55.40	0.20 J	<0.24	10.10	35.60	14.00	<2.4	51.40	3.70	<2.4	<2.4	<2.4	30.30	53.00	<610	<610	<1.2	3.9 J	<1.2	All ND	0.014 J
DCR4-DH-004-01-034.5	0.036 J	<0.62	4.00	56.50	0.25	0.037 J	11.40	39.30	14.10	<2.5	51.60	4.10	<2.5	<2.5	<2.5	32.70	34.00	<620	<620	<1.2	<6.2	<6.2	All ND	NS
DCR4-DH-004-01-034	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	<0.010
DCR4-DH-006-01-033-34.5	0.032 J	<0.61	3.50	39.20	0.21 J	<0.24	11.20	49.40	10.80	<2.4	69.30	2.20	<2.4	<2.4	<2.4	32.30	25.00	<610	<610	<1.2	<6.1	<1.2	All ND	NS
DCR4-DH-006-01-039	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	<0.009
DCR4-DH-008-01 (no depth)	0.22	<0.55	2.1 J	48.90	0.21 J	<0.22	10.30	**51.10**	12.10	<2.2	57.20	2.50	<2.2	<2.2	<2.2	42.20	26.20	<550	<550	<1.1	<5.5	11.00	All ND	<0.009
DCR5-DH-006-01-035.0-035.5	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	<0.010
DCR5-DH-008-01-053.0-053.5	<0.049	<0.62	6.30	65.80	0.23 J	<0.25	9.20	48.30	18.40	<2.4	60.30	2.70	<2.5	<2.5	<2.5	34.80	32.80	NS	NS	<1.2	<6.2	<1.2	All ND	NS
DCR5-DH-008-01-058.0-058.5	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	<600	<600	NS	NS	NS	NS	NS
DCR5-DH-008-01-033.5-034.0	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	<0.010
DCRA-DH-001-01-141	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	<610	<610	NS	NS	NS	NS	NS
DCRA-DH-001-01-158	<0.048	<0.60	<2.4	148.00	0.50	<0.24	19.50	**57.00**	29.00	<2.4	79.70	6.70	<2.4	<2.4	<2.4	44.90	47.40	NS	NS	<1.2	<6.1	2.40	NS	NS
DCRA-DH-002-01-155	0.062	<3.4	<13.7	225.00	0.65 J	<1.4	23.10	**91.20**	58.60	<13.7	116.00	7.40	<13.7	<13.7	<13.7	75.70	93.00	<690	<690	<1.4	<6.8	<6.8	All ND	NS
DCRA-DH-006-01-123.5-124.0	0.018 J	<0.57	1.5 J	237.00	0.58	<0.23	9.30	27.10	24.00	1.1 J	23.30	3.70	<2.3	<2.3	<2.3	52.30	46.80	NS	NS	<1.1	<5.7	NS	NS	NS
DCRA-DH-006-01	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	<320	NA	NS	NS	NS	NS	NS
DCRA-DH-008-01-126	0.015 J	<0.62	2.1 J	130.00	0.48	<0.25	8.30	31.30	26.10	<2.5	21.30	4.60	<2.5	<2.5	<2.5	40.20	47.80	<620	<620	<1.2	<6.2	<1.2	NS	NS
DCRA-DH-0010-01-142.5-144.0	<0.048	<0.60	4.60	72.50	0.24	<0.24	6.00	33.60	13.70	<2.4	33.10	3.00	<2.4	<2.4	<2.4	37.00	30.50	<600 UJ	<600 UJ	<1.2	<6.0	<1.2	NS	NS
DCRA-DH-011-01-149	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	<640	<640	NS	NS	NS	NS	NS
DCRA-DH-011-01-159	0.013 J	<0.61	3.80	225.00	0.71	4.40	12.50	35.30	29.90	<2.4	40.80	7.10	<2.4	<2.4	<2.4	81.30	58.70	NS	NS	<1.2	<6.1	6.10	NS	NS
DCRA-DH-012-01-01A/B-127.5-129.0	0.056	<0.59	3.60	160.00	0.54	<0.24	14.40	38.50	27.80	<2.4	43.70	6.30	<2.4	<2.4	1.5 J	48.70	59.00	<590	<590	<1.1	<5.7	<1.1	NS	NS
DCRA-DH-014-01-(no depth)	0.022 J	<0.67	<2.7	212.00	0.83	<0.67	12.70	44.60	56.90	<2.7	46.40	8.80	<2.7	<13.4	<2.7	52.30	106.00	<640	<640	<1.3	<6.7	<6.7	NS	NS
DCRA-DH-017-01-125.5-126.0	0.032 J	<0.75	9.70	134.00	0.70	<0.30	14.20	**50.10**	33.90	<3.0	55.00	7.40	<3.0	<3.0	<3.0	60.10	74.20	NS	NS	<1.5	<7.6	15.00	NS	NS
DCRA-DH-017-01-150.5-151.0	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	<630	<630	NS	NS	NS	NS	NS
DCRA-DH-022-01-E01 (no depth)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	<620	<620	NS	NS	NS	NS	NS
DCRA-DH-022-01-E02 (no depth)	0.024 J	<0.61	5.10	103.00	0.74	<0.24	12.00	**54.80**	29.70	<2.4	59.90	7.70	<2.4	<2.4	1.1 J	71.90	75.60	NS	NS	<1.2	<6.2	<1.2	NS	NS
DCRA-DH-024-01-107.5-109.0	0.13	<0.66	<2.6	164.00	1.00	<0.26	15.00	**66.80**	36.10	<2.6	53.00	9.90	<2.6	<2.6	<2.6	73.00	96.10	NS	NS	<1.3	<6.5	<1.3	NS	NS
DCRA-DH-024-01-117.5-119.0	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	<310	NA	NS	NS	NS	NS	NS

4.0 RECOMMENDATIONS FOR ADDITIONAL WORK

The average spacing between exploration locations in the 2010 Phase II Geotechnical Investigations was approximately 1.5 miles. But the average is misleading because many explorations were concentrated at the proposed intake locations and at some of the water crossing locations south of the intakes. Potential changes in proposed locations of alignments or intake and other structure locations could reduce the applicability of some of the 2010 Phase II data. Additional geotechnical investigations will be required to provide information to support preliminary and final design. These investigations would include land-based soil borings, additional over-water borings, test pits, geophysical surveys, CPTs, piezometers, aquifer tests, dissolved gas collection, and a variety of standard and specialized laboratory tests. A program will be prepared for continuation of the Phase II Geotechnical Investigations.

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FIGURES