Pacific Gas and
Electric Company

Yvonne J. Meeks
Topock Project Manager
Chromium Remediation Project Office
Gas Transmission & Distribution

6588 Ontario Road
San Luis Obispo, CA 93405

Mailing Address
4325 South Higuera Street
San Luis Obispo, CA 93401

805.546.5243
Internal: 664.5243
Fax:: 805.546.5232
E-Mail: YJM1@pge.com

July 11, 2008

Aaron Yue
Project Manager
California Department of Toxic Substances Control
5796 Corporate Avenue
Cypress, CA 90630

Subject: Revised Work Plan for East Ravine Groundwater Investigation
PG&E Topock Compressor Station, Needles, California

Dear Mr. Yue:

This letter transmits the *Revised Work Plan for East Ravine Groundwater Investigation* at the PG&E Topock Compressor Station. This work plan was previously submitted on December 11, 2007, and has been modified as directed by DTSC's letter dated May 9, 2008 and the United States Department of the Interior's letter dated June 6, 2008.

Please do not hesitate to contact me if you have any questions on the attached work plan. I can be reached at (805) 234-2257.

Sincerely,

Yvonne Meeks

Yvonne Meeks

Cc: Kris Doebbler/DOI
John Earle/HNWR
Cindi Hall/HNWR
Chris Guerre/DTSC
Karen Baker/DTSC

Enclosures

Revised Work Plan for East Ravine Groundwater Investigation

PG&E Topock Compressor Station
Needles, California

Prepared for

California Department of Toxic Substances Control

On Behalf of

Pacific Gas and Electric Company

July 11, 2008

CH2MHILL
155 Grand Avenue, Suite 1000
Oakland, CA 94612

Revised Work Plan for East Ravine Groundwater Investigation

PG&E Topock Compressor Station
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On behalf of
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This work plan was prepared under supervision of a California Certified Professional Geologist:

PROFESSIONAL GEOLOGIST
MICHAEL J. CAVALIERE
5/31/09
No. 7988
STATE OF CALIFORNIA

Michael Cavaliere, P.G. No. 7988
Project Hydrogeologist

Jennifer Ledesma
Project Manager

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Acronyms and Abbreviations

µg/L	micrograms per liter
AOC	Area of Concern
APE	Area of Potential Effect
ASTM	ASTM International (formerly American Society for Testing and Materials)
bgs	below ground surface
BLM	U.S. Bureau of Land Management
BOR	Bureau of Reclamation
Caltrans	California Department of Transportation
CDFG	California Department of Fish and Game
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
CEQA	California Environmental Quality Act
cm/sec	centimeters per section
CMT	Continuous Multichannel Tubing
COPC	constituent of potential concern
Cr(T)	total chromium
Cr(VI)	hexavalent chromium
DI	deionized
DOI	U.S. Department of the Interior
DTSC	California Department of Toxic Substances Control
EM	electromagnetic (flow logging)
ESA	Endangered Species Act
FCR	field contact representative
HNWR	Havasu National Wildlife Refuge
GMP	Groundwater and Surface Water Monitoring Program
gpm	gallons per minute
IDW	investigation-derived waste
IM	Interim Measure

MW	monitoring well
NHPA	National Historic Preservation Act
NRHP	National Register of Historic Places
ORP	oxidation-reduction potential
OSHA	Occupational Safety and Health Administration
PAH	polycyclic aromatic hydrocarbon
PBA	programmatic biological assessment
PG&E	Pacific Gas and Electric Company
PQ-size	inner diameter of pipe adequate for the advancement of coring tools as large as 5-inches in diameter.
PVC	polyvinyl chloride
RCRA	Resource Conservation and Recovery Act
RFI	RCRA Facility Investigation
RI	Remedial Investigation
ROW	right-of-way
RQD	rock quality designation
SHPO	State Historic Preservation Office
SOP	standard operating procedure
SWFL	southwestern willow flycatcher
TPH	total petroleum hydrocarbons
USFWS	United States Fish and Wildlife Service
VOC	volatile organic compound

1.0 Introduction

Pacific Gas and Electric Company (PG&E) is addressing chromium in groundwater at the Topock Compressor Station near Needles, California, under the oversight of the California Department of Toxic Substances Control (DTSC) and the U.S. Department of the Interior (DOI). On October 29, 2007, DTSC issued a letter entitled "Workplan for Groundwater Investigation in Area of Concern 10 – East Ravine at Pacific Gas and Electric Company, Topock Compressor Station" to PG&E (DTSC, 2007a). The DTSC letter required that PG&E submit a work plan for conducting a groundwater investigation in the vicinity of Area of Concern (AOC) 10 - East Ravine, and nearby bedrock monitoring well MW-23.

This work plan was originally submitted to DTSC and DOI on December 11, 2007 (CH2M HILL, 2007a). Comments to the original work were documented and responded to in PG&E's letter dated February 1, 2008 (PG&E, 2008). DTSC and DOI letters dated May 9, 2008 (DTSC, 2008a) and June 6, 2008 (DOI, 2008a), respectively, provided direction to revise this work plan based on comments to the original work plan.

This revised work plan has been prepared in response to DTSC (2007a, 2008a) and DOI (2008a) direction, and describes the objectives, technical approach and rationale, field investigative methods, administrative approvals, proposed schedule, and reporting plans for this groundwater investigation.

1.1 Project Background

The Topock Compressor Station is located in San Bernardino County, approximately 15 miles to the southeast of Needles, California (Figure 1; all figures are located at the end of this document). Investigative and remedial activities are being performed under the Resource Conservation and Recovery Act (RCRA) Corrective Action process as well as the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) pursuant to agreements with DTSC and DOI, respectively. Under the terms of these agreements, PG&E is conducting the RCRA facility investigation/remedial investigation (RFI/RI) at the Topock Compressor Station. The purpose of the RFI/RI is to identify and evaluate the nature and extent of hazardous waste and constituent releases at the compressor station. Since 1996, there have been six phases of investigation at the Topock site to collect data to complete the RFI/RI. PG&E is currently planning additional data collection to complete the RFI/RI, including the activities proposed in this work plan. Information obtained through the implementation of this work plan is intended to be combined with the existing dataset and included in the Final RFI/RI report for the site.

As directed by DTSC, the Final RFI/RI for the site is being separated into three volumes, to efficiently manage the large amount of information associated with the RFI/RI, and to accelerate the remediation by allowing earlier remedial planning for those portions of the RFI/RI completed earlier. The *Revised Final RFI/RI Report, Volume 1 – Site Background and History* (CH2M HILL, 2007b) was completed in August 2007 and includes the site background and history of the Topock Compressor Station, including description and background information for the East Ravine and AOC 10. The *Final RFI/RI, Volume 2 – Hydrogeologic Characterization and Results of Groundwater and Surface Water Investigation Report,* was submitted to DTSC and DOI on July 2, 2008 (CH2M HILL, 2008a). Volume 3 of the Final RFI/RI is pending completion.

Separately from the investigation activities documented in this work plan, PG&E is planning a soil sampling investigation to supplement the existing soil dataset for AOC 10. Planned soil sampling activities for AOC 10 are documented in the *Draft RCRA Facility Investigation/Remedial Investigation Soil Investigation Work Plan, Part A* (CH2M HILL, 2006a), as modified by DTSC (2007b) and DOI (2008b).

1.2 Investigation Background

The site conceptual model developed for the RFI/RI reflects a collective understanding that the groundwater chromium plume is confined to the Alluvial Aquifer and is bounded, south and southeast of the compressor station, by the Miocene Conglomerate and older crystalline bedrock that underlie the site. However, elevated concentrations of hexavalent chromium (Cr[VI]) have been observed sporadically in well MW-23 (Miocene Conglomerate bedrock monitoring well), which is located immediately north of the East Ravine. Additionally, historic soil sampling data indicate some of the highest chromium concentrations in soils at the site have been detected in the drainage depressions in the East Ravine (areas designated AOC-10). Historical aerial photographs of this portion of the site (attached as Appendix A) show the presence of an impoundment within the AOC 10c subarea that contained liquids of unknown composition during several years in the 1960s (CH2M HILL, 2007b). The AOC 10c subarea, where the highest concentrations of chromium were detected in soil, is coincident with the western portion of the area identified as drilling Site A on Figure 2. DTSC has directed that additional drilling and groundwater investigation are needed to characterize the groundwater flow pathway and groundwater conditions of bedrock formations in the East Ravine and MW-23 area.

1.2.1 Investigation Area Overview

The area of remedial investigation lies within a larger geographic area that is considered sacred by the Fort Mojave Indian Tribe and other Tribes. Figure 2 shows the location of the East Ravine and AOC 10, and site features and facilities in the investigation area. The East Ravine is a small ravine located on the southeast side of the compressor station, which drains eastward towards the Colorado River. Portions of the East Ravine are on PG&E property outside the compressor station fence line and other portions of the ravine are located on property owned by the United States Bureau of Reclamation (BOR) and managed by United States Fish and Wildlife Service (USFWS)/Havasu National Wildlife Refuge (HNWR). Existing groundwater monitoring wells in the investigation area include two wells completed in the Alluvial Aquifer (MW-12 and MW-21) and two wells completed in the Miocene Conglomerate formation (MW-23 and MW-48).

Three subareas, designated AOC 10b, 10c, and 10d (Figure 2), have been identified within the East Ravine where water and sediment have collected within low areas or behind small earthen embankments. Based on information available to PG&E, the embankments were not designed as engineered dam structures (Russell, 2007). A description of East Ravine features, prior RFI soil sampling results, and the soil constituents of potential concern (COPC) identified at AOC 10 are described in the Revised Final RFI/RI Report, Volume 1 (CH2M HILL, 2007b).

1.2.2 Conceptual Model of East Ravine Groundwater Conditions

Previous subsurface investigations in East Ravine include only shallow soil sample collection (maximum depth of 2 feet below ground surface [bgs]). Therefore, the conceptual model for this area is based on extrapolation from other parts of the Topock site and observation of bedrock outcrops and surficial geology in the East Ravine area. To facilitate the presentation of the conceptual model, a southwest-northeast oriented conceptual hydrogeologic cross section (Section X-X′) is presented on Figure 3. Additionally, two north-south oriented conceptual hydrogeologic cross sections (Sections Y-Y′ and Z-Z′) are presented on Figure 4. As will be discussed in Section 2.1, these cross sections are oriented along potential flow pathways for groundwater that may infiltrate from ponded water or surface flow in the East Ravine.

The East Ravine lies along the trace of the Chemehuevi detachment fault (John, 1987), which is a regional geologic feature that is exposed along the base of the bedrock slope immediately south and southeast of the Topock Compressor Station. The metadiorite outcrop that forms the southern slope of the East Ravine is likely the footwall of the fault. The northern slope of the ravine, which is likely part of the headwall of the fault, is composed of alluvium deposited on top of the dipping Miocene Conglomerate bedrock surface. An outcrop of Miocene Conglomerate occurs at the mouth of the East Ravine where it meets the Colorado River. Surface drainage passes over this outcrop and has eroded two small channels into the bedrock. As described in the following paragraphs, existing data suggest that the bedrock at the Topock site has relatively low permeability and would therefore represent an impediment to groundwater flow to the south and from the East Ravine to the river.

As observed in the lithologic logs from borings drilled into the bedrock at the Topock site, the uppermost section of the Miocene Conglomerate bedrock has commonly weathered to stiff, clayey silt. This weathered zone varies in thickness from zero to 15 feet and may be thinner or absent in the southern portion of the site, near the East Ravine. Where observed, this zone is distinguished from the overlying alluvium by the relict bedding planes observable in the core samples. Based on observations of the material in the core samples, the permeability of the weathered Miocene Conglomerate would be expected to be very low. The material would not sustain open fractures and the fine grained matrix would transmit very little water. The bottom of the weathered zone has been observed both as an abrupt contact and as a gradational change to competent Miocene Conglomerate. If a fractured zone were present in the uppermost part of the competent Miocene Conglomerate, the weathered zone above it, if present, could function as an aquitard separating the more permeable alluvium from the underlying bedrock.

Based on extrapolation of the bedrock surface and the measurements of groundwater elevations in the nearest wells, it is likely that there is no saturated Alluvial Aquifer beneath the East Ravine. If significant recharge occurred from surface infiltration within the East Ravine, it would likely flow as perched groundwater until it merged with the regional aquifer to the north. Flow in the regional aquifer adjacent to the East Ravine is predominantly north to northeast, controlled by the bedrock outcrop and subsurface bedrock ridge extending northward from near well MW-23. Perched groundwater occurs where infiltrating water is impeded by a lower permeability layer. There are at least three hydrogeologic conditions that could result in perched water beneath the East Ravine.

The first, and perhaps most likely, scenario is that the water infiltrating through the alluvium beneath the East Ravine would encounter competent, low permeability bedrock. In this scenario, the water would pool on the top of the bedrock and flow down-dip on the bedrock contact until it reached and merged with the saturated alluvium of the regional aquifer.

The second scenario would occur if there was significant weathering of the Miocene Conglomerate bedrock beneath the East Ravine. The Miocene Conglomerate weathers to a stiff, low-permeability silt that could provide a perching layer. In this case, the infiltrating water would perch on or within the weathered bedrock layer rather than on the top of the bedrock. Perched water would flow down-dip on the weathered bedrock surface and the direction of flow would be determined both by the dip of the bedrock and the depth and degree of weathering. The perched water would eventually merge with the regional aquifer but it might take a more circuitous path and be flowing at a slower rate because it was flowing within the weathered bedrock layer.

The third scenario would occur if there were a zone of significant open fracturing in the uppermost section of the bedrock which was able to freely transmit water. In this scenario, the competent bedrock beneath the shallower fractured zone would function as the perching layer. Perched water would flow through the shallower, fractured bedrock, down-dip on the competent bedrock surface until it reached the regional aquifer. Based on hydraulic data presented in the next paragraph, after reaching the regional aquifer, upward gradients present between the bedrock and the alluvium would tend force this water upward, out of the fractures, and into the overlying alluvium.

Six wells have been completed in bedrock at the Topock site. However, none of the existing wells are screened in the shallowest portion of the bedrock, and therefore may not be representative of shallow bedrock conditions. The existing bedrock wells include four monitoring wells (MW-23, MW-24BR, MW-48, and decommissioned well MWP-2RD); the former production well PGE-7 that was recently converted to bedrock monitoring well PGE-7BR; and the former injection well PGE-8. Hydraulic tests conducted at these wells have been reported in *Information Review of Groundwater Conditions in Bedrock Formations at PG&E's Topock Compressor Station* (CH2M HILL, 2006b), *Summary Report for Hydraulic Testing in Bedrock Wells* (CH2M HILL, 2008b), and the Evaluation of Bedrock Aquifer Testing near PG&E Topock Compressor Station (CH2M HILL 2008c). With the exception of PGE-8, which based on geophysical logging and hydraulic testing data appears to be drawing water from the overlying alluvium, the hydraulic conductivity of the bedrock wells is very low, ranging from 8.2×10^{-6} centimeters per section (cm/sec) to 1.9×10^{-7} cm/sec (CH2M HILL, 2008b,c).

Strong upward hydraulic gradients have been consistently observed between bedrock and overlying alluvium. Specifically, upward hydraulic gradients are observed between MW-24BR (bedrock) and the other alluvial wells on the MW-24 bench, and between MW-48 (bedrock) and the nearby alluvial well MW-12 (CH2M HILL, 2008b). Additionally, upward gradients are typically observed in wells completed at different depths within the Alluvial

Aquifer (CH2M HILL, 2008a). These upward hydraulic gradients would tend to limit or prevent intrusion of water from the overlying alluvium into the underlying bedrock.

1.2.3 Chromium Sampling Results at Well MW-23

Anomalously high hexavalent chromium [Cr(VI)] results were observed on two occasions in groundwater sampling at bedrock well MW-23. In December 2006, a Cr(VI) concentration of 1,920 micrograms per liter (µg/L) was reported in one of two duplicate samples (samples collected on the same day) from this well. The anomalously high sample was reanalyzed at the lab, and the elevated Cr(VI) concentration was confirmed. The other duplicate sample that day showed nondetectable levels of Cr(VI). The second anomalously elevated Cr(VI) result (1,020 µg/L) was observed in a March 2007 sample from MW-23. A subsequent sample collected in May 2007 from MW-23 contained Cr(VI) at a concentration of 14.4 µg/L, typical of prior historical sampling at this low recharge bedrock monitoring well.

At DTSC's direction, a special sampling effort was conducted in June 2007 at well MW-23 to confirm and further investigate the anomalously high Cr(VI) results, and to better understand the effects of purging, recovery, and sampling methods on groundwater analytical results. The anomalous concentrations and pumping conditions observed in December 2006 and March 2007 were not reproducible in the sampling test. The MW-23 sampling study and results are summarized in PG&E's Second Quarter 2007 groundwater monitoring report (CH2M HILL, 2007c). Cr(VI) concentrations from groundwater samples collected during seven events between October 2007 and March 2008 were between less than analytical detection limits and 43.7 µg/L (CH2M HILL, 2008d), which are similar to the historic concentration range at this well.

1.3 Investigation Objectives

In accordance with DTSC's October 29 directive, additional site investigation is needed to investigate the groundwater pathway at AOC 10 and the adjoining East Ravine area to supplement the final RFI/RI. The primary objectives of the groundwater investigation in the East Ravine area are to:

- Determine whether elevated concentrations of Cr(VI) and other inorganic constituents are present in groundwater beneath the East Ravine area. If elevated concentrations of Cr(VI) are confirmed in bedrock, evaluate the presence and potential extent of the groundwater impact.
- Assess the potential for perched/shallow groundwater to occur at the base alluvium/weathered bedrock/bedrock contact underlying the East Ravine area and install perched/shallow groundwater monitoring wells, as appropriate.
- Install monitoring wells within the bedrock, as appropriate, to facilitate ongoing groundwater quality monitoring in the East Ravine area.

During implementation of the work plan, PG&E will continue coordination with stakeholders regarding field procedures by which potentially affected environmental, cultural, and spiritual resources are best preserved. PG&E also intends to conduct this work in a manner consistent with the conservation/mitigation measures discussed within the Programmatic Biological Assessment (PBA) (CH2M HILL, 2007d).

2.0 Field Investigation and Drilling Activities

This section describes the drilling, well installation, and groundwater characterization activities proposed for the East Ravine. The primary topics addressed include investigation overview; selection and rationale for the drilling sites; site preparation and access; and description of the drilling, characterization, well installation, and sampling activities and methods proposed or considered applicable for this groundwater investigation.

2.1 Investigation Overview

A phased groundwater characterization and well installation program has been developed to address DTSC's October 29 directive for the East Ravine groundwater investigation. Figure 2 shows the potential locations where wells would be installed. The area actually affected by field activities at each location will be smaller than that indicated on Figure 2. The areas are shown larger than the actual drill sites to accommodate minor shifting of well locations and equipment within the identified areas at the time of drilling. Wells will initially be installed at the two primary drilling sites, designated Sites A and B. The primary drilling sites are coincident with impoundments within the ravine. Aerial photos from 1961 and 1967 (see Appendix A) indicate the presence of ponded water within the upper impoundment (Site A). Based on the conceptual model presented in Section 1.2.2, if contaminants were present in the ponded water, groundwater beneath the impoundments, if present, may still be affected. Due of the inherent uncertainty about the direction and rate of groundwater flow beneath the East Ravine, installing wells within or adjacent to the impoundments offers the highest probability of encountering impacted groundwater.

If the results of the groundwater characterization at Sites A or B indicate that further investigation and well installations are needed, five contingency locations, designated as Sites C, D, E, F, and G on Figure 2, have been identified as potential investigation areas. To provide flexibility, alternate drilling sites are included for two of the contingency drilling sites.

Specific information related to each drilling site, including estimated depth to bedrock and target drilling depths, are presented in Table 1. The estimated bedrock depths presented on Table 1 and the projection of the detachment fault on each cross-section are based on the geologic mapping of the surface bedrock outcrops south and east of the investigation area. Site selection and implementation criteria for the five contingency drilling sites are discussed below in Section 2.1.3.

Primary investigation Sites A and B are included on cross section X-X' (Figure 3), which extends southwest to northeast, along the longitudinal axis of East Ravine. These sites are located within or adjacent to the lower surface water impoundments (AOCs 10c and 10d) discussed in Section 1.2.1. The inferred depth and location of the Chemehuevi detachment fault is illustrated on Section X-X'. Based on the water table elevation, saturated alluvium is not inferred along this section.

Cross sections Y-Y′ and Z-Z′ (Figure 4) extend northward from the bedrock surface outcrops that are exposed immediately south of East Ravine to the alluvial deposits near Interstate I-40. These sections are oriented in the inferred direction of bedrock dip, and therefore represent the path that perched/shallow groundwater might flow after infiltrating into the East Ravine down to the less permeable bedrock/weathered bedrock surface. Cross section Y-Y′ includes primary investigation Site A (within the AOC 10c subarea), contingency Site G (to the north), and the depth and elevation of the existing monitoring wells MW-12, MW-48, and MW-23 (projected approximately 400 feet from the east). Cross section Z-Z′ includes primary investigation Site B (adjacent to the 10d impoundment), contingency Site F (to the south), and existing monitoring well MW-23. The inferred depth and location of the Chemehuevi detachment fault and the approximate southern extent of the Alluvial Aquifer in the investigation area is illustrated on both cross sections Y-Y′ and Z-Z′.

Up to three separate borings/wells are proposed at each site to address the investigation objectives. The first boring at each of the primary drilling sites will be a deeper exploration borehole drilled into bedrock to confirm the depth to bedrock and characterize groundwater conditions in bedrock to the target drilling depths. Based on core samples collected from the alluvium and shallow bedrock during the drilling of the first borehole, a second, shallow boring will be advanced adjacent to the bedrock borehole for the installation of a perched/shallow monitoring well. If no saturated alluvium is present, the perched/shallow zone well may be completed as a perched zone groundwater monitoring well, screened across the contact between the Miocene Conglomerate bedrock and the overlying alluvium. If a weathered bedrock zone is present and appears to be a perching layer, the perched / shallow zone well may be screened at the top of the weathered bedrock zone. For perched zone wells, the objective will be to screen the interval that appears most likely to contain and be capable of transmitting perched groundwater. The third boring will only be drilled if it is determined that, based on the data collected during drilling and testing of the initial borehole, the perched/shallow monitoring and bedrock characterization objectives cannot be accomplished within two boreholes.

It should be noted that existing site wells that are screened exclusively within the bedrock yield water; however, well yields observed in these wells are typically extremely low, with some wells requiring a week or more to fully recover after a purge event. If a borehole installed into bedrock does not yield groundwater (i.e., measurable recovery is not observed following a purge event), the more aggressive borehole development techniques, as detailed in Section 2.4.1, will be implemented. If the borehole does not yield groundwater following additional development, PG&E will consult DTSC and DOI as to whether additional drilling and bedrock characterization is required.

The method and procedures that will be used for this investigation are described in Sections 2.3 through 2.7. As discussed below in Section 2.3, among other considerations and based on the scope of work to be performed, the specific drilling locations within the primary and contingency drilling areas indicated on Figure 2 will be based on the results of utility clearance surveys to ensure safe working distances from overhead and underground utility hazards.

2.1.1 Primary Drilling Sites A and B

As shown on Figure 2, drilling Site A is located adjacent to the embankment in East Ravine that forms the upper impoundment (AOC 10c), near the border of PG&E property and the HNWR. Drilling Site B is located adjacent to the lower impoundment (AOC 10d) on the most level portion of the lower embankment that forms the gravel pipeline access road, which crosses East Ravine on the HNWR. Because the sites are located in East Ravine, which generally follows the surface trace of the Chemehuevi Detachment Fault, the depth to bedrock at Sites A and B is estimated to be 20 feet bgs, and the depth to groundwater is estimated to be 56 feet bgs (based on water table information from wells located to the north). The proposed target drilling depths for the deeper, exploratory boreholes at each location are based on the estimated depth to groundwater. Further, the target depths were chosen such that the boreholes will likely penetrate the estimated detachment fault zone; however, the purpose of this investigation is not to characterize the detachment fault zone, specifically. It is not anticipated that the target drilling depths will be deepened if the detachment fault zone is not encountered.

The deeper, exploratory borehole at Site A will be drilled to 115 feet bgs, which is approximately 50 feet below the water table, within bedrock. Based on the projected depth of the detachment fault (50 feet bgs), this boring will likely penetrate both the Miocene Conglomerate and crystalline bedrock formations.

The target drilling depth at Site B is 190 feet bgs, which based on the projected depth of the detachment fault (140 feet bgs), is estimated to extend 134 feet into groundwater and penetrate both the Miocene Conglomerate and crystalline bedrock formations.

2.1.2 Contingency Drilling Sites

Contingency drilling Sites C, D, E, F, and G are identified as potential step-out locations if, based on data collected from primary Sites A and B, additional evaluation of East Ravine groundwater conditions is required. Because of the extreme variations in topography in the East Ravine area, the contingency drilling sites were selected largely based on the practicability of drilling equipment access and operation. In general, the decision to proceed with investigation at contingency sites will be made in consultation with DTSC and DOI based on Cr(VI) concentrations in groundwater samples collected during two winter (December through March) groundwater sampling events and other hydrogeologic data collected at primary Sites A and B. Groundwater samples collected from December through March are necessary to address potential affects of low river stage and/or seasonal effects on groundwater sampling data in the East Ravine area and will be compared to trigger Cr(VI) concentrations suggested by DTSC, as detailed in the list below. Furthermore, contingency investigation may be conducted based on direction from DTSC and DOI if Cr(VI) is present in groundwater from the primary locations at concentrations less than the suggested trigger levels. All drilling and characterization activities conducted at contingency locations would be similar to those conducted at the primary investigation locations.

Criteria that may require investigation at each contingency location is defined as follows:

- Site C/Site C Alternate – Delineation of Cr(VI) in groundwater to the east of East Ravine if Cr(VI) concentrations in groundwater from primary locations are greater than 100 μg/L.
- Site D – Delineation of Cr(VI) in groundwater to the west of East Ravine if Cr(VI) concentrations in groundwater from primary locations are greater than 100 μg/L.
- Site E/Site E Alternates 1 and 2 – Delineation of Cr(VI) concentrations in groundwater along the drainage pathway of East Ravine if Cr(VI) concentrations in groundwater from Site B are greater than 50 μg/L. As directed by DTSC, trigger criteria at this location is lower due to proximity to the Colorado River.
- Site F – Delineation of Cr(VI) in groundwater to the south of East Ravine if Cr(VI) concentrations in groundwater from primary locations are greater than 100 μg/L.
- Site G – Delineation of Cr(VI) in groundwater to the northwest of East Ravine if Cr(VI) concentrations in groundwater from primary locations are greater than 100 μg/L.

Refer to Section 5 for further discussion of the project implementation schedule and the proposed interim reporting plan regarding the contingency groundwater investigations.

2.2 Site Preparation, Access, and Equipment Staging

The proposed access routes and drilling sites will be field-checked and clearly delineated by a qualified biologist before drilling equipment mobilization and following the completion of investigation activities. If modifications to the access routes are needed, the appropriate agency will be contacted for approval before field activities. Field activities associated with the equipment access and well drilling on federal lands will be coordinated with USFWS to ensure the protection of cultural and biological resources. Grading for equipment access is not anticipated for any of the drilling sites shown on Figure 2 except Site E. Minor grading and use of a winch may be required for rig access if the chosen location is in the portion of the indicated area that is within the small ravine at drilling Site E. Modification to the upper embankment in the East Ravine for access to the upper portion of the ravine (including drilling Site A) is being conducted as part a separate investigation (RFI/RI, Soil Investigation Part A); therefore, its is assumed that this pathway does not need to be constructed as part of this investigation.

Site preparation will occur before equipment mobilization. Site preparation will include identifying biologically and/or culturally sensitive areas, identifying subsurface utilities and other structural constraints, identifying site hazards, and establishing access routes and work areas that will minimize impacts to these features to the extent possible. Drill rigs will be cleaned before mobilization to the site and following completion of drilling at the site if visible grease, oil, or other contamination is evident on the equipment. After the drill rigs have been mobilized into place, the staging areas will be established in the drilling work area. Plastic sheeting will be laid on the ground surface in the staging areas to keep the drilling materials and equipment clean and to minimize impacts to the ground surface from the drilling materials and equipment. Materials to be stored at the well site include drilling equipment and well construction materials (e.g., casing and grout). In accordance with

Occupational Safety and Health Administration (OSHA) requirements, the exclusion zones for the drilling sites will be demarcated.

The proposed equipment decontamination area and primary staging area for drilling equipment and investigation-derived waste (IDW) management will be on PG&E property as shown on Figure 2. Additional equipment and material staging will be on compressor station property, as needed.

Drilling and well installations will conform to state and local regulations. PG&E shall obtain authorizations and applications required for drilling and well installation, as required. The specific drilling locations within the areas indicated on Figure 2 will be based on the results of utility clearance surveys to ensure safe working distances from overhead and underground utility hazards. Approvals and authorizations are discussed in Section 4.

2.3 Borehole Drilling and Requirements

The drilling, core/borehole logging, and well construction will be performed under the supervision of a California Professional Geologist. The drilling and well installation activities will be conducted in accordance with this work plan and modified methods and standard operating procedures (SOPs) from the *Topock Program Sampling, Analysis, and Field Procedures Manual* (CH2M HILL, 2005). The SOPs relevant for the investigation activities for this project are included in Appendix C. The methods, equipment, and procedures for drilling, core logging, and depth-specific groundwater sampling are described in the following subsections.

As discussed in Section 2.1, up to three vertical boreholes will be drilled at each primary location (Sites A and B). The deeper borehole(s) will extend into the bedrock through a conductor casing installed through the alluvial interval to isolate the bedrock from overlying alluvium. The depth of the shallow borehole(s) will be based on the core collected from the deeper borehole and will extend to a depth near the top of bedrock, or potentially into shallow bedrock, to provide monitoring of possible perched/shallow groundwater.

At the direction of DTSC (2008a), PG&E conducted a field survey on June 5, 2008, to collect fracture orientation data in the Miocene Conglomerate outcrops in the vicinity of the East Ravine to determine if angled boreholes, as opposed to vertical, would be more likely to intercept fracture sets during this investigation. After review of the field survey data, DTSC determined that vertical boreholes are appropriate for the investigation (DTSC, 2008b). The data collected during the field survey and the associated findings are attached as Appendix B.

2.3.1 Drilling Methods

The drilling methods used may vary depending on the conditions encountered. The preferred drilling methods are described below. Additional methods that may be used if conditions encountered are different than expected include hollow-stem auger, mud rotary, downhole hammer, and dual-tube air methods such as Stratex® or Odex®.

Rotosonic methods are preferred for drilling through unconsolidated materials above bedrock. This method involves advancing a rotating and vibrating drill casing or core barrel through the subsurface. Rotosonic drilling can produce a continuous core from the land surface to the target drilling depths; generates minimal drilling wastes; and typically can drill through gravel, cobble, and softer bedrock formations. Rotosonic methods would not be suitable for penetrating the harder Miocene Conglomerate or crystalline bedrock to the target depths beneath the alluvium. Rotosonic boreholes drilled for well construction within the alluvium will be a minimum of six inches in diameter to provide adequate annular space for annular well construction materials (2-inch diameter polyvinyl chloride [PVC]).

Wireline, diamond-bit core drilling methods are preferred for drilling through consolidated bedrock. This method uses a rotating, dual-barreled drill casing with a diamond bit to efficiently collect relatively undisturbed core. Additionally, as determined necessary, a triple-tube core barrel, which uses the same tools as the dual-barreled system but includes an inner sleeve to maximize core recovery in especially fractured rock, may be used. Drilling fluid, typically water with no additives, is used to move drill cuttings out of the borehole. Coring activities will be initiated using water with no additives. If the driller deems it necessary to add bentonite or an equivalent additive to the drilling fluid to facilitate the removal of cuttings from the borehole or inhibit the loss of drilling fluids to the formation, then it will be added; however, given the low yield that is anticipated in bedrock at these locations, the use of additives in the drilling fluid will be minimized to ease borehole development. Wireline diamond-bit coring minimizes drilling time because the outer barrel and bit remain in the borehole while the inner barrel is lowered and raised in and out of the outer barrel on a wireline to retrieve core, therefore precluding the need to assemble and disassemble drilling rods to retrieve core.

Rotosonic borings drilled to the alluvium/bedrock interface to facilitate perched/shallow groundwater monitoring well installation will be a minimum of 6 inches in diameter. Rotosonic borings drilled to facilitate conductor casing installation for subsequent bedrock coring will be a minimum of 8 inches in diameter. The conductor casing installed will be composed of steel or Schedule 80 PVC and have an inner diameter adequate for the advancement of coring tools as large as 5-inches in diameter (PQ-size).

Rotosonic drilling and wireline bedrock coring activities will be conducted using either standard truck-mounted or a track-mounted rotosonic drilling rig. A tracked or balloon-tired vehicle will be used to support the drilling rig by transporting cuttings, tools, and excess core generated from the drilling sites to the staging area. Given the proximity of each drilling location to National Trails Highway, one or more standard highway vehicles or small all-terrain vehicles may be used to transport crew, equipment, and materials from the staging area to the drill site. Disposal procedures for IDW are discussed in Section 3.

2.3.2 Core Logging

Lithologic descriptions will be logged of each borehole based on visual inspection of the retrieved core under the supervision of a California Professional Geologist; and follow the standard operating procedures for Topock drilling investigations (Appendix C). At a minimum, the field log will document the following information:

General

- Unique boring or well identification
- Purpose of the boring (e.g., monitoring well)

- Location in relation to an easily identifiable landmark
- Names of the drilling subcontractor and logger
- Start and finish dates and times
- Drilling method
- Drilling rate and rig reactions, such as chatter, rod drops, and bouncing
- Volume and composition of drilling fluids, additives used, and depths at which they were used
- Diameters of conductor casing, casing type, and methods of installation

Soil Core Logging

- Depth at which saturated conditions were first encountered
- Lithologic descriptions (based on the Unified Soil Classification System)
- Sampling-interval depths
- Zones of caving or heaving

Rock Core Logging

- Depth at which drilling fluid was lost and the volume lost
- Changes in drilling fluid properties
- Drilling rate
- Fractures per foot
- Lithologic descriptions (including structures, texture, foliations, bedding, grain size, and hardness)
- Alteration and weathering
- Percent core recovery
- Core discontinuity description
- Rock quality designation (RQD)

The results of the continuous core logging of the boreholes will be summarized in an interpretive log for hydrogeologic characterization to assist in selecting well screen intervals. Cores will be photo-documented for use during well screen selection discussions with DTSC and DOI.

2.3.3 Soil Sample Collection for Laboratory Analysis

As requested by DTSC, Site B well(s) will be drilled through the embankment that forms a gravel road through the area indicated on Figure 2, and completed beneath the East Ravine wash. During drilling at this location, opportunistic soil sampling for laboratory analysis will be conducted. Three soil samples, two from within the embankment material (approximately 5 feet thick) and one from the alluvium at the contact between the embankment material and the wash, will be collected from one of the boreholes drilled at this location. Samples will be analyzed for the constituents of potential concern at AOC 10 identified in the *Draft RCRA Facility Investigation/Remedial Investigation, Soil Investigation Work Plan, Part A* (CH2M HILL, 2006a), which include the following:

- Cr(VI) (7199/3060A)

- Title 22 Metals (6010B/7471A)

- volatile organic compound (VOC) (8260B)[1]
- total petroleum hydrocarbons (TPH)-Extractable (8015ME) and TPH-Purgable (8015MP)
- polycyclic aromatic hydrocarbons (PAH) (8270Sim)

In the event that soil sample data collected at AOC 10 during the Soil Part A Investigation is available before the East Ravine groundwater investigation is conducted, the need for these or additional samples will be evaluated with DTSC and DOI in effort to eliminate redundant activity and reduce the number of incursions into the area.

2.4 Bedrock Characterization

The uncased bedrock boreholes, which will be segregated from the alluvium by a grouted conductor casing, provide ideal conditions for characterization of the bedrock. Potential bedrock characterization methods including geophysical logging, interval specific permeability and groundwater quality testing, and hydraulic testing are described in the following subsections; however, the methods chosen for field implementation will be based on field conditions observed during drilling and subsequent bedrock characterization tests. To ensure the final bedrock characterization testing methods are appropriate to meet the objectives of this work plan, methods will be chosen in consultation with DTSC and DOI before implementation.

2.4.1 Borehole Development and Geophysical Logging

Immediately following drilling activities, each borehole drilled into bedrock will be developed to remove drilling fluids from the borehole and obtain an estimate of borehole capacity. Borehole development will be accomplished by pumping. During development pumping, temperature, pH, specific conductance, oxidation-reduction potential (ORP)[2], and turbidity will be measured using field instruments. In addition, groundwater samples for Cr(VI) and specific conductance analysis by the Interim Measures 3 laboratory will be collected during borehole development. Because the bedrock portion of the borehole will be uncased, at least initially, to facilitate geophysical logging as described below, mechanical surging of the borehole is not preferred; however, if mechanical surging is determined necessary, the borehole condition must be evaluated to prevent the loss of borehole or tools. If determined necessary, a temporary PVC screen of appropriate diameter may be installed across the entire bedrock portion of the well to maintain borehole integrity during mechanical surging with the understanding that it may not be retrievable if the borehole collapses on the screen. Should the borehole not produce sufficient groundwater recharge, water (either potable or from the river) may be added to the borehole to facilitate pumping for removal of fines.

For purpose of this investigation, the borehole will be considered developed once groundwater that exhibits water quality measurements indicative of bedrock conditions

[1] VOCs was added as a constituent of potential concern subsequent to the submittal of the *Draft RCRA Facility Investigation/Remedial Investigation, Soil Investigation Work Plan, Part A* (CH2M HILL, 2006).

[2] To collect accurate ORP measurements, the ORP instrument must be used within an in-line flow cell with constant flux such that the instrument has time to stabilize. If the borehole does not yield enough water to maintain flow for the requisite time, ORP data may not be collected.

(e.g., elevated specific conductance) as compared to the water used for drilling. The volume of water lost to the formation during drilling will also be considered when evaluating the completion of the borehole development process.

Following borehole development, a downhole geophysical survey will be conducted in each borehole drilled into the bedrock to assist in hydrogeologic characterization. The following geophysical logs will be performed:

- Caliper log
- Natural gamma ray log
- Electric logs (spontaneous potential, short and long normal)
- Acoustic televiewer log
- Video log

These types of geophysical logs provide information about formation mineralogy, fracturing (quantity, aperture, and orientation), and competence and can be used for hydrogeologic interpretation and water quality characterization. Geophysical logs will not be run in boreholes terminated in the alluvium.

2.4.2 Permeability Testing

Based on data collected during borehole development and geophysical logging, relative permeability testing may be conducted to obtain a flow profile in each borehole drilled into the bedrock, as applicable. The purpose of this testing will be to qualitatively assess the relative permeability of individual fractures or zones of fractures within the borehole. Upon completion of borehole development, PG&E will consult with DTSC and DOI to evaluate if the borehole yield is high enough to effectively conduct permeability testing, and if so, which method should be chosen. Results of the relative permeability testing will aid in the determination of whether additional hydraulic testing, as described in Section 2.4.3, is applicable.

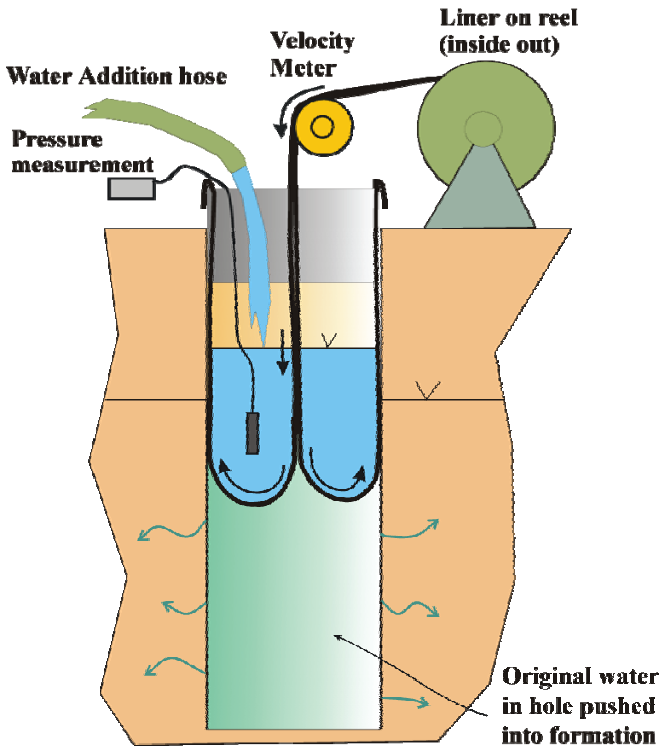
The effectiveness of permeability testing methods is dependent on the yield of the interval tested. Four different permeability testing methods are proposed in the following subsections, in no particular order. Each of these has advantages and disadvantages and different limitations. One method will be chosen based on observations during drilling, borehole development, and geophysical testing.

2.4.2.1 FLUTe™ Hydraulic Conductivity Profiler

This method involves the installation of a flexible membrane liner manufactured by Flexible Liner Underground Technologies, LLC (FLUTe™). A recently developed technique, the FLUTe™ Hydraulic Conductivity Profiler, allows identification of permeable zones within the borehole during installation of the liner. The basis of the technique is that, as the sealing liner descends, it displaces the borehole water into the formation. The description and schematic of this system is presented below from the company's web site (http://flut.com/meth_14.htm):

> As the everting blank liner is installed, the water in the borehole is forced from the hole into the formation by whatever flow paths are available (e.g., fractures). The liner descent rate is controlled by the rate at which water can flow from the hole via

those paths. The everting liner is somewhat like the perfectly fitting piston sliding down the hole, except the liner doesn't slide in the hole, it grows in length at the bottom end of the dilated liner at the "eversion point" as we call it. As the liner everts, it covers the flow paths sequentially. Each time that the liner covers a flow path, the transmissivity of the hole beneath the liner is decreased and the total flow rate out of the hole is reduced. This reduction in flow rate causes a reduction in the descent rate of the liner. The roller at the wellhead measures the liner velocity and the pressure gauge measures the excess head in the liner which is driving the liner down the hole.



When the liner begins its descent into the hole, all of the flow paths are open and the descent rate is highest. As the liner sequentially covers those flow paths, the liner descent rate decreases to produce a monotonically decreasing velocity with depth in the hole.

As changes in velocity are logged, one can determine the location of the flow path in the hole, and the magnitude of the velocity change is the measure of the flow that was occurring in that flow path before it was covered by the everting liner. From the velocity profile, one can calculate a conductivity profile for the hole.

This technique is especially well-suited to situations where flow from the hole is often dominated by a few, relatively free-flowing fractures. However, if the permeability of the bedrock is uniformly low, this technique may not be sensitive enough to identify very small changes in flow at each small fracture zone, and the time required for the test can be excessive. Typical bedrock wells at Topock require days to weeks for water levels to return to normal after sampling. If the new bedrock wells have low permeability similar to the existing wells, the everting liner permeability measurements could require several days to complete because the liner must displace all the water in the borehole. Supplemental information about this method is provided in Appendix D.

2.4.2.2 Borehole Dilution Hydrophysical Testing

Borehole dilution hydrophysical testing can be used to identify intervals of groundwater inflow and outflow as well as vertical flow components within a well or borehole with a high level of precision. Hydrophysical testing can be applied under ambient or pumping conditions and in a wide range of groundwater flow conditions, including very low-flow conditions that may be below the practical application range of other methods.

Each test is typically performed by replacing the groundwater fluid column in the monitoring well with deionized (DI) water. When testing ambient flow conditions, care is taken to maintain the static water level in the monitoring well during DI water emplacement, which prevents 'artificial' inflow or outflow in the borehole; conversely, when testing induced flow conditions, the water level is maintained at a level below the static level during DI water emplacement. Once the DI emplacement is complete, the movement of formation groundwater back into the well is monitored over time by measuring changes in electrical conductance in the borehole fluid column. The DI water has very low electrical conductivity. As formation water moves into the borehole from permeable fractures, the electrical conductivity near those fractures increases. The locations in the borehole and the rates at which the DI water is diluted by formation groundwater is used to determine several physical groundwater parameters such as groundwater flow velocity and hydraulic conductivity. These parameters reflect aquifer hydraulic conditions in the immediate vicinity of the borehole. Supplemental information about this method is provided in Appendix D.

2.4.2.3 Electromagnetic Flow Logging

The borehole electromagnetic (EM) flow meter is a downhole instrument used to measure the vertical distribution of groundwater flow to a well or borehole. As water flows through a magnetic field created within the instrument, a voltage is induced and measured. This measured voltage is proportional to the average velocity of the water within the well. In the absence of ambient vertical flow in a well or borehole, as is likely the case in the bedrock at the site, an upward vertical gradient must be induced by pumping from the top of the fluid column. Flow measurements are then collected at a designated interval from the bottom to the top of the fluid column and analyzed to provide an additive vertical profile of flow. The EM flow meter is most precise when measuring flow rates greater than 0.1 foot per minute.

2.4.2.4 Packer Testing

Packer testing can be performed on individual fractures or groups of fractures identified during bedrock core analysis and geophysical logging. A fracture or fracture group of interest is isolated by positioning an inflatable packer above and below, and pumping from the isolated zone to directly measure yield. During pumping, pressure conditions above, below, and between the packers (i.e., the pumping interval) are monitored to evaluate the degree of segregation and hydraulic response in the pumping interval. Packer testing is most appropriately applied in boreholes with smooth, competent walls (i.e., those that have been cased or cored), so that a competent hydraulic seal can be established with the packer;

however, the method is not effective in very low-flow (less than approximately 0.5 gallon per minute [gpm]) hydraulic conditions.

2.4.3 Hydraulic Testing

Hydraulic testing may be required to characterize the hydraulics of the entire bedrock borehole and evaluate the degree of hydraulic communication with other wells. The type of tests that may be conducted will depend on bedrock yield. The decision to conduct hydraulic testing will be based on data obtained during borehole drilling, geophysical logging, borehole development, and permeability testing, and will be made in consultation with DTSC and DOI.

2.4.3.1 Constant Rate Extraction Testing

If the boreholes can sustain constant pumping rates of 1 gpm or more, constant rate extraction testing may be appropriate to evaluate the hydraulic properties of the bedrock and the degree of hydraulic communication with other bedrock wells and Alluvial Aquifer wells. Results of borehole development and permeability testing will aid in planning the pumping location, rate, and duration of the test such that primary bedrock fractures are drained and influence in other bedrock and alluvial observation wells may be observed. DTSC will be consulted following the collection of permeability testing data to determine if constant rate extraction testing is required to meet the objectives of this work plan.

2.4.3.2 Slug Testing

If the boreholes do not produce groundwater recharge adequate for constant-rate extraction testing, slug testing may be performed on an individual borehole. Slug testing requires a nearly instantaneous decrease or increase in pressure head within a well or borehole and the subsequent monitoring of pressure head recovery to ambient conditions. The analysis of pressure head recovery data provides an estimation of hydraulic conductivity and transmissivity for the tested well only.

2.4.4 Initial Bedrock Groundwater Characterization

Initial groundwater samples may be collected from the uncased bedrock boreholes to determine if multiple zones of different water quality are present. Data collected during geophysical logging and permeability/hydraulic testing will be used to identify discrete target sampling depths. Samples collected will be analyzed for the parameters listed in Table 2.

The tool used for initial groundwater sample collection will depend on the number of target zones identified, and if performed, the method of permeability testing. By choosing the sample collection method based on the equipment used for permeability testing, samples can be collected during the same mobilization. If borehole capacity is determined to be exceptionally low, therefore precluding the need for permeability testing, or if primary zones of inflow are not identified during permeability testing, then depth-discrete groundwater samples may not be collected. In this case, a single initial groundwater sample will be collected from the borehole using the methods approved for the Topock sitewide Groundwater and Surface Water Monitoring Program (GMP).

Proposed depth-discrete groundwater sample collection methods are presented in the following subsections. PG&E will consult with DTSC and DOI to review lithologic and hydraulic data collected during previous phases of the investigation to evaluate if depth-discrete sampling is warranted, and if so, which sample collection method should be used.

2.4.4.1 Hydra-Sleeve™

The Hydra-Sleeve™ tool is proposed for initial groundwater sample collection if the FLUTe™ Hydraulic Conductivity Profiler or EM flow meters are used for permeability testing. The Hydra-Sleeve™ tool has been used successfully at the Topock site for previous sample collection tasks. Supplemental information about this sampling technique is provided in Appendix D.

The Hydra-Sleeve™ sampling tool is used to collect depth-discrete groundwater samples by "coring" a target portion of the well fluid column. The tool is especially applicable in low-yield environments, is designed to minimize the blending of fluid from different vertical zones, and does not draw water in from outside the well screen. To collect the sample, a weighted disposable polyethylene sleeve is lowered to the target depth and then raised to collect the "core" of the fluid column.

2.4.4.2 Wireline Grab Sampler

The wireline grab sampler is proposed for initial groundwater sample collection if borehole dilution hydrophysical testing is performed to characterize borehole permeability. The wireline used for the geophysical logging and hydrophysical testing is the same used to control the wireline grab sampler. This tool has been used successfully to collect depth-discrete groundwater samples for metals analysis at a different PG&E site.

The wireline grab sampler is similar in concept to the Hydra-Sleeve™ sampling tool but is different in that it can be opened and closed using controls at the wellhead. This tool is sealed at surface pressure and lowered to the target depth on a wireline. Once at depth, the sample chamber is opened and groundwater is drawn into the sample chamber via differential pressure. Once full, the sampler is again sealed and raised to the surface.

2.4.4.3 Wireline Straddle Packer

Wireline straddle packer testing may be performed to characterize the permeability of specific intervals of the bedrock borehole. Given that this method of hydraulic testing requires groundwater extraction from a hydraulically segregated portion of the borehole, a groundwater sample from the tested interval can easily be collected once hydraulic tests are complete. Groundwater is extracted from the target interval using an electric submersible pump, which is the same tool used to collect groundwater samples as part of the Topock GMP. As mentioned in Section 2.4.2.4, this tool is most applicable in higher flow environments.

2.5 Monitoring Well Installation

The following subsections describe the potential well designs and construction materials for perched groundwater and bedrock monitoring wells. Figure 5 presents the generalized specifications and schematics for proposed well construction. Consistent with existing wells at the site, the new perched groundwater monitoring wells will be identified by the well number (e.g., MW-99) followed by the total depth of the well, rounded to the nearest 5 feet bgs. The bedrock monitoring wells will be identified by the well number, followed by BR, BR1, BR2, BR3, and so on, as applicable for single- or multiple-completion well construction (e.g., MW-99BR, MW-99BR1, MW-99BR2).

2.5.1 Perched/Shallow Groundwater Monitoring Well Design and Specifications

Single-screen monitoring well(s) will be constructed at primary Sites A and B to monitor the uppermost bedrock/deepest alluvial interval. If the bedrock interface is above the water table, this zone may only temporarily contain groundwater that becomes perched on top of the bedrock during recharge events. As discussed in Section 1.2.2, perched water beneath East Ravine may occur at the interface of bedrock and the alluvium, if the bedrock is not sufficiently permeable, or at the interface of permeable bedrock (e.g., highly fractured) and less permeable bedrock. Additionally, groundwater may perch above a thickness of weathered Miocene conglomerate, if present above bedrock. If weathered Miocene Conglomerate is present above the bedrock, well(s) will not be constructed in a manor such that an artificial conduit from above the weathered material into the bedrock is created. Perched/shallow groundwater monitoring wells may not be installed if the elevation of the perched zone is above that of the former impoundments. Before the installation of perched/shallow groundwater monitoring well(s), PG&E will consult with DTSC and DOI regarding well design.

If the top of bedrock is below the elevation of the groundwater table, the screened interval of the shallow zone wells will be determined based on a review of the lithologic logs and other information from the nearby deep boring. The objective will be to screen the most permeable zone in the interval near the bedrock interface. Depending on the character of the bedrock and overlying alluvium, the perched/shallow zone well screen may be in the uppermost bedrock, deepest alluvium, or possibly across the interface between bedrock and alluvium.

Perched/shallow groundwater monitoring wells will be installed using materials and procedures described in the following subsections and illustrated in Figure 5.

2.5.1.1 Well Casing and Screen

The perched/shallow groundwater monitoring well will be constructed with 2-inch-diameter Schedule 40 PVC casing and of factory-slotted well screen. Casing requirements are as follows:

- Casing will be new, unused, and decontaminated.
- Glue will not be used to join casing, and casings will be joined only with compatible threads that will not interfere with the planned use of the well.
- The PVC casing will conform to ASTM International (ASTM) Standard F 480-88A or the National Sanitation Foundation Standard 14 (Plastic Pipe System).
- The casings will be straight and plumb.
- Centralizers will be installed to keep the well centered in the borehole.

Well screen requirements are as follows:

- Requirements that apply to casing also apply to well screen, except for strength requirements.
- Well screens will be factory-slotted, with a size of 0.020 inch.

2.5.1.2 Borehole Completion Materials

The annular space will be filled with a filter pack, a bentonite seal, or grout between the well casing and the borehole wall.

Filter Pack. The filter pack will consist of No. 3 silica sand (or equivalent) (consistent with other monitoring wells completed in the Alluvial Aquifer) and will extend from the bottom of the hole to approximately 2 feet above the top of the well screen. The top of the sand pack will be sounded to verify its depth during placement. A minimum 1-foot-thick layer of fine sand will be placed above the No. 3 sand filter pack to minimize the potential for the bentonite slurry (seal) material to invade the filter pack adjacent to the top of the well screen during well construction.

The contractor will record the volume of filter pack emplaced in the well. Water (potable or from the river) may be used, with the approval of the field geologist, to emplace the filter pack, as long as no contaminants are introduced to the subsurface. The volume of water added to the borehole will be documented and considered along with the volume of water lost to the formation during drilling to be removed during development.

Annular Seals. The bentonite seal requirements are as follows:

- The bentonite seal will consist of at least 2 feet of bentonite between the filter pack and the casing grout.
- Only 100 percent sodium bentonite will be used.
- Bentonite chips or pellets will be hydrated with potable water if the transition seal is not below the water table; otherwise bentonite slurry (approximately 1 gallon water for 2 pounds bentonite) will be used.

A surface seal will be installed in the uppermost portion constructed wells. The proposed method of grouting the wells is designed to ensure that the wells can be abandoned in place and will not need to be drilled out for abandonment. The grout requirements for the surface seal are as follows:

- The casing grout will extend a minimum of 20 feet bgs, as practicable[3].
- The grout will be a cement mixture in the following proportions: (a) 94 pounds of neat Type I or Type II Portland or American Petroleum Institute Class A cement; (b) not more than 4 pounds of 100 percent sodium bentonite powder; and (c) not more than 8 gallons of water.

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[3] In the event a well is designed such that the screened interval is exceptionally shallow and 20 feet of surface seal is not technically practicable, the surface seal depth will be maximized given the depth of the screen.

- The grout for the surface seal will be pumped into place using tremie pipe in one continuous operation.

The expected volume of each ingredient in the grout mixture will be precalculated and documented.

2.5.2 Bedrock Monitoring Well Design and Specifications

Data collected during drilling and subsequent bedrock characterization testing will be used to evaluate if a well screen or screens are required in the bedrock boreholes. Screen installation for an open bedrock borehole, should it be determined necessary, will be conducted during a mobilization subsequent to borehole drilling. To ensure that future water quality and water level data collected at these locations are appropriate to meet the objectives of this work plan, final well design will be chosen in consultation with DTSC before implementation.

Due to the diameter of a PQ-size core borehole, which is approximately 4.8 inches and the largest core size being considered for this investigation, a conventional monitoring well, as defined above for the alluvial monitoring wells, cannot be properly constructed. Drilling methods that would be required to enlarge the bedrock borehole diameter (air rotary or mud rotary) are not preferred. Health and safety risks associated with Cr(VI) in the aerosol form preclude the use of air rotary drilling methods at the site. Using mud rotary drilling methods would require the use of bentonite-based drilling mud. The relatively "low impact" development methods required to maintain the integrity of the uncased borehole may not effectively remove bentonite mud from the formation and skew the hydraulic characterization of the bedrock interval. It is therefore proposed that alternative methods be used if monitoring wells are constructed within the open rock boreholes.

The preferred materials and procedures for the installation of single- and multiple-screen monitoring wells within the bedrock boreholes are presented in the following subsections; however, alternate well designs and installation procedures may be used as determined necessary based on the analysis of data collected during drilling and subsequent testing. Each well screen will be of suitable construction to facilitate water level monitoring with data logging pressure transducers. If it is determined that more than three zones within one borehole are required for adequate characterization, additional boreholes may be required due to space constraints within the well.

2.5.2.1 Single-Completion Bedrock Monitoring Well

In the event a single zone is chosen for groundwater monitoring and requires segregation from the remainder of the borehole, a Schedule 40 PVC screen of appropriate length will be installed. A filter pack will not be installed around the screen. The screened interval will be hydraulically separated from the remainder of the borehole with pre-packed bentonite packers. The packers consist of mesh socks filled with dry bentonite that are installed on sections of blank PVC casing above and below the screen before installation in the borehole. As the bentonite hydrates it swells and extrudes through the mesh, sealing off the monitoring interval in the borehole.

2.5.2.2 Multiple-Completion Bedrock Monitoring Well

The decision to monitor multiple zones within the bedrock will be based on lithologic, hydraulic, and chemical characterization data collected during a previous mobilization. The Solinst® CMT Multilevel System is proposed to establish up to seven discrete monitoring intervals.

The CMT (Continuous Multilevel Tubing) system utilizes a continuous length of multichannel polyethylene tubing that can be installed to facilitate groundwater sample collection from target depths identified during bedrock characterization. Individual monitoring zones are hydraulically separated by bentonite or inflatable packers. Groundwater samples are collected using small inertial pumps within each channel of the CMT assembly. The CMT system is ideal for depth-specific characterization while only using a single borehole.

2.5.3 Surface Completion

Surface completions for constructed wells will consist of a subsurface well vault, unless access and siting conditions allow an above-ground, steel, locking wellhead monument. Figure 5 provides a schematic diagram of well construction, including surface completion. At the direction of the land owner, the subsurface well vault will be set in a concrete pad up to 4-foot by 4-foot by 4-inch-thick and equipped with an appropriate cover or lid. Wells inside the vault will be equipped with water-tight well seals to prevent surface water from entering the wells if the vaults fill with water. The wells will be secured as soon as possible after drilling by using corrosion-resistant locks. For aboveground completions, the wellhead monument completion will be placed over the casing and cap and seated in a concrete pad up to 4-foot by 4-foot by 4-inch-thick. The ground surface will be free of vegetation and scoured to a depth of 4 inches before setting the concrete pad. The concrete pad will be sloped away from the well sleeve. The identity of the well will be permanently marked on the casing cap and the protective sleeve. In addition, metal tags will be attached to each of the well casings to identify the specific wells within each well monument.

2.5.4 Well Development

Perched/shallow zone monitoring wells that do not encounter groundwater will not be developed. If groundwater is encountered, development of perched/shallow wells will be accomplished through a combination of surging, bailing, and possibly pumping depending on the yield of the wells.

Boreholes installed into bedrock will be developed to remove drilling fluids immediately once drilling is complete, as discussed in Section 2.4.1. Although single- or multiple-screen monitoring wells that may be installed in the bedrock will not be installed using fluids and will not be constructed with a filter pack, each depth-discrete well will be developed to remove groundwater from different aquifer zones mixed during installation. Groundwater samples for Cr(VI) and specific conductance analysis by the interim measure (IM) No. 3 onsite laboratory will be collected during additional well development purge events.

2.5.5 Well Survey and Completion Diagram

Following surface completion, the new monitoring wells will be surveyed for well datum elevation and location. In addition to the lithologic core logs to be prepared for the borings, a well completion diagram will be prepared for each monitoring well installed. The diagrams include well identification; drilling method and boring depth; installation date; elevation of ground surface and well measuring point; and borehole diameter, the length and description of the well screen, well casing, conductor casing, filter pack, bentonite seal, casing grout, and any back-filled material.

2.6 Groundwater Sample Collection

Groundwater sample collection from wells screened in the alluvium/shallow bedrock will be dependent on the occurrence of perched/shallow groundwater at the bedrock-alluvium interface. One groundwater sample will be collected from each perched/shallow well containing groundwater within 30 days of installation. Groundwater samples will be collected in accordance with methods and SOPs used for the Topock GMP (CH2M HILL, 2005 and Appendix C). Samples collected from the perched groundwater will be analyzed as defined on Table 2, assuming sufficient volume of water is available for all parameters.

Initial groundwater samples will be collected from the bedrock monitoring intervals once the wells have reached hydraulic equilibrium following initial groundwater characterization, testing, and well construction/development activities. The wells will be purged and sampled using the casing volume method (CH2M HILL, 2005 and Appendix C). Purge rates will be selected to obtain representative groundwater samples from the aquifer zone. A second, confirmation sampling will be conducted approximately 4 weeks after the initial well sampling.

Consistent with the Topock Field Procedures Manual (CH2M HILL, 2005 and Appendix C), the samples for total chromium (Cr[T]), metals, and cations will be filtered in the field. The Cr(VI) samples will be filtered in the laboratory before analysis. One field duplicate sample is required every 10 samples, at a minimum of one per event. For the initial groundwater sampling, field duplicates will be collected at one well for all analytes (as allowed by well yield). One equipment blank should be collected per day, per crew, per piece of nondedicated equipment.

2.7 Site Restoration Activity

Proposed drilling Sites B, C, E, and F (including alternate locations) are located on HNWR property managed by the U.S. Fish and Wildlife Service (USFWS) and drilling Sites D and G are located on PG&E property (Figure 2). Portions of Site A are located on both HNWR and PG&E property. With the exception of Site E, all areas have been previously disturbed and contain limited to no vegetation. Site E spans an area that is partially disturbed and partially in a ravine/wash, which contains sparse vegetation. Given the sparse vegetation in the proposed work areas, no formal site restoration and revegetation plan is anticipated. Temporary signage or other effects that may be erected during well construction will be removed upon completion of drilling and well installation activities. After well installation at the sites located on HNWR/USFWS property, PG&E will work with the agencies to implement potential restoration at the drilling sites (if grading is required) and to minimize future disturbance from post-installation groundwater monitoring activities.

3.0 Waste Management and Decontamination

The project approach for investigation derived waste management and equipment decontamination is presented in the following subsections.

3.1 Investigation-derived Waste Management

Several types of waste materials will be generated during the drilling, development, and sampling of the exploration borings and monitoring wells. IDW materials that will be generated include groundwater, drill cuttings, and incidental trash.

Water generated during drilling, development, and sampling activities will be collected in bins or portable storage tanks temporarily located in staging areas near the drilling sites, or at the PG&E Topock Compressor Station as needed (Figure 2). Secondary containment will be set up at the drilling area for the portable storage tanks or bins. Water generated from the monitoring well installations will be processed at the IM No. 3 treatment plant or transported to a PG&E-contracted offsite disposal facility.

Drill cuttings include the fragments of rock and soil that are removed to create the borehole. The cuttings will be contained in lined roll-off bins at the staging areas during the drilling and sampling activities. After sampling and characterization, the cuttings bins will be removed from the staging areas. It is estimated that the soil IDW bins temporarily stored in the staging areas will not remain longer than 45 days. Cuttings will be transported to a permitted offsite disposal facility; alternatively, if cuttings are shown to free from contaminants, cuttings may be disposed of onsite if acceptable to the property owner and in compliance with applicable laws and regulations.

Incidental trash will be collected at the end of each drilling shift and hauled from the drill site to an appropriate offsite disposal facility.

3.2 Equipment Decontamination

The backs of the drilling rigs and down-hole drilling tools will be decontaminated before arrival at the site and subsequent to finishing the well installations at each site. Decontamination will be accomplished by steam-cleaning the core barrel, drill stem, drive casing, and back of the drilling rig. The pre- and post-mobilization steam-cleaning will be conducted on a temporary decontamination pad (lined with plastic sheeting) located on PG&E compressor station property (Figure 2). Rinsate from the decontamination operation will be collected on the containment pad and transferred to the cuttings bin or purge water tanks. The decontamination rinsate will be managed along with the cuttings or purge water.

4.0 Approvals and Authorizations

This section presents the anticipated approvals required to implement this work plan, as well as the details pertaining to the various biological and cultural considerations.

4.1 Anticipated Approvals

Implementation of work plan activities will require prior approval from DTSC and the DOI pursuant to their authority under RCRA and CERCLA, respectively. Anticipated approvals and authorizations for implementation of the groundwater investigation outlined in this work plan are listed on Table 3.

Portions of the proposed activities are located on the HNWR, which is managed by the USFWS. The DOI is the parent agency of the USFWS; the anticipated approval mechanism is an approval letter from the DOI. It is expected that the DOI's approval letter will address CERCLA approval, and will also address conditions imposed to comply with Section 7 of the Endangered Species Act (ESA) and Section 106 of the National Historic Preservation Act (NHPA).

As discussed further in Section 4.2 (Biological Evaluation) below, the proposed work plan activities will be conducted in a manner consistent with the Programmatic Biological Assessment (PBA) (CH2M HILL, 2007d), and therefore in compliance with ESA requirements. Compliance with Section 106 of the NHPA is expected to involve a minimum 30-day consultation with local Native American tribes followed by a minimum 30-day consultation with the State Historic Preservation Office (SHPO).

Approval from the DTSC is subject to compliance with the California Environmental Quality Act (CEQA). It is anticipated that the subject activities qualify for an exemption from CEQA, pursuant to Section 15061 of the CEQA Guidelines.

Portions of the work plan activities are within the jurisdiction of the California Department of Fish and Game (CDFG), pursuant to Section 1600 et seq. of the Fish and Game Code. Compliance with Section 1600 requirements is provided via the existing CDFG Streambed Alteration Agreement No. 1600-2005—0140-R6, as amended in January 2007.

The proposed work plan activities are in proximity to Interstate I-40, but outside of the right-of-way (ROW) maintained by the California Department of Transportation (Caltrans). No Caltrans approval is required; however, adjustment to the planned location of project facilities should be reevaluated for proximity to the Caltrans ROW.

Pipeline infrastructure owned and/or maintained by private entities is located at and near the project site, approximate locations of which are shown on Figure 2. Before field work, the precise ROW of any nearby pipelines will be determined and coordination will occur as needed with the affected pipeline company to obtain prior approval and comply with applicable requirements. In addition, before implementation of the subject activities, Underground Service Alert notifications will be made so that utility companies can locate and mark the locations of their underground facilities.

Before drilling activity, CERCLA exemption to the well permit requirements of the County of San Bernardino will be verified.

4.2 Biological Evaluation

The previously completed PBA (CH2M HILL, 2007d) and associated ESA Section 7 consultation addressed a variety of PG&E Topock remedial and investigative actions at the project site, including those identified in this work plan. The PBA provides programmatic coverage of remedial and investigative actions up to the final remedy (expected by 2012) and avoids the need for project-specific consultations under the federal ESA. Groundwater characterization activities, such as those proposed at the East Ravine, are addressed in Section 3.3.1 of the PBA (CH2M HILL, 2007d) as a Category 1 activity (i.e., well installation, maintenance, and operation). Applicable, measures are identified in the PBA to offset potential impacts resulting from this category of activity.

The purpose of this biological evaluation is to outline the proposed groundwater characterization activities at the East Ravine as they relate to federally listed species and to determine if the actions are within the context and boundaries of the PBA, as requested by the DOI Bureau of Land Management (BLM). To achieve this purpose, this section discusses project timing, project location and habitat sensitivity, habitat loss, conservation measures, listed species determinations, and conclusions.

The federally listed species being considered and evaluated include the southwestern willow flycatcher (SWFL—*Empidonax traillii extimus*), Yuma clapper rail (*Rallus longirostris yumanensis*), Mojave desert tortoise (*Gopherus agassizii*), bonytail chub (*Gila elegans*), and razorback sucker (*Xyrauchen texanus*).

4.2.1 Project Timing

The proposed work plan activities are estimated to commence in December 2008. The precise start date is contingent upon receipt of necessary approvals and authorizations as discussed in Section 4.1. Because of the proximity of contingent well Site E (including alternate locations) to potentially sensitive avian habitat, drilling activity in this area may need to occur outside of the bird nesting season, defined as March 15 to September 30 in the PBA. Alternatively, construction activity at contingent well Site E may be allowed to occur during this time period, subject to appropriate conservation measures described below in Section 4.2.4 of this work plan (e.g., nesting bird surveys and establishment of sufficient buffers).

Contingent well Sites D and G (Figure 2) are located within PG&E's compressor station property, and are sufficiently upland from the sensitive riparian habitat along the Colorado River such that no direct or indirect effects to avian species would result. Similarly, primary well Sites A (partially on PG&E property) and B, and contingent well Sites C and F are located over 200 feet from sensitive riparian habitat identified in the PBA and therefore are not expected to be subject to the nesting bird restrictions established in the PBA.

4.2.2 Project Location and Habitat Sensitivity

Contingent well Sites D and G are located within the property boundary of the PG&E compressor station. This industrialized area is located upland from the Colorado River floodplain and does not include sensitive biological habitat. Well Sites A[4], B, C, E, and F are located on the HNWR several hundred feet upland of the Colorado River floodplain. Project activity at these sites will be limited to the existing roadways and immediately adjacent areas. Well Site E (including alternative sites) is within 200 feet of the Colorado River floodplain, including potentially sensitive avian habitat and designated critical habitat for the bonytail chub.

4.2.3 Habitat Loss

With the exception of a portion of contingent well Site E, habitat loss is not anticipated to occur during well installation activities; these sites are primarily within or adjacent to existing access roads. Well installation activities at Site E may require limited vegetation removal (less than 0.25 acre), but is expected to be sited primarily within or adjacent to existing access roads. Installation activity at well Site E (including alternative sites) could result in floodplain habitat loss, defined as “the removal of trees and perennial shrubs” in the PBA. However, the maximum total habitat loss resulting from the work plan activities is estimated to be less than 0.25 acre. Therefore, the proposed work plan activities described herein would conform to the cumulative limits of 2.5 acres of floodplain habitat loss and 3.0 acres of upland habitat loss prescribed in the PBA. Additional conservation measures applicable to the work plan activities are described below.

4.2.4 Conservation Measures

The work plan activities related to contingent well Site E locations would conform to the applicable conservation measures specified for the SWFL, including minimizing habitat loss. Construction activity at contingent well Site E may be conducted outside of the bird nesting season to minimize impacts to potentially sensitive riparian habitat. If construction activity at well Site E occurs during the bird nesting season, a preconstruction survey for nesting birds will be conducted and construction activity within 200 feet of active nesting areas would be prohibited in accordance with the measures established in the PBA. Well Sites A through D, and F through G are located sufficiently upland from the Colorado River floodplain (i.e., over 200 feet) to avoid potential impacts to riparian areas.

Groundwater sampling at the wells and other well operation and maintenance activities subsequent to construction may be subject to the modified floodplain sampling procedures referenced in the PBA. These procedures are in effect during the SWFL nesting season (defined as May 1 through September 30 in the PBA) and may be applicable to access and sampling at contingent well Site E. Due to the distance from sensitive riparian habitat on the Colorado River floodplain, well Sites A through D, or F though G would not be subject to these modified procedures.

Implementation of the work plan activities will also be subject to the applicable general management measures provided for in the PBA. This is expected to include designation of a field contact representative (FCR) responsible for overseeing compliance with applicable

[4] Depending on the final location of primary Well Site A, the well could be either on PG&E or HNWR property.

mitigation measures, construction awareness training, and preparation of a construction completion report that includes a quantification of impacted habitat.

4.2.5 Listed Species Determinations

Southwestern willow flycatcher. Through application of the conservation and management measures referenced above and described in detail in the PBA, the potential direct or indirect effects of the proposed work plan activities to the SWFL are expected to be either insignificant or discountable. A determination of "may affect, but not likely to adversely affect" is concluded for this species. This determination is within the context of the PBA.

Yuma clapper rail. Prior surveys conducted at the project site and documented by the PBA have not indicated the presence of Yuma clapper rail in the vicinity of the proposed work plan activities. The application of conservation and management measures referenced above would serve to further limit the potential direct or indirect effects to the Yuma clapper rail, which are expected to be either insignificant or discountable. A determination of "may affect, but not likely to adversely affect" is concluded for this species. This determination is within the context of the PBA.

Mojave desert tortoise. This action will have no direct effect upon this species. The USFWS protocol surveys that were performed in 2004, 2005, 2006, and 2007 resulted in no recent evidence of species presence within the Area of Potential Effect (APE). Therefore, any potential direct effects will be avoided. This determination is within the context of the PBA.

Razorback sucker. This action will have no effect upon this species. The project will not occur within the Colorado River or 100-year floodplain as delineated in the PBA. Therefore, potential direct and indirect effects to this species will be avoided. This determination is within the context of the PBA.

Bonytail chub. This action will have no effect upon this species. The work plan activities will be proximate to, but will not occur within the designated critical habitat for this species, which is coincident with the Colorado River 100-year floodplain. No direct or indirect impacts to critical habitat or the bonytail chub would result from implementation of the work plan activities. This determination is within the context of the PBA.

4.2.6 Conclusion

The activities proposed in this work plan are within the context and boundaries outlined in the PBA, including the general management measures, mitigation measures, and BLM Lake Havasu Field Office. Therefore, this action will be compliant with the federal ESA provided that applicable mitigation measures identified in the PBA are implemented. Additional consultation with the USFWS is not required.

4.3 Archaeological Surveys, Reviews, and Consultations

The area subject to activities described in this work plan was included in an archaeological survey of the APE (Applied Earthworks, 2007). Only one significant archaeological resource was found in this area; a small portion of historic Route 66 (CA-SBR-2910H) is located along an existing gas pipeline (Line 300B) and road alignments in this area. Contingency Site E and its two alternate sites (Alt-1 and Alt-2) are in proximity to this section of Route 66. This portion of Route 66 has been greatly disturbed by the construction of Line 300B. A recent examination of this area indicated that only a very small portion of the original Route 66 pavement is intact. Although deteriorated, the original Route 66 guardrail is still in place at a majority of this location. The narrow roadbed and guardrail at this portion of Route 66 provides this National Register of Historic Places (NRHP) property with integrity of location and feel. Because of the past disturbance to this portion of the Route 66 roadbed, restrictions on temporary vehicle use are not deemed necessary. The general configuration and historic guardrail at the section of Route 66 will be protected so as to not impact the integrity of location and feel of this NRHP historic property.

An additional resource, an unrecorded tin can scatter of approximately 30 to 40 cans and other materials, was recently noted in a small ravine southeast of Site E Alt-1 and within the northern portion of Site E. The oldest artifacts of this scatter appear to be from the 1940s and 1950s.

Sites A, B, C, C Alt-1, D, E Alt-1, E Alt-2, F, and G present no potential to impact either of the two historic resources noted above. Both of the historic sites will be protected from work activities and will be monitored during the course of work. The PG&E FCR will be responsible for providing archaeological sensitivity training to the workers implementing this work plan and for ensuring compliance with all applicable archaeological measures during drilling activities.

Contingency drilling at Site E will occur only if warranted by the results of groundwater characterization at the proposed primary Sites A and B (see Section 2.1.2). In the event that drilling at Site E becomes necessary, the unrecorded tin-can scatter will be recorded and evaluated in accordance with NRHP criteria. As noted in Table 1, Site E Alt-1 or Alt-2 may be implemented if Site E is not approved.

The Topock site and adjacent lands are contained within a larger geographic area that is considered sacred by the Fort Mojave Indian Tribe and by other Native American tribes. In recognition of this, work activities will be conducted in a manner that recognizes and respects these resources and the spiritual values of the surrounding lands. PG&E understands that the environmental, cultural, and spiritual resources may not be physically perceptible. To this end, site orientation will stress that all site activities must be conducted in a respectful manner that is conscious of this context. In addition, PG&E will contact the Tribes, which have in the past expressed a desire for tribal monitors. In the event there is a desire to monitor this work, PG&E will make arrangements for monitoring of field activities, if acceptable to the landowner and if consistent with security and health and safety considerations.

5.0 Schedule and Reporting

The estimated project implementation schedule and approach to the reporting of findings are presented in the following subsections.

5.1 Project Schedule

Table 4 lists the estimated implementation schedule for the field and reporting activities for the East Ravine groundwater investigation. As detailed on Table 4, the primary field program at Sites A and B, not including the two initial groundwater sampling events, is estimated to require 5 weeks. Subsequent to the primary field program, the two initial groundwater sampling events will be conducted over an approximately 2-month period. The date and schedule for conducting the primary drilling, investigation, and reporting activities are subject to obtaining approvals and authorizations from DTSC, DOI, HNWR, and other agencies, as described in Section 4. Once all approvals and authorizations are obtained for the primary field program, a more detailed implementation schedule, which will include conference calls to discuss field data as it becomes available, will be provided to DTSC and DOI.

5.2 Reporting

Following completion of the primary investigation at Sites A and B, an interim results technical memorandum will be prepared to present the results and document the drilling, well installation, and initial groundwater sampling. The interim results technical memorandum will include: core logs for the borings, initial groundwater characterization data from first two sampling events, well construction logs, groundwater sampling data, validated analytical results, and an analytical data quality review. The analytical data quality review will summarize the independent review of the laboratory analytical data by project chemists to assess data quality and to identify deviations from analytical requirements. In addition, the memorandum will include a summary of geophysical logging, permeability testing, and hydraulic testing that may have been conducted. The technical memorandum will be submitted approximately 4 weeks after the completion of data validation of the second round of initial groundwater well sampling.

Following DTSC and DOI review of the interim results technical memorandum, the need for contingency well drilling will be assessed. DTSC has directed that it will be necessary to have results of groundwater samples collected during winter months (December through March) before making the final decision about the need for contingency wells. This requirement is based on the fact that the elevated chromium results in well MW-23 were observed only during sampling events in December and March. If contingency drilling is conducted, the final reporting schedule will be determined based on discussion with DTSC and DOI.

Following the initial sampling, the new wells will be incorporated, as appropriate, in the Topock GMP. Monitoring reports under this program are prepared under separate, routine reporting schedules.

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Tables

TABLE 1
Drilling and Well Installation Plan
Revised Work Plan for East Ravine Groundwater Investigation
PG&E Topock Compressor Station, Needles, California

Site ID	Ground Surface Elevation (feet msl)	Estimated Bedrock Depth (feet bgs)	Proposed Boring	Objective	Drilling Plan		Well Installation
					Target Depth [1] (feet bgs)	Method	
PRIMARY DRILLING SITES							
Site A	521	20	Vertical Boring #1	Exploratory Boring - Characterize bedrock groundwater conditions	115	Rotosonic / Rotary Rock Core	Well construction is to be determined based on borehole characterization data
			Vertical Boring #2	Assess perched/shallow water conditions	20	Rotosonic	Single-screen perched-zone monitoring well based on lithologic log
			Vertical Boring #3	Necessity of boring/objective is to be determined based on data from exploratory boring	TBD	TBD	TBD
Site B	510	20	Vertical Boring #1	Exploratory Boring - Characterize bedrock groundwater conditions	190	Rotosonic / Rotary Rock Core	Well construction is to be determined based on borehole characterization data
			Vertical Boring #2	Assess perched/shallow water conditions	20	Rotosonic	Single-screen perched-zone monitoring well based on lithologic log
			Vertical Boring #3	Necessity of boring/objective is to be determined based on data from exploratory boring	TBD	TBD	TBD
CONTINGENCY DRILLING SITES				**(Potential Objective)**			
Site C	525	15	Up to 3 Vertical Borings	Assess Chromium in groundwater east of East Ravine	TBD	TBD	TBD - based on data from Primary Characterization Sites
Site C - Alt	550	0		*pursue if Site C not feasible or approved*			
Site D	573	50	Up to 3 Vertical Borings	Assess Chromium in groundwater west of East Ravine	TBD	TBD	TBD - based on data from Primary Characterization Sites
Site E	502	0	Up to 3 Vertical Borings	Assess Chromium in groundwater along axis of East Ravine, down-wash of Primary Sites	TBD	TBD	TBD - based on data from Primary Characterization Sites
Site E - Alt-1	505	0		*pursue if Site E not feasible or approved*			
Site E - Alt-2	502	0		*pursue if Site E not feasible or approved*			
Site F	552	0	Up to 3 Vertical Borings	Assess Chromium in groundwater south of East Ravine	TBD	TBD	TBD - based on data from Primary Characterization Sites
Site G	538	30	Up to 3 Vertical Borings	Assess Chromium in groundwater northwest of East Ravine	TBD	TBD	TBD - based on data from Primary Characterization Sites

Notes:

(1) Target depths for contingency sites will be determined based on data collected from the primary characterization sites.
TBD = to be determined
bgs = below ground surface
msl = mean seal level

TABLE 2

Groundwater Sampling and Analysis Plan, Primary Well Locations

Revised Work Plan for East Ravine Groundwater Investigation

PG&E Topock Compressor Station, Needles, California

Analyte	Analytical Method	Standard Reporting Limit	Potential Number of Samples from Primary Well Locations
Initial Bedrock Groundwater Characterization - Open-hole (post-drilling) Grab Samples			
Hexavalent chromium	Method SW7199	0.2 μg/L	6
Dissolved total chromium (field filtered)	Method SW6010B	1 μg/L	6
Specific conductance	field instrument	NA	6
Oxidation reduction potential	field instrument	NA	6
Dissolved oxygen	field instrument	NA	6
pH	field instrument	NA	6
Temperature	field instrument	NA	6
Groundwater Samples from Installed Bedrock Monitoring Wells			
Hexavalent chromium	Method SW7199	0.2 μg/L	12
Dissolved total chromium (field filtered)	Method SW6010B	1 μg/L	12
Title 22 Metals	Methods SW6010B,SW6020A, SW7470A	various	12
VOC	Method SW8260B	various	12
Specific conductance	field instrument	NA	12
Oxidation reduction potential	field instrument	NA	12
Dissolved oxygen	field instrument	NA	12
pH	field instrument	NA	12
Temperature	field instrument	NA	12
Total dissolved solids	EPA 160.1	10 mg/L	12
Chloride, Sulfate, Nitrate	EPA 300.0	0.5 mg/L	12
Alkalinity	EPA 310.1	5 mg/L	12
Ammonia	EPA 350.2	0.5 mg/L	12
General minerals (Ca, Mg, K, Na) (dissolved)	Method SW6010B	1 mg/L	12
Iron (dissolved)	Method SW6010B	0.5 mg/L	12
Manganese (dissolved)	Method SW6010B	0.5 mg/L	12
Total Organic Carbon (TOC)	EPA 415.1/2	0.5 mg/L	12
Oxygen 18	CF-IRMS	NA	12
Deuterium	CF-IRMS	NA	12
Groundwater Samples from Perched/Shallow Monitoring Wells			
Hexavalent chromium	Method SW7199	0.2 μg/L	to be sampled when perched water present
Dissolved total chromium (field filtered)	Method SW6010B	1 μg/L	
VOC	Method SW8260B	various	
Oxidation reduction potential	field instrument	NA	
Dissolved oxygen	field instrument	NA	
pH	field instrument	NA	
Temperature	field instrument	NA	
Total dissolved solids	EPA 160.1	10 mg/L	
Chloride, Sulfate, Nitrate	EPA 300.0	0.5 mg/L	
Oxygen 18	CF-IRMS	NA	
Deuterium	CF-IRMS	NA	

NOTES:

Micrograms per liter (μg/L), milligrams per liter (mg/L)

One equipment blank to be collected per day, per crew, per nondedicated equipment.

Samples analyzed with Method SW6010B may also be analyzed with Methods SW6020A, EPA 200.7 and EPA 200.8.

Installed bedrock wells may be single completion or multi-level wells (assume 3 sample zones per well)

Continuous flow isotope ratio mass spectrometry (CF-IRMS). Not applicable (NA)

TABLE 3
Approvals and Authorizations for Drilling and Well Installation
Revised Work Plan for East Ravine Groundwater Investigation
PG&E Topock Compressor Station, Needles, California

Agency/Organization	Approvals and Authorizations
U. S. Department of Interior (DOI)/Havasu National Wildlife Refuge (HNWR)	Approval letter from DOI/HNWR anticipated. Approval subject to National Historic Preservation Act (NHPA) Section 106 and Endangered Species Act (ESA) Section 7 consultations (see below).
California Department of Toxic Substances Control (DTSC)	As state lead agency, approval letter from DTSC is required. California Environmental Quality Act (CEQA) compliance anticipated to occur via a Categorical Exemption.
California Department of Fish and Game	Project activities have been previously authorized by Streambed Alteration Agreement No. 1600-2005-0140-R6.
U. S. Bureau of Land Management	DOI lead with Section 7 ESA requirements. Guides work plan compliance within the scope of the Programmatic Biological Assessment (CH2M HILL, 2007) and conducts associated Section 7 consultation.
State Historic Preservation Office (SHPO)	U. S. Fish and Wildlife Service HNWR approval subject to NHPA Section 106 process involving a minimum 30-day Tribal consultation followed by a minimum 30-day SHPO consultation.
San Bernardino County	Compliance with substantive well drilling permit requirements.
Private Pipeline Companies	As needed, activities located in the right-of-way of any pipelines will be subject to prior coordination with the owner/manager of the associated facilities.

TABLE 4
Estimated Project Schedule
Revised Work Plan for East Ravine Groundwater Investigation
PG&E Topock Compressor Station, Needles, California

Task / Activity	Estimated Duration	Remarks
1.0 Primary Field Investigation		
Project Kickoff Meeting	1 day	Onsite meeting to discuss project details
Drilling, Characterization, Well Installation	30 days	Primary Investigation Sites A and B
Well Development	5 days	
Estimated Total Primary Drilling Investigation Period	*5 weeks*	
2.0 Primary Sites Sampling & Reporting		
Two Initial Sampling Events	9 weeks	Includes sample collection, laboratory analysis, and data validation of two events (approximately 4 weeks apart)
Interim Results Technical Memorandum	4 weeks	Draft report scheduled 4 weeks after receipt of validated results of second sampling event
Estimated Total Primary Sampling and Reporting Period	*13 weeks*	
3.0 Contingency Sites Field Investigation (Separate Mobilization)		
Select and Conduct Contingency Investigation	TBD	
4.0 Reporting for Contingency Investigations (if implemented)		
Contingency Investigation Results Technical Memorandum	TBD	

Notes:
1. The duration of all activities are estimated and may vary based on field conditions or data collected during the investigation.
2. TBD = to be determined

Figures

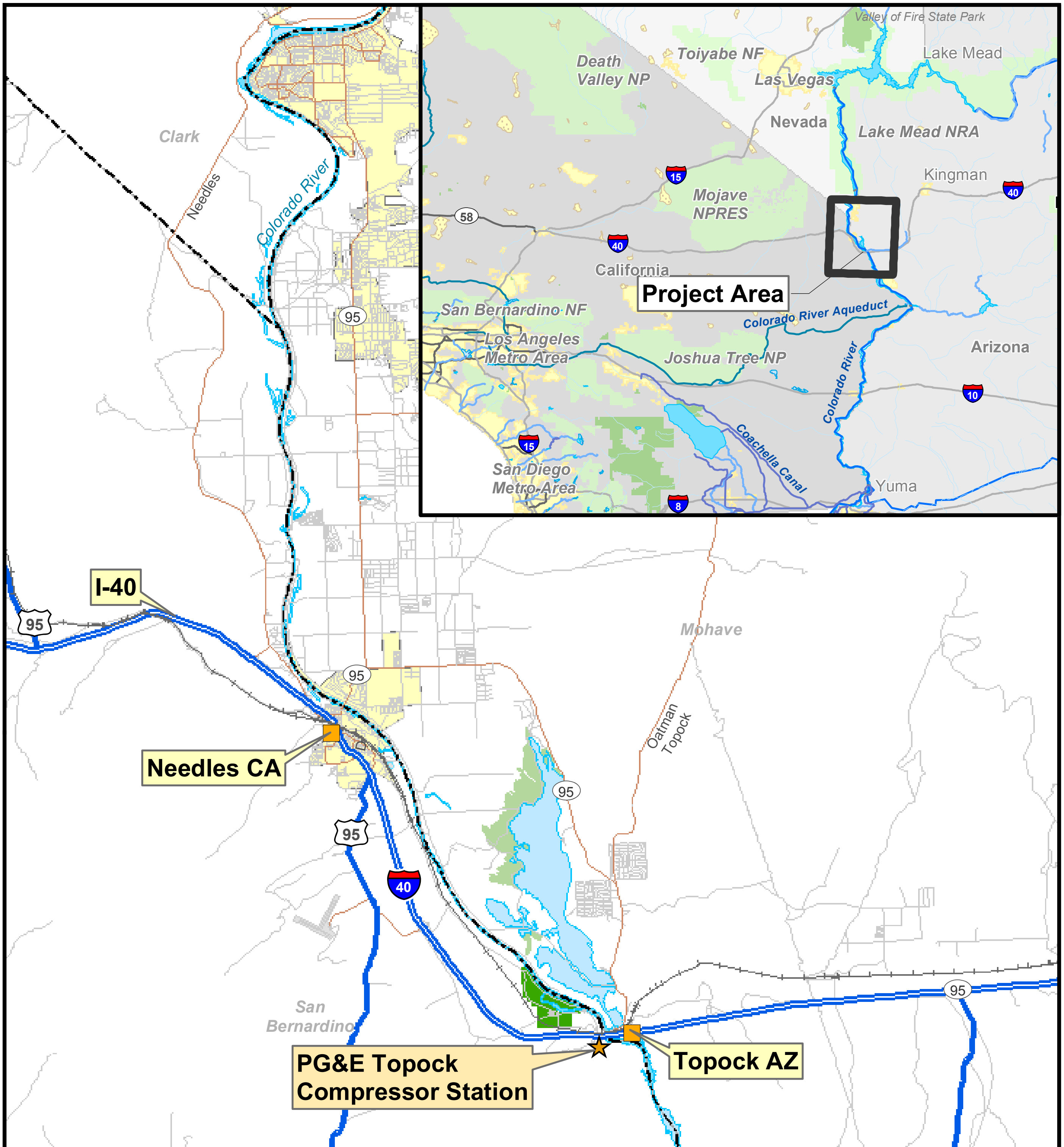

FIGURE 1
SITE LOCATION MAP

PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

CH2MHILL

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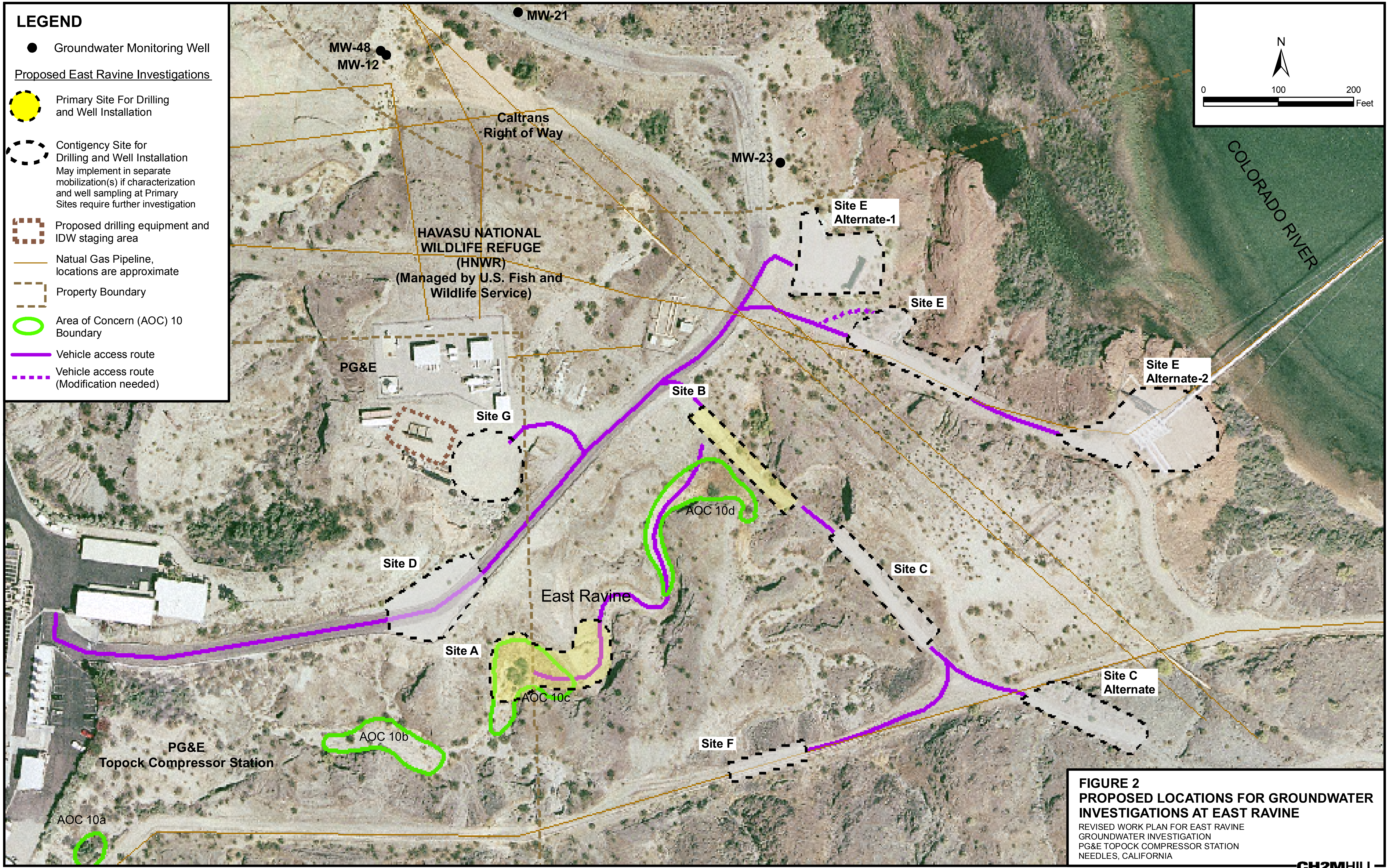

FIGURE 2
PROPOSED LOCATIONS FOR GROUNDWATER INVESTIGATIONS AT EAST RAVINE
REVISED WORK PLAN FOR EAST RAVINE GROUNDWATER INVESTIGATION
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

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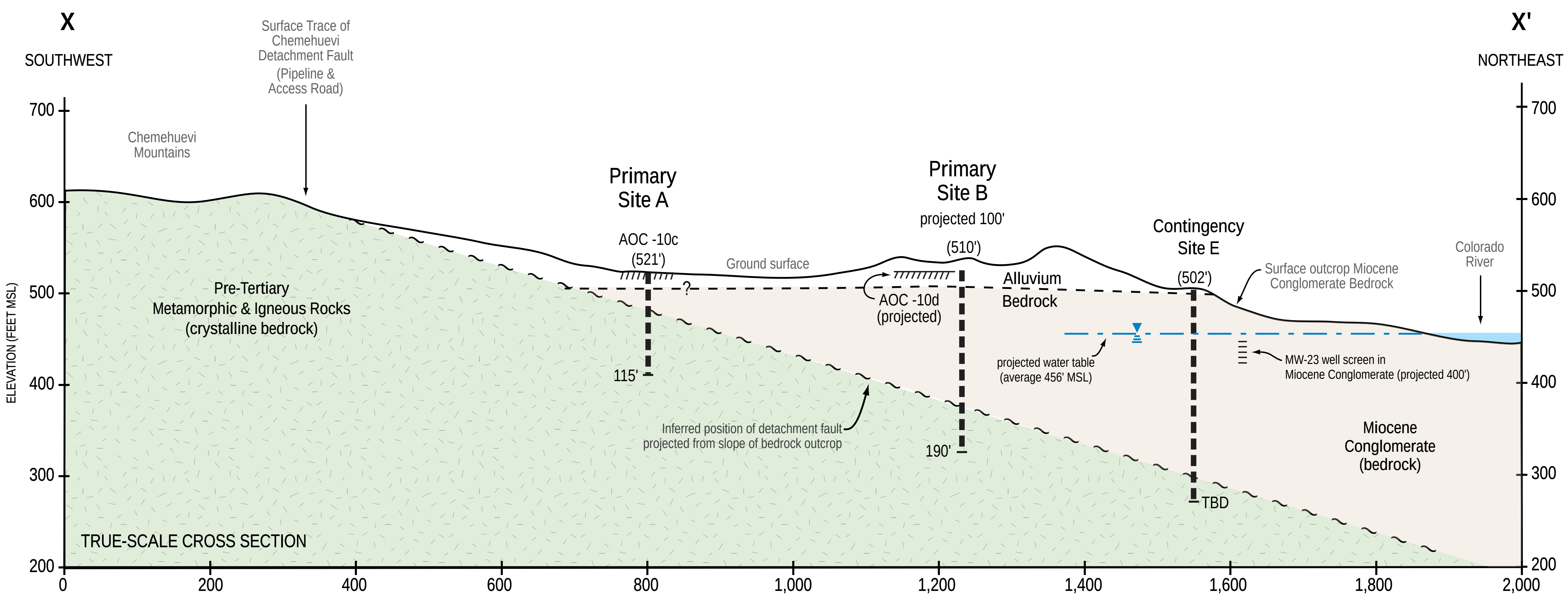
Conceptual Hydrogeologic Cross-Section X



LEGEND

MW–23	Well ID
505'	Ground surface elevation (feet msl)
	Water level
	Well screen
80'	Total depth of boring (feet bgs)
	TBD = to be determined
	Surface Impoundment

NOTES:
1. Elevations in feet above mean sea level (MSL)
2. Subsurface conditions are conceptual and based on limited emperical data (drilling logs from wells MW-12, MW-23, MW-48, and published USGS information).

LOCATIONS OF HYDROGEOLOGIC CROSS SECTIONS

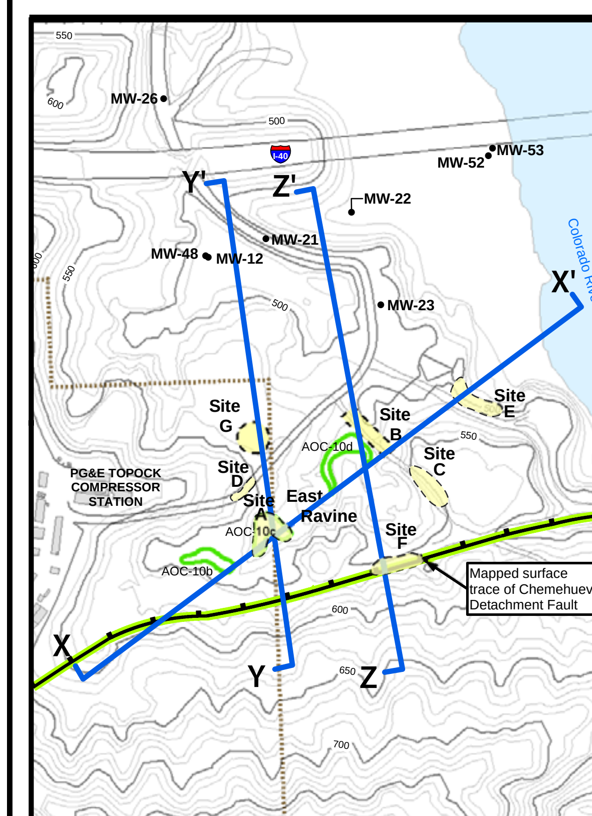


FIGURE 3
EAST RAVINE AREA – CONCEPTUAL HYDROGEOLOGIC CROSS-SECTION X
REVISED WORK PLAN FOR EAST RAVINE GROUNDWATER INVESTIGATION
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

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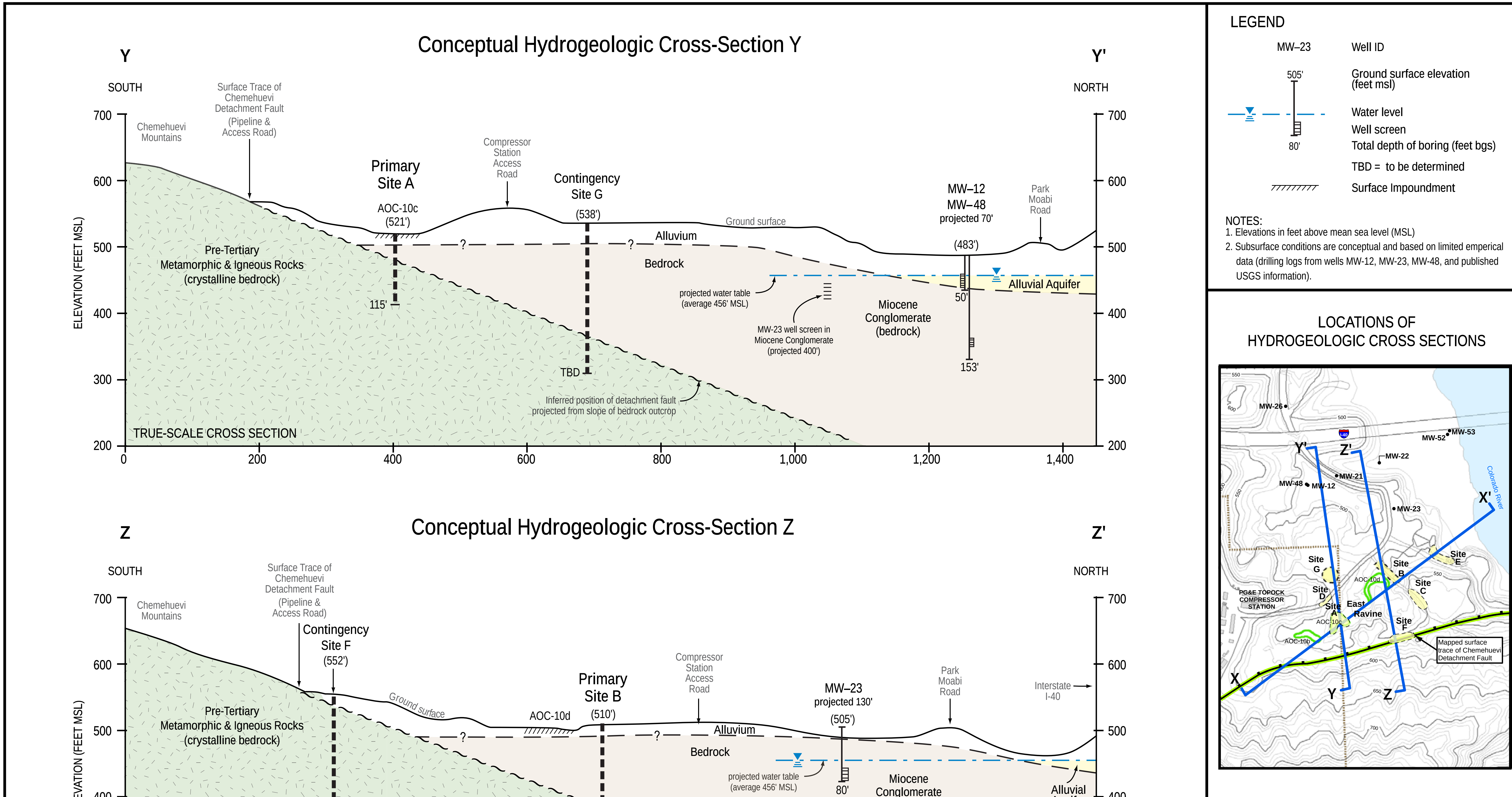
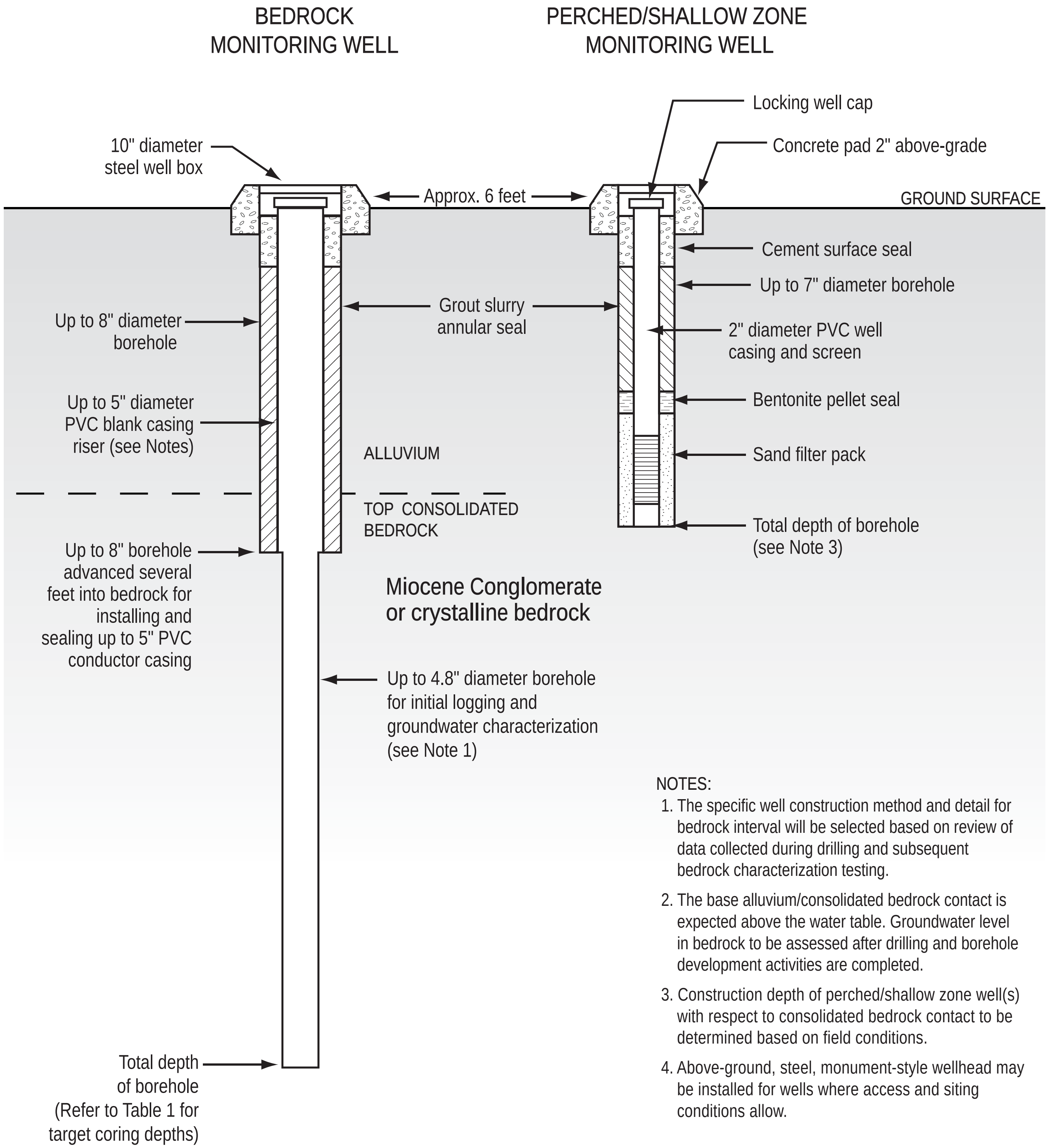


FIGURE 4
EAST RAVINE AREA – CONCEPTUAL HYDROGEOLOGIC CROSS-SECTIONS Y AND Z
REVISED WORK PLAN FOR EAST RAVINE GROUNDWATER INVESTIGATION
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

CH2MHILL

ES112007007BAO_REVISED_EastRavine_HydroGW_xsect_YZ.ai_070808_lho



NOTES:

1. The specific well construction method and detail for bedrock interval will be selected based on review of data collected during drilling and subsequent bedrock characterization testing.
2. The base alluvium/consolidated bedrock contact is expected above the water table. Groundwater level in bedrock to be assessed after drilling and borehole development activities are completed.
3. Construction depth of perched/shallow zone well(s) with respect to consolidated bedrock contact to be determined based on field conditions.
4. Above-ground, steel, monument-style wellhead may be installed for wells where access and siting conditions allow.

DIAGRAM NOT TO SCALE

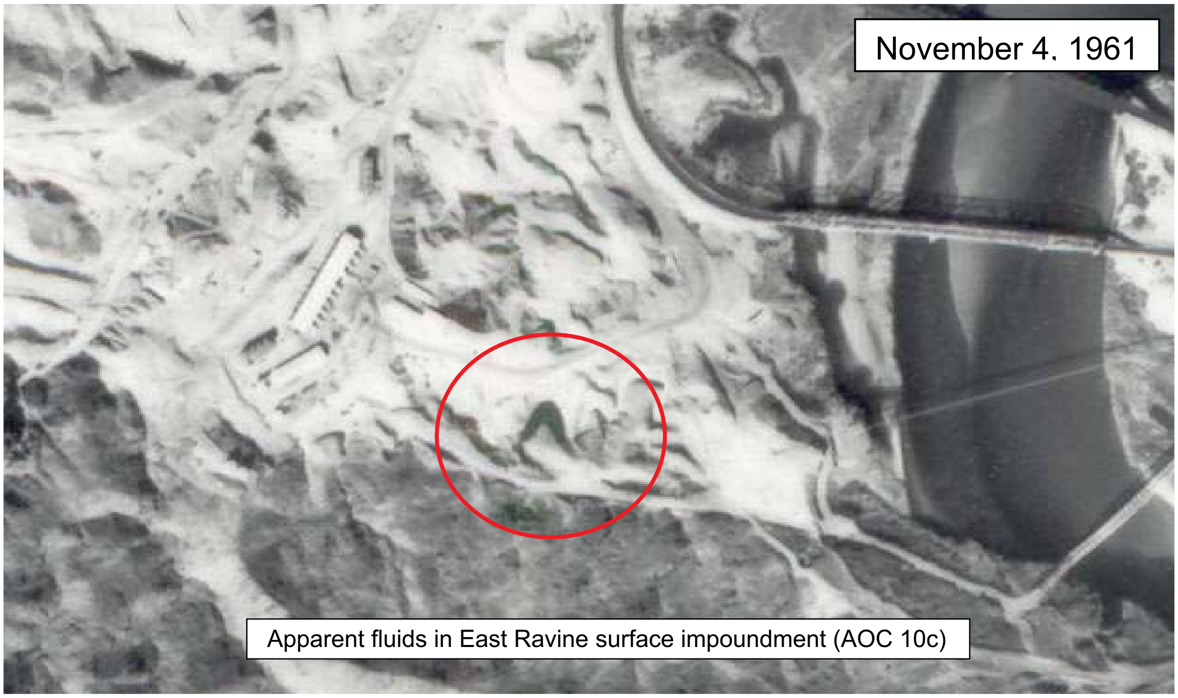
All depths in feet below ground surface (bgs) are approximate and drilling and well installation depths will be determined based on drilling log and characterization results.

FIGURE 5
PROPOSED WELL CONSTRUCTION SCHEMATICS

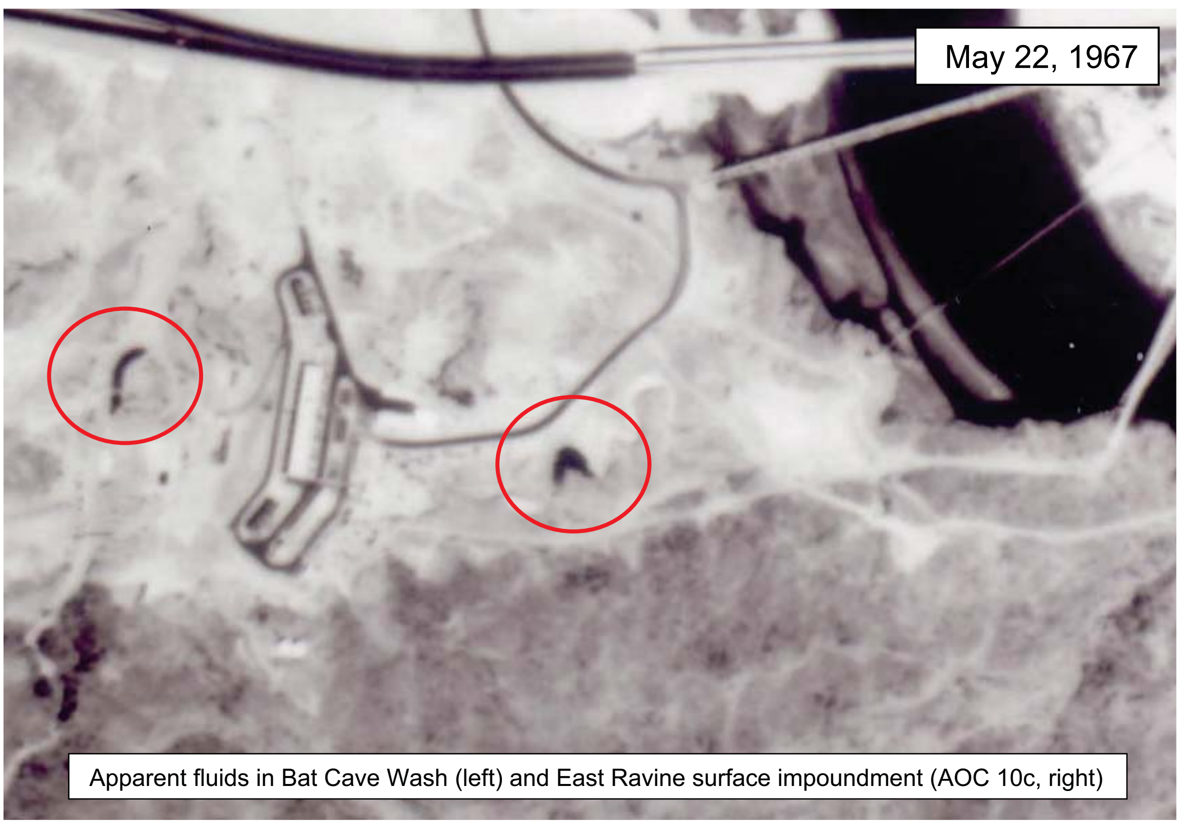
REVISED WORK PLAN FOR EAST RAVINE GROUNDWATER INVESTIGATION
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

CH2MHILL

Appendix A
Historical Aerial Photographs



Apparent fluids in East Ravine surface impoundment (AOC 10c)



Apparent fluids in Bat Cave Wash (left) and East Ravine surface impoundment (AOC 10c, right)

Appendix B
Fracture Documentation in Miocene Conglomerate Outcrop

TECHNICAL MEMORANDUM CH2MHILL

East Ravine Bedrock Fracture Study, PG&E Topock Compressor Station, Needles, California

PREPARED FOR: California Department of Toxic Substances Control

ON BEHALF OF: Pacific Gas and Electric Company

PREPARED BY: CH2M HILL Inc.

DATE: June 13, 2008

This technical memorandum presents the results of fracture orientation field mapping and data collection from bedrock outcrops in the East Ravine area near the Pacific Gas and Electric Company (PG&E) Topock Compressor Station near Needles, California. This study is conducted to support PG&E's *Work Plan for East Ravine Groundwater Investigation, PG&E Topock Compressor Station* (CH2M HILL, 2007). This technical memorandum will be discussed and attached to the forthcoming Revised Work Plan for East Ravine Groundwater Investigation that is being finalized in accordance with the California Department of Toxic Substances Control direction (DTSC, 2008a).

This field study was conducted in response to DTSC's comment and direction to PG&E to assess bedrock fracture orientations in the area of the proposed investigation (addressing a stakeholder comment on the December 2007 Work Plan). Specifically, DTSC's General Comment 7 (DTSC, 2008a-b) provided the following direction and objective for this study: "…the Work Plan should indicate that results of mapping the Miocene Conglomerate bedding and structures (e.g., fracture analysis) that outcrop in the immediate area will be evaluated to determine if angled well borings are necessary for primary or contingent well locations."

Field Activity Procedures

Fracture orientation data were collected from outcrops of Miocene Conglomerate bedrock in the East Ravine investigation area on June 5, 2008. Procedures from *Geology in the Field* (Compton, 1985) were employed. Strike and dip of the fractures were measured using a Brunton 5008 com-pro pocket transit (compass). The locations of the fractures measured were recorded using a Trimble GeoXT global position system (GPS) unit, and plotted as shown on Figure 1.

Miocene Conglomerate outcrops near the Colorado River to the east of the East Ravine study area were examined for through-going fractures with large surface area (several square feet) or long linear extent visible on outcrop. The true dip and strike of fractures were measured using a clipboard or notebook oriented parallel to the observed fracture plane. The compass was leveled to the surface, and the bearing was recorded to determine strike. The compass was then oriented perpendicular to strike to measure the dip angle and the dip direction of the fracture surface. The strike directions in tables and figures are presented as bearings in the northern compass quadrants. The dip directions are presented as azimuth bearings of 0° to 359°, oriented down-dip.

Results

A total of 37 fractures were measured in the Miocene Conglomerate outcrops in the East Ravine study area. The locations of the fracture measurements are shown on Figure 1. GPS location data and the data for the strike and dip orientation of the fractures are listed in Attachment 1. Figures 2 and 3 are histograms of the measured fracture orientation data. A photographic log showing fractures in the bedrock outcrops is included in Attachment 2.

In general, there is a large spread of the dip angles and orientations of the fracture surfaces in the Miocene Conglomerate outcrops. The average and median of the dips are 49° and 52°, respectively. The strike direction of the fractures also appears to have a large spread, although the majority of the fractures trend to the west and northwest. The average and median strike directions are N85°W and N65°W, respectively. The measured fracture plane orientations are summarized as follows:

- 4 fracture planes dip from 0° to 15°
- 8 fracture planes dip from 15° to 30°
- 5 fracture planes dip from 30° to 45°
- 6 fracture planes dip from 45° to 60°
- 6 fracture planes dip from 60° to 75°
- 8 fracture planes dip from 75° to 90°

- 5 fracture planes are oriented north - northwest
- 10 fracture planes are oriented northwest
- 8 fracture planes are oriented northwest - west
- 2 fracture planes are oriented east - northeast
- 4 fracture planes are oriented northeast
- 8 fracture planes are oriented northeast - north

Certification

This report was prepared by CH2M HILL under the supervision of the professional whose seal and signature appears herein in accordance with currently accepted professional practices. No warranty, expressed or implied, is made.

Paul Bertucci
Certified Engineering Geologist, CEG No. 1977

Report Reviewed by:

Jay Piper
CH2M HILL Project Manager

References

CH2M HILL. 2007. *Work Plan for East Ravine Groundwater Investigation, PG&E Topock Compressor Station*. December 11.

Compton, Robert R. 1985. *Geology in the Field*. Page 36.

DTSC. 2008a. *Directions on the Responses to Comments, East Ravine Groundwater Investigation for Pacific Gas and Electric Company (PG&E), Topock Compressor Station, Needles, California.* May 9.

DTSC. 2008b. *Pacific Gas & Electric (PG&E) Response to Comments on the Work Plan for East Ravine Groundwater Investigation, PG&E Topock Compressor Station.* GSU Technical Memorandum. May 9.

Figures

FIGURE 2
Frequency and Range of Dip Measurements

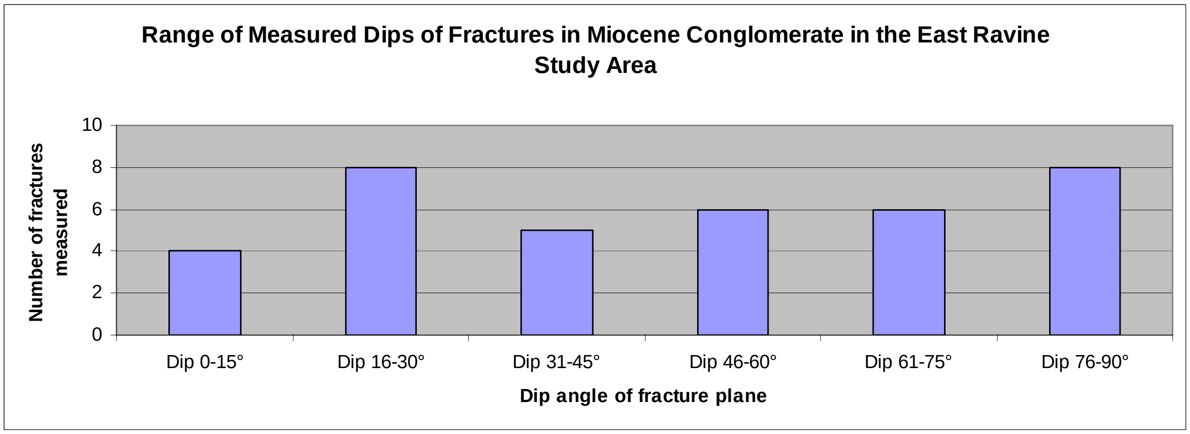
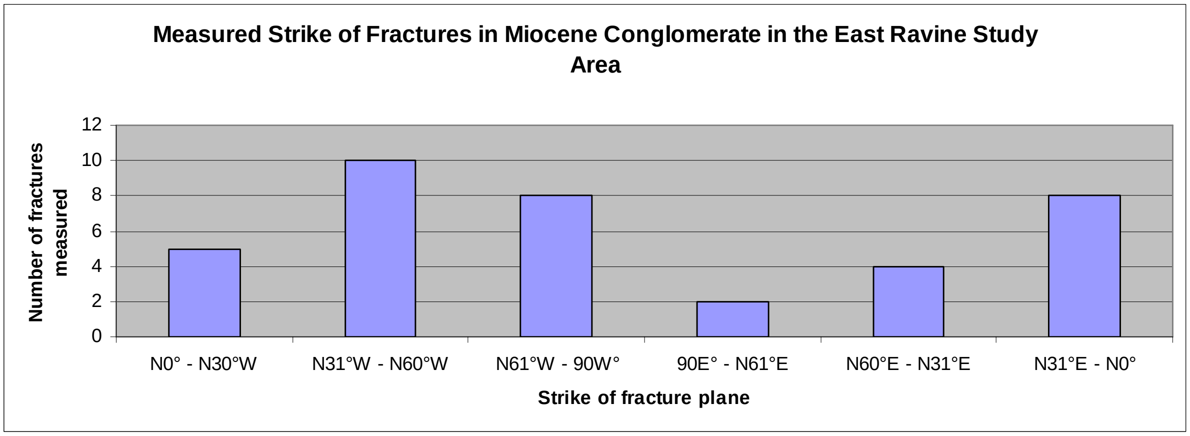


FIGURE 3
Frequency and Range of Strike Measurements



Attachment 1
Locations and Orientation of Measured Fractures

ATTACHMENT 1
Locations and Measured Orientation of Fracture Planes

LocationID	Strike	Dip	Dip Direction	Northing	Easting
Location_1	N75°W	20	195	2100899.212	7616821.849
Location_2	N59°W	33	211	2100899.358	7616821.522
Location_3	N32°W	65	238	2100898.817	7616817.301
Location_4	N21°W	72	69	2100895.269	7616818.612
Location_5	N20°E	87	110	2100899.043	7616811.583
Location_6	N42°E	49	132	2100903.152	7616802.571
Location_7	N56°W	55	214	2100901.148	7616800.840
Location_8	N71°W	26	199	2100893.477	7616843.148
Location_9	N1°E	90	91	2100893.773	7616839.811
Location_10	N7°W	72	263	2100888.818	7616865.902
Location_11	N72°W	20	198	2100885.003	7616873.796
Location_12	N56°W	36	214	2100883.440	7616868.857
Location_13	N10°E	86	100	2100864.943	7616899.020
Location_14	N48°W	14	42	2100865.215	7616901.684
Location_15	N60°E	78	150	2100863.527	7616902.189
Location_16	N5°W	85	265	2100870.687	7616899.525
Location_17	N50°W	80	40	2100834.975	7616920.029
Location_18	N76°E	67	346	2100840.130	7616909.424
Location_19	N47°W	80	223	2100846.344	7616921.089
Location_20	N37°W	14	233	2100847.944	7616915.774
Location_21	N50°E	25	320	2101001.322	7616891.917
Location_22	N60°W	53	210	2101157.106	7616621.690
Location_23	N5°E	30	275	2101161.558	7616626.433
Location_24	N6°W	20	84	2101166.749	7616634.858
Location_25	N17°W	16	253	2101177.326	7616634.983
Location_26	N30°W	52	240	2101193.075	7616642.166
Location_27	N65°W	57	205	2101187.780	7616647.921
Location_28	N85°E	75	175	2101185.330	7616649.694
Location_29	N20°E	14	110	2101185.189	7616648.883
Location_30	N40°W	42	230	2101218.500	7616644.029
Location_31	N78°W	77	192	2101223.363	7616644.435
Location_32	N63°W	56	207	2101232.498	7616653.126
Location_55	N65°W	10	205	2101049.429	7616648.429
Location_56	N8°E	44	278	2101049.826	7616661.191
Location_57	N51°E	25	321	2101049.647	7616689.932
Location_58	N5°E	35	275	2101068.217	7616706.653
Location_59	N8°E	70	98	2101268.250	7616598.500

Attachment 2
Photographic Log of Fractures

Location 9 vertical fracture with strike of N1°E and dip of 90° cutting Location 8, a fracture with a strike of N71°W and dip of 26°.

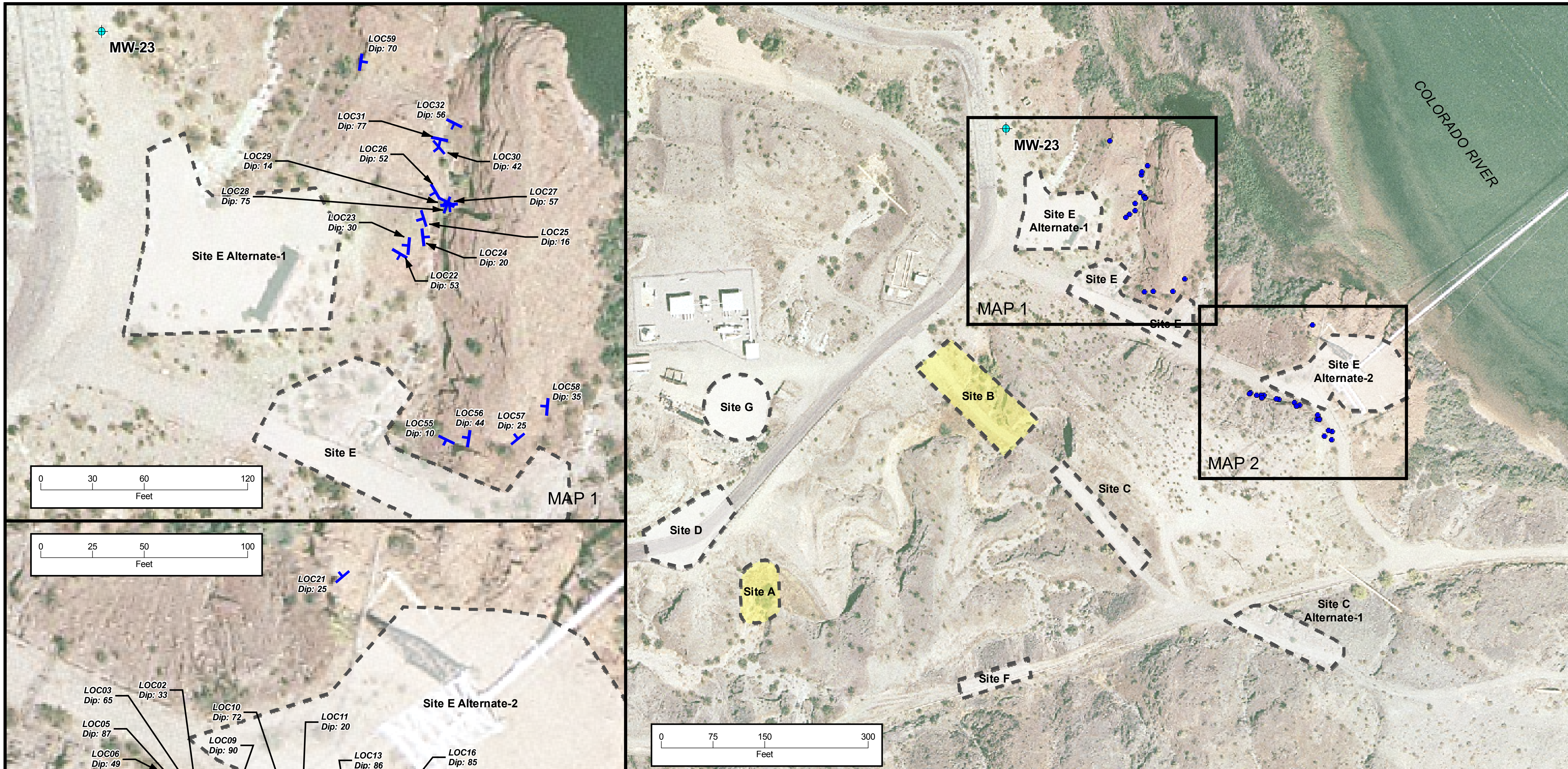
Location 13, vertical fracture with strike of N10°E and dip of 86° with calcite filling and Location 14, a fracture (being pointed out with the blue binder) with a strike of N48°W and a dip of 14°.

Location 56, fracture with a visible calcite filling with a Strike of N8°E and a dip of 44°.

Overview picture of East Ravine area, view North from East side of Park Moabi Road. MW-23 is located past the sign.

Location 24 with calcite filling with strike of N6°W and dip of 20°.

Location 32, fracture with strike of N63°W and dip of 56°.



LEGEND

- Location (GPS station) where fracture orientation measured
- Strike and dip of fracture measured in Miocene Conglomerate bedrock
- Groundwater Monitoring Well
- Primary Sites for Drilling and Well Installation
- Contingency Sites for Drilling and Well Installation

N

FIGURE 1
MEASURED FRACTURE LOCATIONS, EAST RAVINE AREA
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

CH2MHILL

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Appendix C
Standard Operating Procedures for Drilling, Logging, Well Installation, and Groundwater Sampling

SOP-A1

Purging and Sampling of Groundwater Monitoring Wells Well-Volume Method Standard Operating Procedures for PG&E Topock Program

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This standard operating procedure (SOP) addresses the procedures and equipment to be used for purging and sampling all groundwater monitoring wells at the Topock site with casing diameters in excess of 1-inch. This SOP should be used for sampling groundwater monitoring wells using an electric submersible pump with a single discharge rate dedicated pump, a dedicated electric pump with a controllable discharge rate, and a portable electric pump with a controllable discharge rate. A well-volume based purging and sampling method will be used for these wells.

REQUIRED DOCUMENTS

1) Event-specific sampling and analysis plan (SAP).
2) Applicable project work plan or monitoring plan. Refer to Topock Program Sampling, Analysis, and Field Procedures Manual and QAPP (Procedures Manual), as required.
3) Topock Program Health and Safety Plan (HSP)
4) Well construction logs/specifications
5) Previous sampling logs or tabular historic field data
6) Blank sampling logs and field notebook

PREPARATION & SETUP

1) Review event-specific SAP or event-specific field instructions, previous sampling logs, Procedures Manual, and HSP.
2) Initiate field logbook for sampling activity.
3) Inspect all equipment and verify that the field water quality (WQ) meters have been calibrated prior to use according to SOP-A9, *Calibration of Field Instruments*.
4) Inventory sample bottles, required analyses, and confirm the lab courier schedule.
5) Field-check and setup sampling equipment: water level (WL) meter, WQ meters, flow-through cell, pump control and power supply, pump discharge/sampling tubing, etc.
6) Open well protection lid and measure initial static WL according to SOP-A7, *Water level Measurements*. Record WL value on sampling log.
7) If well is equipped with a transducer, remove transducer from the well according to SOP-C1, *Temporary Removal and Replacement of Transducers*.
8) If well is not equipped with a dedicated sampling system, install a decontaminated pump at the same intake/sampling depth used in prior events and record intake depth.

If the well has not been previously sampled, install the pump with the intake 15 feet below the static water column, or at the depth prescribed by the PM or FTM.

PURGING AND SAMPLING PROCEDURES

9) Prepare groundwater sampling log (use attached form dated February 2005).

10) Use the water level determined in Step 6 above and the total depth provided in the field sampling plan to evaluate the column of standing water in the well, as described on the Topock Groundwater Sampling Log sheet.

11) Calculate 3-casing volumes.

12) Evaluate previous purge rates, amount of drawdown, and purge volume prior to sample collection from previous sampling records and historical data tables (see July 2004 SAP Table 3-2, or Appendix B of *Monitoring Plan for Groundwater and Surface Water Monitoring Program* [currently in preparation]). If the well has not been previously sampled, estimate the expected purge parameters using previous sampling information from nearby wells. Start purging, measure WL, and calculate purge rate.

13) Continue purging and measuring WL, and field indicator parameters every 3 minutes at minimum. Decrease the purge rate and measure/record new purge rate if significant drawdown is observed. Significant drawdown is considered to be 5 percent of the total height of the water column or to the top of screen. <u>Record time for all measurements collected</u>. Note and provide qualifying remarks if parameter readings are anomalous or unstable due to instrument problem.

14) Observations on sample appearance and clarity during purging and at sampling are required. For standardization, use a glass jar or clear plastic bottle to collect and record observations of discharge water appearance during purging. Also note characteristics of any odors associated with discharge.

15) Continue purging until **<u>3-casing volumes</u>** have been purged **<u>and</u>** field parameters stabilize. Field parameters should be measured at intervals no less than 3 minutes apart or no less than the time frame for a complete exchange of water in the flow-through cell. Indicator parameters are considered stabilized when 3 consecutive readings made several minutes apart fall within the following EPA stabilization criteria:

- pH +/- 0.1 pH units
- Specific conductance +/- 3%
- ORP +/- 10 millivolts
- Turbidity +/- 10% NTU units (when turbidity is >10 NTUs)
- Dissolved oxygen +/- 0.3 mg/L
- Temperature +/- 2^{o} Celsius

16) Collect samples for analyses according to event-specific SAP. For all samples, decrease the discharge rate to reduce water turbulence at the pump discharge point. Prepare sample containers and collect gas-sensitive analytes first. The preferred collection order will be volatile organic compounds (VOCs), semi-volatile organic compound (SVOCs), metals (including hexavalent chromium [Cr(VI)] and total chromium [Cr(T)]; see SOP-A6), then general chemistry (cations, anions, stable isotopes). Sample containers are to be

filled by transferring water directly from the pump discharge to the appropriate sample container.

17) Record sample information, final WL, and purge volume data on field log.

18) If well was equipped with a transducer, replace transducer according to SOP-C1, *Temporary Removal and Replacement of Transducers*.

19) Close and secure well protection lid.

20) Follow *Procedures Manual* for sample handing and management, equipment decontamination, and investigation-derived waste (IDW) management.

LOW VOLUME AND POOR RECOVERY WELLS

Some groundwater monitoring wells under the GMP may exhibit slow or poor recovery upon purging. These groundwater monitoring wells may not recover sufficiently during purging and run completely dry without an opportunity to collect the required series of groundwater stabilization parameters, or run dry prior to sampling. The following procedures should be followed for collection representative groundwater samples from wells that go dry during purging activities in preparation for groundwater sampling.

PREPARATION & SETUP

Follow steps 1 through 8 as above and evaluate the volume of water to be discharged prior to the groundwater monitoring well going dry, if known.

PURGING AND SAMPLING PROCEDURES FOR LOW RECOVERY WELLS

9) Prepare groundwater sampling log (use attached form dated February 2005).

10) Use the water level determined in Step 6 above and the total depth measurement from the field sampling table to evaluate the column of standing water in the well as described on the Topock Groundwater Sampling Log sheet.

11) Calculate 3-casing volumes.

12) Evaluate previous purge rates, amount of drawdown, and purge volume prior to sample collection from previous sampling records and historical data tables (see July 2004 SAP Table 3-2, or Appendix B of *Monitoring Plan for Groundwater and Surface Water Monitoring Program* [currently in preparation]). If the well has not been previously sampled, estimate the expected purge parameters using previous sampling information from nearby wells. Start purging at a rate of less than one gallon per minute if the pump capacity allows. Measure WL, and calculate purge rate.

13) Continue purging and measuring WL, and field indicator parameters every 3 minutes at minimum. Record time for all measurements collected. Note and provide qualifying remarks if parameter readings are anomalous or unstable due to instrument problem.

14) Observations on sample appearance and clarity during purging and at sampling are required. For standardization, use a glass jar or clear plastic bottle to collect and record

observations of discharge water appearance during purging. Also note characteristics of any odors associated with discharge.

15) Continue purging until **3-casing volumes** have been purged **and** field parameters stabilize, or until the well is purged dry. Field parameters should be measured at intervals no less than 3 minutes apart or no less than the time frame for a complete exchange of water in the flow-through cell. If the well purges dry during the observation period, immediately shut off the pump and collect a final set of water quality parameters (ph, specific conductance, ORP, turbidity, dissolved oxygen, and temperature).

16) Record the final water level, note the time, the volume of water discharged and the elapsed time for the complete discharge of the well.

17) Allow the well to recharge to 80 percent of the original height of the water column. Ideally, this should be the following day within 24 hours of the groundwater monitoring well being purged dry. The recovery period to achieve 80 percent of the height of the water column could take longer than 24 hours in some instances. Calculate the volume of water in the well and volume of water needed to fill all of the sample containers. Initiate procedures for the well sampling. Begin to slowly purge the well and collect at least one set of water quality parameters prior to filling the sample containers. Collect samples for analyses according to event-specific SAP. Prepare sample containers and collect gas-sensitive analytes first. The preferred collection order will be volatile organic compounds (VOCs), semi-volatile organic compound (SVOCs), metals (including hexavalent chromium [Cr(VI)] and total chromium [Cr(T)]), then general chemistry (cations, anions, stable isotopes). If an insufficient volume of water will be generated to fill all of the sample containers, prioritize the sample collection to obtain the critical analytes for the main COCs first, then continue collecting samples until the groundwater supply is exhausted. Verify the critical analyte list with the PM or the FTM. Sample containers are to be filled by transferring water directly from the pump discharge to the appropriate sample container.

18) Record sample information, final WL, and purge volume data on field log.

19) If well was equipped with a transducer, replace transducer according to SOP-C1, *Temporary Removal and Replacement of Transducers*.

20) Close and secure well protection lid.

21) Follow Procedures Manual for sample handing and management, equipment decontamination, and IDW management.

Project Name PG&E Topock PROJECT
Job Number ____
Field Team ____ Field Conditions ____
Sampling Event ____
Date ____
Page ____ of ____

Well/Sample Number ____ **QC Sample ID** ____ QC Sample Time ____
Purge Start Time ____ Purge Method: ____ Ded. Pump MAKE/MODEL
Flow Cell: Y / N Instrument Serial Number: ____ Min. Purge Volume (gal)/(L) ____ Purge Rate (gpm)/(mLpm) ____

Water Level	Time	Vol. Purged gallons / liters	pH	Conductivity UNITS	Turbidity NTU	Diss. Oxygen mg/L	Temp. °C	Salinity %	TDS g/L	Eh / ORP mv	Comments (See descriptors below)
Parameter Stabilization Criteria:			+/- 0.1 pH units	+/- 3%	+/- 10% NTU units when >10 NTUs	+/- 0.3 mg/L	NA	NA	NA	+/- 10 mV	
Did Parameters Stabilize prior to sampling?							NA	NA	NA		
Are measurements consistent with previous?							NA				

Sample Time ____ Sample Location: pump tubing ____ well port ____ spigot ____ bailer ____ other ____
Comments: ____

Initial Depth to Water (ft BTOC): ____
WD (Well Depth - from table) ft btoc: ____
SWH (Standing Water Height) = WD-Initial Depth ____
D (Volume as per diameter) 2" = 0.17, 4"= 0.66, 1" = 0.041 ____
One Casing Volume = D*SWH ____
Three Casing Volumes = ____

Measure Point: Well TOC Steel Casing WATER LEVEL METER SERIAL NUMBER: ____

TRANSDUCER

Before Removal		Approx. 5 min After Reinstallation		
Time	Initial DTW	Time	Final DTW	Time of Removal ____ Time of Reinstallation ____

Comments:

Color: clear, grey, yellow, brown, black, cloudy, green **Odor**: none, sulphur, organic, other **Solids**: Trace, Small Qu, Med Qu, Large Qu, Particulate, Silt, Sand

Project Name PG&E Topock PROJECT

Job Number ______

Sampling Event ______

Date ______

Well/Sample Number	
QC Sample ID	

Samples Samples are to be collected in the order listed

Analyte	Bottle			Preservative	Field Filtered Y/N?	pH check	Notes
	Material	Size	Number				

WELL INSPECTION LOG

Project Name: PG&E Topock

Staff: ______________________________

Well/Piezometer	Date	Survey Mark Present?	Standing or Ponded Water?	Lock in Place?	Evidence of Well Subsidence?	Well Labeled on Casing or Pad?	Traffic Poles Intact?	Concrete Pad Intact?	Erosion Around Wellhead?	Steel Casing Intact?	PVC Cap Present?	Standing Water in Annulus?	Well Casing Intact?	NOTES
		Y N	Y N	Y N	Y N	Y N	Y N	Y N	Y N	Y N	Y N	Y N	Y N	
		Y N	Y N	Y N	Y N	Y N	Y N	Y N	Y N	Y N	Y N	Y N	Y N	
		Y N	Y N	Y N	Y N	Y N	Y N	Y N	Y N	Y N	Y N	Y N	Y N	
		Y N	Y N	Y N	Y N	Y N	Y N	Y N	Y N	Y N	Y N	Y N	Y N	
		Y N	Y N	Y N	Y N	Y N	Y N	Y N	Y N	Y N	Y N	Y N	Y N	
		Y N	Y N	Y N	Y N	Y N	Y N	Y N	Y N	Y N	Y N	Y N	Y N	
		Y N	Y N	Y N	Y N	Y N	Y N	Y N	Y N	Y N	Y N	Y N	Y N	
		Y N	Y N	Y N	Y N	Y N	Y N	Y N	Y N	Y N	Y N	Y N	Y N	
		Y N	Y N	Y N	Y N	Y N	Y N	Y N	Y N	Y N	Y N	Y N	Y N	
		Y N	Y N	Y N	Y N	Y N	Y N	Y N	Y N	Y N	Y N	Y N	Y N	

Equipment Model/Type	**Serial Number**	**Last Calibration Date**
Water Level Meter		
Horiba		
Hach		

SOP-A10

Decontamination of Water Sampling Equipment
Standard Operating Procedures for PG&E Topock Program

This standard operating procedure (SOP) addresses the procedures and equipment to be used for decontamination of sampling equipment at the Topock site.

Required Documents

1) Event-specific sampling and analysis plan (SAP).
2) Applicable project work plan or monitoring plan. Refer to Topock Program Sampling, Analysis, and Field Procedures Manual and QAPP (Procedures Manual), as required.

Preparation and Setup

1) Initiate field log sampling book for activity.
2) Inspect all equipment necessary to carry out activities detailed in event-specific SAP.
3) Review decontamination guidelines for equipment necessary to carry out activities.

Equipment List:

-Distilled water
-2.5 percent (W/W) Alconox and distilled water solution
-Large plastic pails or tubs for Alconox and distilled water, scrub brushes, squirt bottles for Alconox solution, distilled water, and clean plastic bags.
-Trash pump to transfer used decontamination water from tubs to holding tank for disposal of waste.
-Phthalate-free gloves

Guidelines

Field Equipment

Water-level Indicators

Any portion of a water-level indicator (e.g. probe and/or cable) that contacts the groundwater must be decontaminated by washing with Alconox or Liquinox solution and rinse with distilled water after use.

Probes/Cables
Probes (e.g., pH or specific ion electrodes, geophysical probes, etc..) and/or cables that come into contact with groundwater will be decontaminated using the procedures specified below unless manufacturer's instructions indicate otherwise.
For probes that make no direct contact (e.g.,OVM equipment), the probe will be wiped with paper towels.

Other Sampling Equipment
Other sampling equipment such as surface water sampling containers, spatulas, spoons, or bowls should be decontaminated and cleaned in the manner prescribed in this SOP.

Procedures

Sampling Equipment Decontamination – Groundwater Sampling Pumps

Sampling pumps are decontaminated after each use as follows:

1. Don phthalate-free gloves.
2. Turn off pump after sampling. Remove pump from well and place pump in decontamination tub, making sure that tubing does not touch the ground.
3. Turn pump back on and pump 1 gallon of Alconox solution through the sampling pump.
4. Rinse with a minimum of 1 gallon of distilled water.
5. Keep decontaminated pump in decontamination tub or remove and wrap in clean plastic sheeting or clean plastic garbage bag.
6. Collect all rinsate and dispose of in a DOT-approved 55-gallon drum or holding tank.
7. Decontamination materials (e.g., plastic sheeting, tubing, etc.) that have come in contact with used decontamination fluids or sampling equipment will be disposed of in DOT-approved 55-gallon drums.

Sampling Equipment Decontamination – Other Equipment

Reusable sampling equipment is decontaminated after each use as follows.

1. Don phthalate-free gloves.
2. Wash all equipment surfaces that contacted the potentially contaminated soil/water with Alconox solution.
3. Rinse with distilled water or triple rinse with potable water.
4. Air dry and wrap exposed areas with plastic sheeting or a clean plastic garbage bag for transport and handling if equipment will not be used immediately.
5. Collect all rinsate and dispose of in a DOT-approved 55-gallon drum or holding tank.
6. Decontamination materials (e.g., plastic sheeting, tubing, etc.) that have come in contact with used decontamination fluids or sampling equipment will be disposed of in DOT-approved 55-gallon drums.

Key Checks and Items

- Clean with solutions of Alconox and distilled water.
- If necessary, decontaminate the outside of filled sample bottles before relinquishing them to anyone.

- All materials generated during sampling (debris, PPE, decontamination liquids, etc.) will be placed in 55-gallon drums or rolloff bins for storage pending analysis and disposal off site.
- Document all decontamination procedures in the field log book. Prior to use of equipment during a sampling event, check log book to see that equipment was decontaminated, if not proceed with decontamination procedures prior to use. At the end of an event, tag equipment as decontaminated with initials and date. Remove the tag prior to use at the beginning of the next event. If at the beginning of a sampling event this tag is not visible/complete, proceed with decontamination of equipment.
- The effectiveness of field cleaning procedures will be monitored by rinsing decontaminated equipment (i.e. portable pump) with organic-free water and submitting the rinse water in standard sample containers for analysis. The minimum number of equipment blank samples will be at least one per team (per event), per piece of equipment decontaminated, during large-scale field sampling efforts.

SOP-A11

Total Depth Measurements
Standard Operating Procedures for PG&E Topock Program

This standard operating procedure (SOP) addresses the procedures and equipment to be used for manually measuring the total depth at groundwater monitoring wells and production wells.

REQUIRED DOCUMENTS

1) Event-specific sampling and analysis plan (SAP).
2) Applicable project work plan or monitoring plan. Refer to Topock Program Sampling, Analysis, and Field Procedures Manual and QAPP (Procedures Manual), as required.
3) Topock Program Health and Safety Plan (HSP)
4) Well construction logs/specifications
5) Previous total depth data
6) Blank sampling logs and field notebook

PREPARATION & SETUP

1) Review event-specific SAP or event-specific field instructions, previous sampling logs, Procedures Manual, and HSP.
2) Ensure that the measurement probe (weighted tape measure) has been decontaminated (check for label/tag) or decontaminate as needed following SOP-A10 *Decontamination of Water Sampling Equipment.*
3) Initiate field logbook for sampling activity.
4) If a transducer is present in the well and it is necessary to remove transducer to allow well access, refer to SOP-C1, *Temporary Removal and Replacement of Transducers.*
5) Calibrate wrist-watch to the atomic clock at the Topock Compressor Station.

MEASUREMENT PROCEDURES

6) Prepare Total Depth measurement log (use attached form dated March 2005).
7) Decontaminate the entire length of the measuring tape before using, according to SOP-A10, *Decontamination of Water Sampling Equipment*.
8) Place measurement tape into well and lower until the bottom of the probe touches the bottom of the well. Note total depth (TD) measurement to mark on well casing, if there is no mark on casing measure to the north. Repeat 3 times and record final TD to the nearest hundredth of a foot on the log. Also note the condition of the well bottom (i.e. hard bottom, soft bottom). Record well identification, time, date, TD, and measurement tape identification.

9) Compare TD measurement with previous data and note discrepancies on the sampling form. Repeat step #8 if an unexpected discrepancy is noted.

10) Decontaminate the entirety of the measuring tape, or any portion of the instrument that came in contact with water, following SOP-A10, *Decontamination of Water Sampling Equipment*.

Field Staff: __________________ Topock Total Depth Survey Log Updated: March 2005

Well ID	Date	Measured Total Depth ft BTOC	Constructed Total Depth ft BTOC	Comments

SOP-A13

Spill Prevention, Containment, and Control Measures for Monitoring Well Sampling Standard Operating Procedures for PG&E Topock Program

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This standard operating procedure (SOP) addresses the procedures and equipment to be used for spill prevention, containment, and control associated with groundwater sampling activities at the Topock site. This SOP applies to containment and control of potential spills of purge and equipment decontamination water generated during the sampling of monitoring wells.

REQUIRED DOCUMENTS

1) Topock Program Health and Safety Plan (HSP).
2) Emergency Notification Binder. Note: This binder will be carried by field crews.

PREPARATION & SETUP

1) Prepare and load required spill containment equipment for use during monitoring well purging
2) Inspect reusable spill containment equipment for damage and report any damage found to the Field Task Manager.
3) Review this SOP and the Emergency Notification Binder.

EQUIPMENT LIST

- Small (4′ by 6′ by 1′ deep) "Throw N′ Go" spill containment basin for ATV trailer-mounted purge water tank, when sampling on floodplain. Containment capacity is 154 gallons on level ground.
- Large (8′ by 23′ by 1′ deep) "Throw N′ Go" spill containment basin for truck bed-mounted purge water tank. Containment capacity is 1,274 gallons on level ground
- Vinyl liner for ATV trailer-mounted purge water tank that fits inside the trailer bed, for sampling in the upload areas.
- Portable work surface (4′ x 4′ Collapse-a-tainer Lite) for 5-gallon purge buckets and smaller equipment such as water quality meters.
- Small spill containment pad (2′ x 2′).
- 5-gallon buckets
- Hydrophilic sorbent material (absorbent pads or mats).
- Hand-operated or other water pump for transferring fluids.
- Plastic sheeting/visqueen
- Shovel and/or other hand tools.
- Plastic bags for storage and disposal of used sorbent material.

GENERAL SPILL PREVENTION PRACTICES

- Do not place wet items or items that have been in the well onto the ground. All items with fluids should be placed on the small spill containment pad as a working surface
- No drops of water should hit the ground. Use either 5-gallon buckets or the small spill containment pad to avoid drops from equipment
- Only use restroom facilities at the GMP trailer or the IM3 facility.

CONTAINMENT SCENARIO 1: SAMPLING ON FLOODPLAIN

For monitoring well sampling on the floodplain, purge water is placed in a 200-gallon ATV trailer-mounted tank. The trailer-mounted tank is situated adjacent to the monitoring well to be sampled. Purge water is pumped directly into the tank via transfer hose at approximately 3 gallons per minute (gpm). Purge water from the Horiba flow cell is contained in a 5-gallon bucket and is manually transferred into the purge water tank.

Potential Spill Scenarios

- Overfill of ATV trailer-mounted purge water tank
- Spills at time of hose disconnection from tank or during manual transfer into tank from bucket
- Disrupted bucket of purge water

Required Equipment

- Small (4′ by 6′) "Throw N' Go" spill containment basin for ATV trailer-mounted purge water tan
- Vinyl liner for ATV trailer
- Portable work surface
- Small spill containment pad
- Sorbent material
- Hand-operated or other water pump for transferring fluids

Procedures

1) Deploy the ATV trailer-sized "Throw N' Go" containment basin. Situate ATV trailer with purge water tank inside the containment basin, as close to well head as possible. Secure the transfer hose in the tank opening.

2) Evaluate the remaining capacity of the tank prior to initiating well purging to ensure that there is sufficient capacity to hold the amount of purge water anticipated to be generated during purging of the well.

3) Any buckets for purge water and smaller equipment such as the Horiba must be placed inside the portable work surface prior start of purging.

4) During purging, field staff will remain at the discharge end of the hose and will monitor transfer of water into the purge water tank. If tank approaches being full, discontinue purging.

5) If there are any small drips that arise (i.e. from hose fittings), immediately place the small spill containment pad underneath the drip.

6) At completion of purging, when disconnecting the transfer hose from the tank opening, perform hose disconnection within the containment basin to ensure that any drips or spills of purge water are contained within the basin. If any purge water is present in the containment basin, transfer the water into the purge water tank.

7) Secure purge water tank openings and ensure that the tank is well secured to the ATV trailer. Remobilize to the next well to be sampled.

8) Repeat the preceding steps at the next well to be sampled.

9) When the ATV trailer-mounted purge water tank is full, continue with procedures under Containment Scenario 3.

CONTAINMENT SCENARIO 2: SAMPLING IN NON-FLOODPLAIN AREA

For monitoring well sampling in non-floodplain areas of the site, wells can be accessed by truck, and purge water is placed in a 400-gallon truck bed-mounted tank. Purge water is pumped directly into this tank via transfer hose at rates up to 10 gpm. Purge water from the Horiba flow cell is contained in a 5-gallon bucket and is manually transferred into the purge water tank.

Potential Spill Scenarios

- Overfill of truck bed-mounted purge water tank
- Spills at time of hose disconnection from tank or during manual transfer into tank from bucket
- Disrupted bucket of purge water

Required Equipment

- Large (8′ by 23′) “Throw N′ Go” spill containment basin for truck bed-mounted purge water tank
- Portable work surface
- Small spill containment pad
- Sorbent material
- Hand-operated or other water pump for transferring fluids

Procedures

1) Deploy the truck-sized “Throw N′ Go” containment basin. Situate truck with purge water tank inside the containment basin, as close to well head as possible. Secure transfer hose in tank opening.

2) Evaluate the remaining capacity of the tank prior to initiating well purging to ensure that there is sufficient capacity to hold the amount of purge water anticipated to be generated during purging of the well.

3) Any buckets for purge water and smaller equipment such as the Horiba must be placed inside the portable work surface prior start of purging.

4) During purging, field staff will remain at the discharge end of the hose and will monitor transfer of water into the purge water tank. If tank approaches being full, discontinue purging.

5) If there are any small drips that arise (i.e. from hose fittings), immediately place the small spill containment pad underneath the drip.

6) At completion of purging, when disconnecting the transfer hose from the tank opening, perform hose disconnection within the containment basin to ensure that any drips or spills of purge water are contained within the basin. If any purge water is present in the containment basin, transfer the water into the purge water tank.

7) Secure purge water tank openings and ensure that the tank is well secured to the truck bed. Remobilize to the next well to be sampled.

8) Repeat the preceding steps at the next well to be sampled.

9) When the truck-mounted purge water tank is full, continue with procedures under Containment Scenario 4.

CONTAINMENT SCENARIO 3: TRANSFER OF PURGE WATER FROM ATV TRAILER-MOUNTED TANK TO TRUCK BED-MOUNTED TANK

When the ATV trailer-mounted purge water tank requires emptying to a truck bed-mounted tank, the following procedures will be used. Purge water is transferred using a sump pump and transfer hose at rates up to 10 gpm.

Potential Spill Scenarios

- Overfill of truck bed-mounted poly tank
- Pump or transfer hose leakage during pumping into tank or at time of hose disconnection

Required Equipment

- Large (8′ by 23′) "Throw N′ Go" spill containment basin for truck bed-mounted purge water tank
- Small (4′ by 6′) "Throw N′ Go" spill containment basin for ATV trailer-mounted purge water tank
- Sorbent material
- Hand-operated or other water pump for transferring fluids

Procedures

1) Ensure that the truck with truck bed-mounted purge water tank is situated within its containment basin.

2) Deploy the ATV trailer-sized containment device. Situate ATV trailer with purge water tank inside the containment basin, as close to the truck as possible.

3) Evaluate the remaining capacity of the truck bed-mounted tank prior to initiating transfer from the ATV trailer-mounted tank, to ensure that there is sufficient capacity to hold the amount of purge water to be transferred.

4) Using sump pump and transfer hose, pump water from the ATV trailer-mounted tank to the truck bed-mounted tank. Field staff will be present during the entire transfer to

monitor the water level in the receiving tank and to ensure no leakage or spills occur. If the tank approaches being full, discontinue transfer operations.

5) At the completion of transfer operations, when disconnecting the transfer hose from the receiving tank opening, perform hose disconnection within the containment basin to ensure that any drips or spills of purge water are contained within the basin. If any purge water is present in the containment basin, transfer the water into the purge water tank.

6) Secure purge water tank openings and ensure that the tank is well secured to the truck bed.

7) When the truck-mounted purge water tank is full, continue with procedures under Containment Scenario 5.

CONTAINMENT SCENARIO 4: TRANSFER OF PURGE WATER FROM TRUCK BED-MOUNTED TANK TO FINAL STORAGE LOCATION

When the truck bed-mounted purge water tank requires emptying, the following procedures will be used. Purge water is transferred into a 5,500-gallon storage tank at the PG&E Topock Compressor Station, at rates up to 20 gpm. The 5,500-gallon tank is located within a permanent containment structure.

Potential Spill Scenarios

- Overfill of tank at final storage location
- Pump or transfer hose leakage during pumping into tank or at time of hose disconnection.

Required Equipment

- Large (8′ by 23′) “Throw N′ Go” spill containment basin for truck bed-mounted purge water tank
- Sorbent material
- Hand-operated or other water pump for transferring fluids

Procedures

1) Ensure that the truck with bed-mounted tank is situated within its containment basin.

2) Evaluate the remaining capacity of the receiving tank prior to initiating transfer from the truck-mounted tank, to ensure that there is sufficient capacity to hold the amount of purge water to be transferred.

3) Using pump and transfer hose, pump water from the truck-mounted tank to the receiving tank. Field staff will be present during the entire transfer to monitor the water level in the receiving tank and to ensure no leakage or spills occur. If the receiving tank approaches being full, discontinue transfer operations.

4) At the completion of transfer operations, when disconnecting the transfer hose from the receiving tank opening, perform hose disconnection within the containment basin to

ensure that any drips or spills of purge water are contained within the basin. If any purge water is present in the containment basin, transfer the water into the purge water tank.

5) Secure tank openings on the receiving tank.

SPILL RESPONSE ACTIONS

In the event purge water is spilled outside of containment basins, the field team will take the following actions.

Required Equipment

- Sorbent material
- Plastic sheeting/visqueen
- Hand-operated or other water pump for transferring fluids
- Shovel and/or other hand tools
- 5-gallon buckets
- Plastic bags for storage and disposal of used sorbent material

Procedures

1) To the extent possible, use sorbent material and plastic sheeting/visqueen to contain the spilled purge water.

2) With the exception of the low-impact area of the floodplain, dig a small pit and line with visqueen to serve as a containment area for collection of spilled purge water. Use of this technique will be limited to only those areas where water does not immediately percolate into the ground surface. DO NOT dig into the ground or otherwise disturb the ground surface in the low-impact area of the floodplain.

3) Transfer any contained purge water into the purge water tank.

4) Manually dig up any saturated soil and place in 5-gallon bucket(s) or other appropriate containers. DO NOT dig into the ground or otherwise disturb the ground surface in the low-impact area of the floodplain.

5) Dispose of containerized soil, used sorbent material, and gloves in accordance with SOP-B6, *Disposal of Waste Fluids and Solids (IDW)*.

6) Perform notifications as required in the Emergency Notification Binder. Complete the Notification Documentation Form provided in the Binder.

SOP-A6

Sample Field Filtration and Preservation for Metals Analyses
Standard Operating Procedures for PG&E Topock Program

This standard operating procedure (SOP) addresses the procedures and equipment to be used for collecting groundwater / surface water samples for field filtered metals analyses at the Topock site. Refer to SOP- A1, A2, A3, or A4 for specific groundwater and surface water sampling methods.

REQUIRED DOCUMENTS

1) Event-specific sampling and analysis plan (SAP).
2) Applicable project work plan or monitoring plan. Refer to Topock Program Sampling, Analysis, and Field Procedures Manual and QAPP (Procedures Manual), as required.
3) Topock Program Health and Safety Plan (HSP)
4) Previous sampling logs
5) Blank sampling logs and field notebook

PREPARATION & SETUP

1) Review event-specific SAP or event-specific field instructions, previous sampling logs, Procedures Manual, and HSP.
2) Initiate field logbook for sampling activity.
3) Inventory sample bottles, required analyses, and lab courier schedule.
4) Field-check and setup sampling equipment: field filters, buffering solution, acid, and sample bottles.

FIELD-FILTRATION AND SAMPLE COLLECTION PROCEDURES FOR GROUNDWATER FROM MONITORING AND EXTRACTION WELLS

1) Follow SOPs A1 and A2.

Sample Collection

1) Once parameters are stabilized and a minimum 3-casing volumes have been removed from the well, disconnect the tubing from the flow-through cell and connect the inline 0.45 micron filter.
2) Allow 500 milliliters to flow through the inline filter. Fill the sample container by transferring water directly from the filter discharge to the appropriate sample container.

Total Chromium and Metals Method SW 6010B

(i) Fill a laboratory provided pre-preserved sample bottle (250 ml poly containing HNO_3) or unpreserved sample bottle (250 mL poly) with the sample to the top of the bottle neck. CARE MUST BE TAKEN NOT TO OVERFILL THE BOTTLE.

(ii) Test the pH of the sample with laboratory provided pH paper.

(iii) If the pH of the sample is greater than 2, add 5 drops of HNO_3. Close the bottle, shake, test pH. Continue adding HNO_3 in 5-drop increments until the pH is less than 2.

(iv) Record the total amount of HNO_3 added to the sample and the pH on the chain of custody and field form. Seal, label, and place the sample on ice.

Hexavalent Chromium Method SW 7196A

(i) Fill a laboratory provided sample bottle (250 mL poly) to the top of the bottle neck.

(ii) Seal, label, and place the sample on ice.

Hexavalent Chromium Method SW 7199

(i) Fill a laboratory provided sample bottle (250 mL poly) to approximately 235 mL, leaving headspace for the addition of buffer solution.

(ii) Add 3 mL of laboratory provided buffer solution using a pipette. Place the lid on the sample bottle and shake gently. Test the pH using laboratory provided pH strips.

(iii) If the pH is less than 9, add ten drops (0.5 mL) of buffer solution, close bottle and shake gently. Test pH using laboratory provided pH strips. If the pH is less than 9, continue adding the buffer solution in 10-drop increments until the pH is between 9 and 9.5 or until 12.5 mL of buffer solution is added.

(iv) If the pH is less than 9 and 12.5 mL of buffer solution has been added, add one drop of 20% NH_4OH, close bottle, gently shake, test pH. Continue until the pH is between 9 and 9.5.

(v) When the pH of the sample is between 9 and 9.5, record the total amount of pH buffer and 20% NH_4OH added to the sample and the pH of the sample on the chain of custody and field form. Seal, label, and place the sample on ice.

3) Discard used pH paper(s) and filter in IDW bin.

4) Record sample information, final WL, and purge volume data on field log.

FILTRATION AND SAMPLE COLLECTION PROCEDURES FOR SURFACE WATER AND GROUNDWATER FROM PRODUCTION WELLS

5) Follow SOP-A4 for surface water and SOP-A3 for production well sampling.

Sample Collection

6) At the support vehicle, use a peristaltic pump to pump collected surface water from the 1-liter laboratory-provided sample container through an inline 0.45 micron filter. 500 milliliters of sample should be passed through the filter prior to sample collection.

7) Sample containers are to be filled by transferring water directly from the filter discharge to the appropriate sample container.

Total Chromium and Title 22 Metals Method SW 6010B

(i) Fill a laboratory provided pre-preserved sample bottle (250 ml poly containing HNO_3) or unpreserved sample bottle (250 mL poly) with the sample to the top of the bottle neck. CARE MUST BE TAKEN NOT TO OVERFILL THE BOTTLE.

(ii) Test the pH of the sample with laboratory provided pH paper.

(iii) If the pH of the sample is greater than 2, add 5 drops of HNO_3. Close the bottle, shake, test pH. Continue adding HNO_3 in 5-drop increments until the pH is less than 2.

(iv) Record the total amount of HNO_3 added to the sample and the pH on the chain of custody and field form. Seal, label, and place the sample on ice.

Hexavalent Chromium Method SW 7196A

(i) Fill a laboratory provided sample bottle (250 mL poly) to the top of the bottle neck.

(ii) Seal, label, and place the sample on ice (no field preservation required).

Hexavalent Chromium Method SW 7199

(i) Fill a laboratory provided sample bottle (250 mL poly) to approximately 235 mL, leaving headspace for the addition of buffer solution.

(ii) Add 3 mL of laboratory provided buffer solution using a pipette. Place the lid on the sample bottle and shake gently. Test the pH using laboratory provided pH strips.

(iii) If the pH is less than 9, add ten drops (0.5 mL) of buffer solution, close bottle and shake gently. Test pH using laboratory provided pH strips. If the pH is less than 9, continue adding the buffer solution in 10-drop increments until the pH is between 9 and 9.5 or until 12.5 mL of buffer solution is added.

(iv) If the pH is less than 9 and 12.5 mL of buffer solution has been added, add one drop of 20% NH_4OH, close bottle, gently shake, test pH. Continue until the pH is between 9 and 9.5.

(v) When the pH of the sample is between 9 and 9.5, record the total amount of pH buffer and 20% NH_4OH added to the sample and the pH of the sample on the chain of custody and field form. Seal, label, and place the sample on ice.

8) Discard used pH paper(s), filter, and initial sample collection bottle in IDW bin.

9) Record sample information on field log.

SOP-A7

Water Level Measurements
Standard Operating Procedures for PG&E Topock Program

This standard operating procedure (SOP) addresses the procedures and equipment to be used for manually measuring the depth to water at surface water locations, groundwater monitoring wells and production wells.

REQUIRED DOCUMENTS

1) Event-specific sampling and analysis plan (SAP).
2) Applicable project work plan or monitoring plan. Refer to Topock Program Sampling, Analysis, and Field Procedures Manual and QAPP (Procedures Manual), as required.
3) Topock Program Health and Safety Plan (HSP)
4) Well construction logs/specifications
5) Previous water level data
6) Blank sampling logs and field notebook

PREPARATION & SETUP

1) Review event-specific SAP or event-specific field instructions, previous sampling logs, Procedures Manual, and HSP.
2) Ensure that the WL meter has been decontaminated (check for label/tag) or decontaminate as needed following SOP-A10 *Decontamination of Water Sampling Equipment.*
3) Initiate field logbook for sampling activity.
4) Inspect all equipment and calibrate water level meters if multiple meters are being used according to SOP-A9, *Calibration of Field Instruments*.
5) If a transducer is present in the well and it is necessary to remove transducer to allow well access, refer to SOP-C1, *Temporary Removal and Replacement of Transducers.*
6) Calibrate wrist-watch to the atomic clock at the Topock Compressor Station.

MEASUREMENT PROCEDURES

7) Prepare groundwater sampling log (use attached form dated March 2005).
8) At the beginning of a sampling event, if a decontamination label is not visible/complete on the water level meter to be used, proceed with decontamination of equipment. If present, remove the tag prior to use.
   During a sampling event, if the water level meter is not noted as decontaminated in the field notes, decontaminate the lower 5 feet of the water level probe before using according to SOP-A10*, Decontamination of Water Sampling Equipment*.

9) Place water level probe into well or from surface water monitoring point and lower until sensor sounds. Shake the line to remove any retained water. Note depth to water (DTW) measurement to mark on well casing, if there is no mark on casing measure to the north. Repeat 3 times and record final DTW to the nearest hundredth of a foot on the sampling log. Record well identification, time, date, DTW, and water level meter number.

10) Compare DTW measurement with previous data and note discrepancies on the sampling form. Repeat step #8 if an unexpected discrepancy is noted.

11) Decontaminate the lower five feet of measuring tape, or any portion of the instrument that came in contact with water, by unwinding the tape and following SOP-A10, *Decontamination of Water Sampling Equipment*. Record decontamination procedures and the serial number of the water level meter in the field book. If the field event is complete, attach a label to the water level meter and note decontamination procedure, initials, and date, and place the water level meter in a clean plastic bag.

SOP-A8

Field Water Quality Measurements Using a Flow-through Cell Standard Operating Procedures for PG&E Topock Program

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This Standard Operating Procedure (SOP) provides general guidelines for using the Horiba® U-22 meter and flow-through cell or similar device for field measurements of pH, specific conductance, turbidity, dissolved oxygen, oxidation-reduction potential (ORP), and temperature of groundwater samples. Additionally addressed are procedures for measuring water sample turbidity using the Hach turbidity meter. The manufacturer's manual should be consulted for detailed calibration and operating procedures.

REQUIRED DOCUMENTS

1) Event-specific sampling and analysis plan (SAP).
2) Applicable project work plan or monitoring plan. Refer to Topock Program Sampling, Analysis, and Field Procedures Manual and QAPP (Procedures Manual), as required.
3) Topock Program Health and Safety Plan (HSP)
4) Manufacturer Manuals
5) Previous sampling logs
6) Blank sampling logs and field notebook

PREPARATION & SETUP

1) Review event-specific SAP or event-specific field instructions, previous sampling logs, Procedures Manual, and HSP.
2) Initiate field logbook for sampling activity.
3) Inspect all equipment : Horiba® U-22 Water Quality Meter with flow-through cell, or similar device; Hach turbidity meter; distilled water in squirt bottle.
4) Prior to each day's use, clean the probes and flow-through cell according to manufacturer's directions and calibrate the field water quality (WQ) meters according to SOP-A9, *Calibration of Field Instruments*.

The Horiba® U-22 meter is capable of measuring the following parameters:

Parameter	Range of Measurement	Accuracy
pH	0 – 14 pH	+/- 0.1 pH units
Specific Conductivity	0 – 100 mS/cm	+/- 3 % full scale
Dissolved Oxygen	0 – 19.9 mg/l	+/- 0.2 mg/l
Temperature	0 – 55 °C	+/- 1.0 °C
ORP	-1999 mv - +1999 mv	+/- 15 mV
Salinity	0 - 4 %	+/- 0.3 %
Turbidity	0 – 800 NTU	+/- 5 % full scale

Note: Experience with field instruments indicates the Hach® turbidity meter provides a more consistent and responsive measurement of turbidity compared to the turbidity probe on the Horiba® U-22. Therefore, the Hach® turbidity meter should be used for turbidity measurements when available.

SAMPLE MEASUREMENT PROCEDURES

1) Connect the discharge tubing from the pump to the inlet side (bottom port) of the flow-through cell.
2) Connect the discharge tubing to the outlet side (top port) of the flow-through cell.
3) Place the discharge tube in a purge water collection vessel.
4) Record the time and start the pump.
5) Establish a suitable discharge rate of the pump that is consistent with the SAP and guidance.
6) Allow the well drawdown to stabilize and the temperature of the flow-through cell to equilibrate with the water temperature.
7) Turn the meter on to the measure mode.
8) Record water quality readings at regular intervals every three minutes; however the time interval between successive readings should not be shorter than the recharge time of the flow-through cell. For example, if the volume of the flow-through cell is 375 mL and the stabilized discharge rate is 137 mL/minute, the water quality readings should be at least 3 minutes apart.
9) Fill the sample vial associated with the Hach turbidity meter from the flow-through cell's discharge point. Wipe the vial dry and place in the Hach meter . Close the lid of the Hach meter completely and record the turbidity of the sample by pressing 'Read'. Adjust the range as needed.

10) Record the water quality information, volume of water discharged, the ending water quality characteristics, the ending water level, and the sample time and number in the field logbook and/or field sampling data sheet, if used.

Key Checks and Preventive Maintenance

- Calibrate meter.
- Clean probe with distilled water when done.
- If probes are dirty, rinse with a weak Alconox solution in the flow-through cell. If the device still does not calibrate, rinse with weak Alconox solution, isopropyl alcohol, Alconox, and rinse well with distilled or tap water.
- Store device using tap water. Use of deionized water will ruin the probes.
- Refer to operations manual for recommended maintenance.
- Check batteries, and have a replacement set on hand.

SOP-A9

Calibration of Field Instruments
Standard Operating Procedures for PG&E Topock Program

This standard operating procedure (SOP) addresses the procedures and equipment to be used for calibration of field instruments at the Topock site. This SOP should be used for calibration of water level meters, Horiba-U22, Orion meter, and a Hach turbidity meter.

Required Documents

1) Event-specific sampling and analysis plan (SAP).
2) Applicable project work plan or monitoring plan. Refer to Topock Program Sampling, Analysis, and Field Procedures Manual and QAPP (Procedures Manual), as required.
3) Equipment Manufacturers' Manual
4) Previous Calibration Records
5) Field Equipment Binder (documents equipment servicing, calibration, etc..)
6) Blank Calibration Sheets (see attached)

Preparation and Setup

1) Initiate field log sampling book for activity.
2) Inspect all equipment necessary to carry out activities detailed in event-specific SAP.
3) Always use fresh solutions for calibration.
4) Calibration should be performed prior to initiating sampling each day.
5) Review Field Equipment Binder equipment servicing records to anticipate next service.
6) All equipment and solutions are stored in an air-conditioned office onsite to maintain the integrity. Due to extreme temperature at the site, all calibrations are performed within this office.
7) The Horiba U-22 or Horiba U-23 and Hach turbidity meter shall be used as the principal field instruments for measuring water quality parameters during groundwater and surface water sampling. Use of the Orion pH/ORP meter should be restricted to field laboratory due to the less robust mechanics of the Orion and the specific design of the Horiba as a field instrument. If a Horiba instrument initial calibration fails and cannot be properly calibrated after repeated attempts and a replacement Horiba instrument is not available at the time, the Orion can be used as a field instrument on a temporary basis until a replacement Horiba is obtained.

<u>*Horiba U-22 – Equipment List:*</u>

-Autocal solution
-Level II solution
-Zobell's ORP check solution

-Spare batteries
-DI water

<u>*Orion pH/ORP Meter – Equipment List*</u>

-pH 7 and 10 calibration standards
-Zobell's ORP check solution
-DI water
-Spare batteries

<u>*Hach Turbidity Meter – Equipment List*</u>

-Hach DI water, NTU =0
-Gell standard solutions, NTU= 10 and NTU=100
-Spare Batteries

Calibration Procedures

Horiba U-22

1) Check expiration date of calibration solution and discard if expired.
2) Fill Horiba calibration cup to fill line with fresh autocal solution.
3) Remove storage cap (containing DI water) from probes and place probes into the calibration cup.
4) Allow approximately 10 minutes for probe stabilization (view 'read parameter' screen to determine).
5) Follow procedures in Horiba U-22 manual for auto-calibration using autocal solution.
6) Once auto-calibration is complete, check the accuracy by recording all parameters in the measurement mode. Record Horiba serial number, measured parameters, date, and time on the calibration sheet.
7) If measured parameters are not within acceptable limits (+/-0.1 pH units and +/-10% for specific conductance), repeat procedure as needed and investigate equipment malfunction. Note temperature as standard values are expected at 25^{0}C.
8) Discard used auto-cal solution.
9) Rinse calibration cup and probes with DI water.
10) Fill calibration cup to fill line with Level II solution.
11) Place probes in calibration cup.
12) Allow approximately 10 minutes to equilibrate.
13) Operate Horiba in read mode and record field parameter measurements on the calibration sheet.

14) If measured parameters are not within acceptable limits (+/-0.1 pH units and +/-10% for specific conductance), perform manual calibration of each parameter standard to match Level II solution. Note temperature as standard values are expected at 25^{0}C.

15) Operate Horiba in read mode and record field parameter measurements on the calibration sheet.

16) Discard used Level II solution.

17) Rinse probes with DI water.

18) Mix a fresh bottle of Zobell's solution using DI water as per manufacturer's instructions.

19) Fill calibration cup with the Zobells's solution

20) Place probes into calibration cup.

21) Allow 10 minutes to equilibrate (view 'read parameter' screen to determine).

22) Operate Horiba in read mode and record field parameter measurements, temperature, time, and date on field calibration sheet.

23) If ORP exceeds +/- 25mV troubleshoot and repeat calibration. If the discrepancy persists, mark meter as "Not in Service" and use a different Horiba if available. Otherwise, use the Orion ORP meter.

24) Cap probes with transfer cup containing DI water.

25) Proceed with field measurements as needed while noting:

   -probes must be rinsed thoroughly with DI water after each well.
   -probes must always be submersed in liquid (DI water when not in use).
   –absolutely no air bubbles nor leaks should be present in the flow-through cell, repair and/or replace as needed.
   –ensure all readings have stabilized prior to recording a measurement.
   –all field parameters must be compared with previous data and documented on the field data sheet.

Orion pH/ORP Meter

1) Inspect electrode for scratches, cracks, salt crystal build-up, or membrane/junction deposits.

2) Rinse off any salt build-up with DI water. Follow manufacturer cleaning procedures if needed.

3) Check expiration date of calibration solution and discard if expired.

<u>pH probe</u>

1) Attach the pH probe to the Orion meter.

2) Rinse electrode with DI water.

3) Place electrode into fresh container of pH 7 and wait until reading stabilizes.

4) Record reading, time, and date on field calibration sheet.

5) Rinse electrode with DI water and then pH 10 buffer.
6) Place electrode in container of pH 10 buffer and wait until reading stabilizes.
7) Set meter to the actual pH value of the buffer.
8) Record reading, time, and date on field calibration sheet.
9) If the slope is between 92 and 102% or < +/- 0.1 pH units, proceed with pH measurements. If values are not within this range, troubleshoot and repeat as needed.

<u>ORP probe</u>

1) Mix a fresh bottle of Zobell's solution using DI water as per manufacturer's instructions.
2) Attach the ORP probe to the Orion meter.
3) Rinse electrode with DI water.
4) Place electrode into fresh container of Zobell's, wait at least 10-15 minutes until reading stabilizes.
5) Record ORP, temperature, time, and date on field calibration sheet.
6) Use the temperature/ORP table to determine the standard and compare.
7) If ORP is within 25 mV proceed with ORP measurements. If ORP is not +/- 25 mV, troubleshoot and repeat as needed.

Hach Turbidity Meter

1) Perform a check as per manufacturer's instructions with Hach DI water and standard solutions.
2) Record reading, time, and date on calibration sheet for both DI water and standard solution.
3) If the readings are within 10%, proceed with turbidity measurements; If not within this range, troubleshoot and repeat as needed.

Water-level Meters

When using multiple water-level meters at the site it is necessary to calibrate each against each-other at least once during the sampling event using the following procedure:

1. At a well with shallow depth to water (less than 20 feet), without dedicated tubing, piping, pump, or transducer, lower each water level meter into the well and record the reading to the nearest hundredth of a foot on the calibration sheet along with water-level meter number, time, and date.
2. Repeat step #1 at a well with deep depth to water (greater than 70 feet).

Horiba U-22/U-23, ORION, and Hach Turbidity Meter Calibration Sheet
Project Site: PG&E Topock

Updated: February 2005

Calibrate each day prior to inititating sampling following SOP-A9.

U-22 instrument serial #								
Auto Calibration Performed: Y / N	**Units**	**Date/Time**	**Standard**	**Measured**	**Standard**	**Measured**	**Standard**	**Measured**
Auto Calibration solution reading:								
pH	pH		4.00		4.00		4.00	
Conductivity	mS/cm		4.49		4.49		4.49	
Turbidity	ntu							
DO	mg/L							
Temperature	celsius		25.00		25.00		25.00	
Salinity	%							
TDS	g/L							
ORP	mV (Ag/AgCl)							
Manufacturer, expiration date, lot number of auto calibration solution								
Manual Calibration Performed: Y / N								
Readings (Auto Calibration solution)								
pH	pH							
Conductivity	mS/cm							
Turbidity	ntu							
DO	mg/L							
Temperature	celsius							
Salinity	%							
TDS	g/L							
ORP	mV (Ag/AgCl)							
Manufacturer, expiration date, lot number of auto calibration solution								
Level II Solution Readings								
pH	pH		6.68		6.68		6.68	
Conductivity	mS/cm		53.00		53.00		53.00	
Turbidity	ntu		10 or 100		10 or 100		10 or 100	
DO	mg/L							
Temperature	celsius							
Salinity	%							
TDS	g/L							
ORP	mV (Ag/AgCl)							
Manufacturer, expiration date, lot number of solution								
Manual Calibration Performed: Y / N								
Readings (Level II solution)								
pH	pH							
Conductivity	mS/cm							
Turbidity	ntu							
DO	mg/L							
Temperature	celsius							
Salinity	%							
TDS	g/L							
ORP	mV (Ag/AgCl)							

Auto Calibration Performed: Y / N	Units	Date/Time	Standard	Measured	Standard	Measured	Standard	Measured
Auto Calibration solution reading:								
ORP - Zobell Check Only								
Temperature	celsius							
ORP	mV (Ag/AgCl)							
Manufacturer, expiration date, lot number of solution								
Within 25 mV of ORP standard? Y / N								
End of Day Zobell Check								
Temperature	celsius							
ORP	mV (Ag/AgCl)							
ORION Serial #								
pH 7 calibrated: Y / N								
pH 7 solution reading								
pH 10 Calibrated: Y / N								
pH 10 Solution Reading								
Manufacturer, expiration date, lot number of solution								
ORP - Zobell Check Only								
pH	pH							
Conductivity	mS/cm							
Turbidity	ntu							
DO	mg/L							
Temperature	celsius							
Salinity	%							
TDS	g/L							
ORP	mV (Ag/AgCl)							
Manufacturer, expiration date, lot number of solution								
Within 25 mV of ORP standard? Y / N								
Turbidity meter serial #								
	Units		**Standard**	**Measured**	**Standard**	**Measured**	**Standard**	**Measured**
Hach DI water reading	NTU		0					
Standard Solution Reading	NTU		10 or 100					
Manufacturer, expiration date, lot number of solution								
			DTW at one site well					
Water Level Meter ID								
Water Level Meter ID								
Water Level Meter ID								

Notes: * From the measured temperature value, find the closest standard temperature from the Zobell table and use the corresponding ORP standard.

Zobell solution-Temp/ORP Table

Temp in deg C	ORP (Ag/AgCl) (4M KCl) mV	Temp in deg C	ORP (Ag/AgCl) (4M KCl) mV
-5	270.0	23	233.6
-4	268.7	24	232.3
-3	267.4	25	231.0
-2	266.1	26	229.7
-1	264.8	27	228.4
0	263.5	28	227.1
1	262.2	29	225.8
2	260.9	30	224.5
3	259.6	31	223.2
4	258.3	32	221.9
5	257.0	33	220.6
6	255.7	34	219.3
7	254.4	35	218.0
8	253.1	36	216.7
9	251.8	37	215.4
10	250.5	38	214.1
11	249.2	39	212.8
12	247.9	40	211.5
13	246.6	41	210.2
14	245.3	42	208.9
15	244.0	43	207.6
16	242.7	44	206.3
17	241.4	45	205.0
18	240.1	46	203.7
19	238.8	47	202.4
20	237.5	48	201.1
21	236.2	49	199.8
22	234.9	50	198.5

SOP-B1

General Guidance for Monitoring Well Installation and Development Standard Operating Procedures for PG&E Topock Program

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This Standard Operating Procedure provides site personnel with a review of well installation procedures. These procedures are to be considered general guidelines only and are in no way intended to supplement or replace the contractual specifications in the driller's subcontract.

REQUIRED DOCUMENTS

1) Event-specific sampling and analysis plan (SAP).
2) Applicable project work plan or monitoring plan. Refer to Topock Program *Sampling, Analysis, and Field Procedures Manual* and *Quality Assurance Project Plan* (Procedures Manual), as required.
3) Topock Program Health and Safety Plan.
4) Well construction logs/specifications.
5) Previous sampling logs or tabular historic field data.
6) Blank sampling logs and field notebook.
7) Blank CH2M HILL Well Completion Diagrams.

EQUIPMENT LIST

- Drilling rig (hollow stem auger, sonic, air hammer, air rotary, or mud rotary).
- Polyvinyl chloride (PVC), Schedule 40, minimum 2-inch-diameter, flush-threaded, blank casing; alternatively, stainless-steel casing.
- PVC, Schedule 40, minimum 2-inch-inside-diameter, flush-threaded, factory-slotted screen; alternatively, stainless-steel casing.
- PVC or stainless-steel centering guides (if used).
- Above-grade well completion: PVC, threaded or push-on type, vented cap.
- Clean silica sand, in-factory-sealed bags, non-reactive, rounded, water-washed for constructing the primary (coarse) filter pack and secondary (fine optional) filter pack. Grain size determined based on sediments observed during drilling, geotechnical tests, or from previous well installations.
- Pure, additive-free bentonite pellets, chips, and/or powder.
- Coated bentonite pellets.
- Portland cement.

- Above-grade well completion: minimum 6-inch-inside-diameter steel pipe with locking cover, diameter at least 2 inches greater than the well casing, painted for rust protection; heavy duty lock; protective posts if appropriate.
- Flush-mount well completion: Morrison 9-inch or 12-inch 519 manhole cover or equivalent; rubber seal to prevent leakage; locking cover inside of traffic-rated box.
- Single- or double-surge block with solid bottom, open top, separated by 2 feet of slotted pipe (double surge block only).
- Well-development pump, pump controller, and steam cleaner.
- Calibrated meter(s) to measure pH, temperature, specific conductance, turbidity, dissolved oxygen, and total dissolved solids (TDS) of purged water during well development.
- Containers (Department of Transportation [DOT]-approved 5-gallon drums or trailer-mounted water tank) for water produced from well.

GUIDELINES

1) Wells will be installed in accordance with standard United States Environmental Protection Agency (USEPA) procedures.
2) The threaded connections will be water-tight.
3) Well screens generally will be constructed of 10-slot or 20-slot Schedule 40 PVC and will be 10 to 20 feet long, depending on the requirements of the well. The exact slot size and length will be determined by the field team supervisor. Stainless steel may be required under certain contaminant conditions.
4) Wells will be surrounded by four concrete-filled, 3-inch-diameter guard posts.
5) A record of the finished well construction will be compiled.
6) All soils and liquids generated during well installations will be placed in lined, roll-off containers pending proper disposal.

WELL TYPES

There are several basic types of monitoring wells: single-cased, double-cased, clustered, nested, and multiple-port wells. The first three are recommended for general use in most hydrogeologic investigations.

Single-cased Wells. A single-cased well consists of a section of slotted well screen connected to a riser pipe that extends to above or just below the ground surface. An artificial filter pack is placed in the annulus between the screen and the borehole to 2 to 3 feet above the top of the well screen. A transitional seal fills the annular space directly above the filter pack, followed by bentonite-cement or sand-cement grout to the ground surface.

Double-cased Wells. Double- or multiple-cased wells are often installed when the aquifer zone to be sampled must be isolated from overlying aquifer zones to prevent cross contamination between aquifer zones. Typically, a large-diameter boring (14 to 16 inches or more in diameter) is drilled into a low-permeability material (clay) immediately below the zone to be sealed off. Steel conductor casing with welded joints and an outside diameter that is at least 4 inches smaller than the hole diameter is lowered into the borehole, centered, and pushed into the clay up to 10 feet. A bentonite-cement or sand-cement grout is then pumped through a tremie pipe into the annular space, between the conductor casing and the formation from the bottom up to the ground surface.

Clustered Wells. Well clusters consist of two or more wells installed in proximity to one another but screened at different intervals in different boreholes. Single- and double-cased wells may both be included in the well cluster. Well cluster systems allow sampling of groundwater from different aquifers or from different zones within the same aquifer with essentially no risk of cross contamination between the aquifers. Installation procedures for each well in a well cluster are the same as for single- or double-cased wells.

Nested Wells. Nested wells consist of more than one well casing installed in a single borehole. Nested wells allow groundwater sampling and measurement of water levels from two or more different zones or aquifers using one borehole. Each well is screened at a different depth, and seals are placed above and below each well screen.

Multiple-port Wells. Multiple-port wells have multiple screens on the same casing string with sampling ports at different depths separated by inflatable or mechanical packers. This arrangement allows for discrete sampling at different depths across a large vertical extent in one thick aquifer or in several thinner ones.

PROCEDURES

Monitoring Well Installation

This section presents procedures for the installation of the monitoring wells, including discussion of borehole completion; installation of the casing and screen, artificial filter pack, and borehole seals; and surface completion.

1) Monitoring wells in unconsolidated materials will be installed in at least 6-inch-diameter boreholes to accommodate well completion materials in designated locations.

2) Monitoring wells in unconsolidated materials will be constructed of 2-inch-diameter, factory manufactured, flush-jointed, Schedule 40 PVC screen with threaded bottom plug and riser.

3) Screens will be filter packed with a properly-sized, properly-graded, thoroughly-washed, sound, durable, well-rounded basalt or siliceous sand. When using sonic drill casing, the filter pack will be installed by slowly pouring the sand into the annular space while raising the casing in 1 to 3 foot intervals and using a weighted tape to sound for the sand surface.

4) Following each lift of the drill casing, the well casing height will be checked for settling or to see if the casing was pulled up.

5) The primary filter sand pack (typically Monterey #3 or equivalent) will extend from 1 to 2 feet below the base to 2 feet above the top of the screen; for non-sonic drilling methods the filter pack will be allowed to settle and hydrate before final measurement is taken. Alternately, a surge block can be used to agitate the sand and facilitate settling. For sonic drilling, the vibration induced during casing removal serves to properly settle the sand.

For wells that are installed with approved screen lengths longer than 20 feet, the filter pack will be proportionally extended above the top of the screen to allow for settling of the longer pack.

6) A secondary filter sand pack (typically Monterey #30 or equivalent) 1 foot thick will be placed above the primary sand pack.

7) Annular well seals will consist of 2 to 5 feet of pelletized or granular bentonite clay placed above the filter pack. If necessary, the pellets will be hydrated using potable water. For wells drilled using sonic, the bentonite will be poured into the annular space while raising the drill casing in 1- to 3-foot increments and sounding for the top of the bentonite with a weighted tape. The height of the well seal also will be sounded with a weighted tape.

8) The top of the annular seal will be measured after the pellets have been allowed to hydrate and before the grout is applied. The pellets will be allowed to hydrate for at least 30 minutes before work in the well continues.

9) The annular space above the bentonite seal will be filled to grade with a bentonite-cement slurry grout mixture.

10) The grout mixture consists of 94 pounds of cement (1 bag) per 6 gallons of water and 2 to 3 pounds of powdered bentonite per bag of cement to reduce shrinkage.

11) The grout mix will be carefully applied to avoid disturbing the bentonite seal; the method of grout placement must force grout from the bottom of the space to be grouted to the surface.

12) After allowing the grout to settle and set up overnight, additional grout will be added to maintain grade.

13) A protective steel casing equipped with keyed-alike locking caps will be grouted in place for each new well; the casing will extend at least 2 feet above grade and 3 feet below grade and will be painted a bright color.

Well Development

1) New monitoring wells will be developed after the well has been completely installed and the grout has hardened (a minimum of 24 hours following grouting).

2) The well will be developed by bailing, surging, and pumping.

3) Equipment placed in the well will be decontaminated before use.

4) If information is available, the least-contaminated well will be developed first.

5) Initial development will be with a bailer (i.e., stainless-steel, 10-foot-long bailer) to facilitate removal of coarse-grained sediment.

6) The well will subsequently be surged using a surge block across the screened interval. Additional bailing will be performed if significant coarse sediment is still present.

7) Following bailing and surging, a submersible pump will be lowered into the well. Development may include surging the well by abruptly stopping flow and allowing water in the well column to fall back into the well.

8) Pumping will continue until the water produced is free of turbidity (less than 10 NTU) and water quality parameters (i.e., pH, temperature, conductivity, TDS, and dissolved oxygen) have stabilized.

9) Development water will be considered hazardous and placed in sealed 55-gallon DOT-approved steel drums or other approved containers (i.e., lined roll-off bins).

KEY CHECK AND ITEMS

- Ensure that all equipment is properly decontaminated as needed.
- Only new, sealed materials (e.g., screens, risers, and sand) will be used in constructing the well.
- Care will be taken when making downhole measurements to ensure that proper heights of sand, seal, and grout are achieved.
- Fill out CH2M HILL Well Completion Diagram (see Attachment A).
- All materials generated during sampling (debris, PPE, decontamination liquids, etc.) will be placed in approved investigation-derived waste storage containers (i.e., drums or roll-offs) for storage pending analysis and disposal off site.

SOP-B2

Soil Classification and Logging Procedures
Standard Operating Procedures for PG&E Topock Program

This standard operating procedure (SOP) provides guidance to obtain accurate and consistent descriptions of soil characteristics during soil-sampling operations. The characterization is based on visual examination and manual tests not on laboratory determinations.

REQUIRED DOCUMENTS

1) Event-specific sampling and analysis plan, work plan or event-specific field instructions. Planned borehole depth, proposed well construction/specifications, and field sampling summary table, if available.
2) Applicable project work plan or monitoring plan. Refer to Topock Program *Sampling, Analysis, and Field Procedures Manual* and *Quality Assurance Project* Plan (Procedures Manual), as required.
3) Topock Program Health and Safety Plan (HSP).
4) Previous sampling, drilling, or well construction logs from other boreholes or wells in the vicinity, if available.
5) Blank field notebook.
6) Blank CH2M HILL soil boring log Form D1586.

PREPARATION AND SETUP

1) Review event-specific work plan or event-specific field instructions, previous sampling logs, Procedures Manual, and HSP.
2) Initiate field logbook for sampling activity.
3) Review sampling procedures and equipment, and planned sample depths with drilling contractor and field crew.

EQUIPMENT LIST

- Indelible pens
- Tape measure or ruler
- Field logbook
- Spatula
- HCl, 10-percent solution
- Squirt bottle/Spray bottle with water

- Rock- or soil-color chart (e.g., Munsell)
- Grain-size chart
- Hand lens
- Unified Soil Classification System index charts and tables to help with soil classification

PROCEDURES

This section covers several aspects of the soil characterization: instructions for completing the CH2M HILL soil boring log (see Form D1586, Attachment A) and the field logging of soil using the "Unified Soil Classification System and Logging Criteria" (Attachment B).

Instructions for Completing Soil Boring Logs

- Soil boring logs will be completed on field boring log forms. Information collected will be consistent with that required for Form D1586 (attached), a standard CH2M HILL form, or an equivalent form that supplies the same information.
- The information collected in the field to perform the soil characterization is described below.
- Field personnel should review completed logs for accuracy, clarity, and thoroughness of detail. Samples also should be checked to see that information is correctly recorded on both jar lids and labels and on the log sheets.

Heading Information

1) **Boring/Well Number.** Enter the boring/well number. A numbering system should be chosen that does not conflict with information recorded for previous exploratory work done at the site. Number the sheets consecutively for each boring.
2) **Location.** If stationing, coordinates, mileposts, or similar project layout information is available, indicate the position of the boring to that system using modifiers such as "approximate" or "estimated," as appropriate.
3) **Elevation.** Elevation will be determined at the conclusion of field activities.
4) **Drilling Contractor.** Enter the name of the drilling company and the city and state where the company is based.
5) **Drilling Method and Equipment.** Identify the bit size and type, drilling fluid (if used), and method of drilling (e.g., rotary, hollow-stem auger, sonic). Information on the drilling equipment (e.g., CME 55, Mobile B61) should be noted.
6) **Water Level and Date.** Enter the depth below ground surface to the apparent water level in the borehole. The information should be recorded as a comment. If free water is not encountered during drilling or cannot be detected because of the drilling method, this information should be noted. Record date and time of day (for tides, river stage) of each water level measurement.

7) **Date of Start and Finish.** Enter the dates the boring was started and completed. Time of day should be added if several borings are performed on the same day.

8) **Logger.** Enter the first initial and full last name of the logger.

Technical Data

1) **Depth Below Surface.** Use a depth scale that is appropriate for the sample spacing and for the complexity of subsurface conditions.

2) **Sample Interval.** Note the depth at the top and bottom of the sample interval.

3) **Sample Type and Number.** Enter the sample type and number. SS-1 = split spoon, first sample. Number samples consecutively regardless of type. Enter a sample number even if no material was recovered in the sampler.

4) **Sample Recovery.** Enter the length to the nearest 0.1 foot of soil sample recovered from the sampler. Often, there will be some wash or caved material above the sample; do not include the wash material in the measurement. Record recovery in feet.

5) **Soil Description.** The soil classification should follow the format described in the "Field Classification of Soil" subsection below.

6) **Comments.** Include all pertinent observations (changes in drilling fluid color, rod drops, drilling chatter, rod bounce as in driving on a cobble, damaged Shelby tubes, and equipment malfunctions). In addition, note if casing was used, the sizes and depths installed, and if drilling fluid was added or changed. You should instruct the driller to alert you to any significant changes in drilling (changes in material, occurrence of boulders, and loss of drilling fluid). Such information should be attributed to the driller and recorded in this column. Specific information might include:

   - The date and the time drilling began and ended each day.
   - The depth and size of casing and the method of installation.
   - The date, time, and depth of water level measurements.
   - Depth of rod chatter.
   - Depth and percentage of drilling fluid loss.
   - Depth of hole caving or heaving.
   - Depth of change in material.
   - Health and safety monitoring data.
   - Drilling interval through a boulder.

Field Classification of Soil

This section presents the format for the field classification of soil. In general, the approach and format for classifying soils should conform to the "United Soils Classification System and Logging Criteria" (see charts and criteria, Attachment B).

- The Unified Soil Classification System (USCS) is based on numerical values of certain soil properties that are measured by laboratory tests (ASTM D 2487). It is possible, however, to estimate these values in the field with reasonable accuracy using visual-manual procedures (ASTM D 2488). In addition, some elements of a complete soil description, such as the presence of cobbles or boulders, changes in strata, and the relative proportions of soil types in a bedded deposit can be obtained only in the field.
- Soil descriptions should be precise and comprehensive without being verbose. The correct overall impression of the soil should not be distorted by excessive emphasis on insignificant details. In general, similarities rather than differences between consecutive samples should be stressed.

Soil Descriptions

Soil descriptions must be recorded for every soil sample collected. The format and order for soil descriptions should be:

1) Soil name (synonymous with ASTM D 2488 Group Name) with appropriate modifiers. Soil name should be in all capitals in the log, for example "POORLY-GRADED SAND."
2) Group symbol, in parentheses, for example, "(SP)."
3) Color, using Munsell color designation.
4) Particle size distribution (i.e., sand, silt, clay).
5) Moisture content.
6) Relative density or consistency.
7) Soil structure, mineralogy, or other descriptors.

This order follows, in general, the format described in ASTM D 2488.

(1) Soil Name

The basic name of a soil should be the ASTM D 2488 Group Name on the basis of visual estimates of gradation and plasticity. The soil name should be capitalized.

Examples of acceptable soil names are illustrated by the following descriptions:

- A soil sample is visually estimated to contain 15-percent gravel, 55-percent sand, and 30-percent fines (passing No. 200 sieve). The fines are estimated as either low- or highly-plastic silt. This visual classification is SILTY SAND WITH GRAVEL with a Group Symbol of (SM).
- Another soil sample has the following visual estimate: 10-percent gravel, 30-percent sand, and 60-percent fines (passing the No. 200 sieve). The fines are estimated as low-plastic silt. This visual classification is SANDY SILT. The gravel portion is not included in the soil name because the gravel portion was estimated as less than 15 percent. The Group Symbol is (ML).

The gradation of coarse-grained soil (more than 50 percent retained on No. 200 sieve) is included in the specific soil name in accordance with ASTM D 2488.

- There is no need to further document the gradation.
- However, the maximum size and angularity or roundness of gravel and sand-sized particles should be recorded.
- For fine-grained soil (50 percent or more passing the No. 200 sieve), the name is modified by the appropriate plasticity/elasticity term in accordance with ASTM D 2488.

Interlayered soil should each be described starting with the predominant type.

- An introductory name, such as "Interlayered Sand and Silt," should be used.
- In addition, the relative proportion of each soil type should be indicated (see Table 1 for example).

Where helpful, the evaluation of plasticity/elasticity can be justified by describing results from any of the visual-manual procedures for identifying fine-grained soils, such as reaction to shaking, toughness of a soil thread, or dry strength as described in ASTM D 2488.

(2) Group Symbol

The appropriate group symbol from ASTM D 2488 must be given after each soil name.

1) The group symbol should be placed in parentheses to indicate that the classification has been estimated.
2) In accordance with ASTM D 2488, dual symbols (e.g., GP-GM or SW-SC) can be used to indicate that a soil is estimated to have about 10-percent fines.
3) Borderline symbols (e.g., GM/SM or SW/SP) can be used to indicate that a soil sample has been identified as having properties that do not distinctly place the soil into a specific group. Generally, the group name assigned to a soil with a borderline symbol should be the group name for the first symbol. The use of a borderline symbol should not be used indiscriminately. Every effort should be made to first place the soil into a single group.

(3) Color

Soil color is described by comparing the sample with the Munsell Soil Color Charts. The Munsell colors should be used unless directed otherwise by project sampling plans. Instructions for their proper use are in the color charts. The color name shall precede the Munsell color notation (e.g., "yellowish brown, 10 YR 5/4"), with color hue and chroma number parenthetically entered in the borelog description. If no color chip is available, the color should be simply described as primary color (i.e., green, brown, gray, yellow, tan, etc.).

(4) Particle Size Distribution

Within the gravel sizes and the sand sizes, there are further divisions based on particle sizes. Gravel is divided into fine and coarse gravel. Fine-gravel particles (pebbles) are those that would pass through 3/4-inch opening but not a 1/4-inch opening. The fine gravel ranges from pea- to marble-sized. Coarse-gravel particles are those that would pass through a 3-inch opening but not a 3/4-in opening. Common objects of this size are grapes and tennis balls. Cobbles range from 3 inches to 12 inches in size; boulders are larger than 12 inches.

Sand is divided into three sizes: fine, medium, and coarse. Sand passes a No. 4 sieve (approximately 1/4 inch) and is retained in a No. 200 sieve (0.003 inch). Fine-sand particles pass a No. 40 sieve (approximately 1/64 inch) and are retained in the No. 200 (0.003 inch) sieve. These particles are sugar- or table salt-sized. Medium sand passes the No. 10 sieve (approximately 1/2 inch) and retained on the No. 40 sieve. These particles are about the same size as the openings in window screening. Coarse-sand particles would pass a No. 4 sieve (approximately 1/4 inch) and be retained on a No. 10 sieve. Rock salt granules fall in this size range. Sand and gravel particle sizes are illustrated in ASTM D2488 along with percentage estimating charts. The percentages of different grain size fractions are important in the soil type determination.

(5) Moisture Content

Soil moisture content shall be estimated using only the terminology described below:

- Dry - Absence of moisture, dusty, dry to the touch
- Moist - Damp but no visible water
- Wet - Visibly free water, usually sampled from below the water table

(6) Relative Density or Consistency

An estimate of the consistency shall accompany descriptions of all fine-grained soil (silt and clay where more than 50 percent of the material would pass the No. 200 sieve). A pocket penetrometer is the most accurate method for estimating the consistency of fine-grained soils. The table below lists characteristics for soil consistency identification.

Consistency	Unconfined Compressive Strength (tons/ft)[a]	Blows/foot (SPT) [b]	Manual Procedure
Very soft	<0.25	0 – 4	Thumb will penetrate soil more than 1 inch (25 mm).
Soft	0.25 - 0.50	4 – 8	Thumb will penetrate soil about 1 inch (25 mm).
Firm (formerly stiff)	-1.50	8 – 15	Thumb will indent soil about 1/4 inch (6 mm).
Hard	-2.00	15 – 30	Thumb will not indent soil but readily indented with thumbnail.
Very hard	>4.0	> 30	Thumbnail will not indent soil.

Notes:

[a] Pocket penetrometer

[b] Blows/foot is defined as the total number of blows required to drive the second and third 6 inches of penetration (blow counts for the first 6 inches are also noted) while driving an 18-inch SPT sampler with a 140-pound hammer falling a free height of 30 inches. Conversion factors may be applied when the field log information is transferred to the final log when using a sampler other than an SPT (Standard penetrometer) (e.g., S&H or Modified California), or when using different hammer weights and drop. The conversion factor is approximately 0.5 for an S&H sampler with a hammer weight of 140 pounds falling 30 inches.

Descriptions of all coarse-grained soil (sand and gravel where less than 50 percent of the material would pass the No. 200 sieve and 100 percent would pass the 3-inch sieve) shall be accompanied by an estimate of the density based upon standard penetrometer (SPT) blow counts. The following terminology should be used:

Density	Blows/foot (SPT)
Very loose	< 4
Loose	4-10
Medium dense	10-30
Dense	30-50
Very dense	> 50

(7) Soil Structure, Mineralogy, and Other Descriptors

Discontinuities and inclusions are important and should be described. Such features include joints or fissures, slickensides, bedding or laminations, veins, root holes, and wood debris.

Significant mineralogical information such as cementation, abundant mica, or unusual mineralogy should be described.

Other descriptors may include particle angularity or shape, maximum particle size, hardness of large particles, plasticity of fines, dry strength, dilatancy, toughness, reaction to HCl, and staining, as well as other information such as organic debris, odor, or presence of free product. Criteria for the use of these other descriptions include:

- Structure:
  - Stratified - Alternating layers of varying material or color with layers at least 1/4-inch thick; note thickness.
  - Laminated - Alternating layers of varying material or color with the layers less than 1/4-inch thick; note thickness.
  - Fissured - Breaks along definite planes of fracture with little resistance.
  - Slickensides - Fracture planes appear polished or glossy, often striated.
  - Blocky - Cohesive soil that can be broken down into small angular lumps that resist further breakdown.
  - Lensed - Inclusion of small pockets of different soils, such as lenses of sand within clay; note thickness.
  - Homogeneous - Same color and appearance throughout.
  - Grading - Whether the particles increase or decrease in size toward the top of logged interval.
- Particle Shape:
  - Flat - Particles with width/thickness ratio > 3.
  - Elongated - Particles with length/width ratio > 3.

- Elongated and flat - Particles meet criteria for both flat and elongated.

- Particle Angularity:
  - Angular - Particles have sharp edges and relatively planar sides with unpolished surfaces.
  - Subangular - Particles are similar to angular description but have rounded edges.
  - Subrounded - Particles have nearly planar sides but have well-rounded corners and edges.
  - Rounded - Particles have smoothly-curved sides and no edges.

- Cementation:
  - Weak - rumbles or breaks with handling or little finger pressure.
  - Moderate - Crumbles or breaks with considerable finger pressure.
  - Strong - Will not crumble or break with finger pressure.

- Reaction with HCl:
  - None - No visible reaction.
  - Weak - Some reaction, bubbles forming slowly.
  - Strong - Vigorous reaction, bubbles forming immediately.

Comments

This section should be reserved for information not pertaining to lithologic description. Sample information including sample identifier, analysis, matrix, and depth interval should be included in the boring log comments. Information related to drilling, such as drilling rate, chatter, and equipment malfunctions should also be well documented in the comments section of the boring log. Additionally interpretations of the lithologic data may also be presented in the comments section. Examples of this include "transition between Older Alluvium and Fanglomerate," "paleosol horizon B," or "conductive zone."

Recovery

Recovery data are entered along the left side of the boring log. Enter the length of retrieved core to the nearest 0.1 foot of sample recovered and record the value in feet. Do not count slough or caved material as part of the total recovered length of core. Record total length and percent of sample recovered. If using a 5-foot sample barrel, multiply the total length by 2 and 100 to get a percentage number. Similarly, if using a 2.5-foot sampler, multiply by 4 and 100 to get the percent recovery.

Backfilling

When a boring is completed and the water level measured, the boring shall be backfilled to ground surface according to applicable regulations. The destruction of the hole shall be noted on the log. Borehole destruction should follow SOP 28 *Soil Boring Abandonment*

Attachments

- Soil Boring Log, CH2M HILL Form D1586, and a completed example
- Unified Soil Classification System and Logging Criteria

Key Checks and Preventive Maintenance

Check entries to the soil boring log and field logbook in the field; because the samples will be disposed of, confirmation and corrections cannot be made later. Check that sample numbers and intervals are properly specified. Check that drilling and sampling equipment is decontaminated using the procedures defined in SOP *Decontamination of Drilling Rigs and Equipment*.

ATTACHMENT A

Examples of Soil Bore Logs

CH2MHILL

PROJECT NUMBER	BORING NUMBER SHEET OF

SOIL BORING LOG

PROJECT ______________________ LOCATION ______________________

ELEVATION ______________ DRILLING CONTRACTOR ______________________

DRILLING METHOD AND EQUIPMENT ______________________

WATER LEVELS ______________ START ________ FINISH ________ LOGGER ________

DEPTH BELOW SURFACE (FT)	SAMPLE			STANDARD PENETRATION TEST RESULTS	SOIL DESCRIPTION	COMMENTS
	INTERVAL	NUMBER AND TYPE	RECOVERY (FT)	6"-6"-6" (N)	SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS AND INSTRUMENTATION

REV 9/96 FORM D1586

PROJECT NUMBER:	BORING NUMBER:
326128.01.16.EN	*MW-47*

SOIL BORING LOG - DRAFT FOR DISCUSSION

PROJECT NAME:	HOLE DEPTH (ft):	DRILLING CONTRACTOR:	
IMPM Drill Program	288.0	Prosonic Corp. Phoenix, AZ	

SURFACE ELEVATION:	NORTHING (CCS NAD 27 Z 5):	EASTING (CCS NAD 27 Z 5):	DATE STARTED:	DATE COMPLETED:
482.6 ft. MSL	2,103,450.05	7,615,629.49	02/27/2006	03/13/2006

DRILLING METHOD:	DRILLING EQUIPMENT:
Rotosonic	Sonic AT (track mounted)

LOCATION:	LOGGED BY:
PG&E Compressor Station - Flood Plain, Topock, California	B. Moayyad, K. Ebel

DEPTH BGS (feet)	SAMPLE INTERVAL	SAMPLE TYPE/ NUMBER	SAMPLE RECOVERY (ft)	USCS CODE	SOIL DESCRIPTION SOIL NAME, USCS SYMBOL, COLOR, PERCENT COMPOSITION, GRADING, GRAIN SHAPE, MINERALOGY, DENSITY/CONSISTENCY, STRUCTURE, MOISTURE.	COMMENTS DRILLING OBSERVATIONS AND OPERATIONS, DAILY START AND END TIMES , DRILL RATE, REFUSALS, SAMPLING AND TESTING NOTES.
			6	SP	**POORLY GRADED SAND (SP)** - very lt brn (10YR7/3), =2% fines, 98% f to m lithic quartz sand, subang to subrnd, dry - fine roots, iron staining, some iron oxide coating on grains	Hand augured to 5' bgs
5					- slightly moist - dry	
10			10			Rapid drill rate, no chatter
15				SW	**WELL GRADED SAND w/ GRAVEL (SW)** - lt yellowish brn (10YR6/4), 45% gravel up to 7cm, 50% f to m sand, 5% fines, loose, met subang gravel, dry(moist@ 17') - cobble present in slough - one subrnd chert gravel - Possible Fluvially Reworked Alluvium - lt grey (10YR7/2), subang to rnd met gravel up to 9cm, 2% to 5% fines - dk yellowish brn (10YR4/4), mostly c sand subang to ang, met, some Miocene conglomerate gravel - 65% sand, 30% gravel up to 4cm, 5% fines	
20						
25			16	SW	**WELL GRADED SAND w/ GRAVEL (SW)** - dk yellowish brn (10YR3/6), 35% gravel up to 4cm, 55% m to c sand, 10% silty fines, met clasts are grain supported some mm siltstone - some oxide staining	
30				SW	**WELL GRADED SAND w/ GRAVEL AND CLAY (SW)** - dk yellowish brn (10YR3/6), 30% subang met gravel up to 7 cm, 55% subrnd to subang m to c sand, 15% clayey fines, m density, moist	Drill rate slowed to clean out 8" pipe
35						

CH2MHILL

PROJECT NUMBER: 326128.01.16.EN

BORING NUMBER: *MW-47*

SOIL BORING LOG - DRAFT FOR DISCUSSION

PROJECT NAME: IMPM Drill Program		**HOLE DEPTH (ft):** 288.0	**DRILLING CONTRACTOR:** Prosonic Corp. Phoenix, AZ	
SURFACE ELEVATION: 482.6 ft. MSL	**NORTHING (CCS NAD 27 Z 5):** 2,103,450.05	**EASTING (CCS NAD 27 Z 5):** 7,615,629.49	**DATE STARTED:** 02/27/2006	**DATE COMPLETED:** 03/13/2006
DRILLING METHOD: Rotosonic			**DRILLING EQUIPMENT:** Sonic AT (track mounted)	
LOCATION: PG&E Compressor Station - Flood Plain, Topock, California			**LOGGED BY:** B. Moayyad, K. Ebel	

DEPTH BGS (feet)	SAMPLE INTERVAL	SAMPLE TYPE/ NUMBER	SAMPLE RECOVERY (ft)	USCS CODE	SOIL DESCRIPTION: SOIL NAME, USCS SYMBOL, COLOR, PERCENT COMPOSITION, GRADING, GRAIN SHAPE, MINERALOGY, DENSITY/CONSISTENCY, STRUCTURE, MOISTURE.	COMMENTS: DRILLING OBSERVATIONS AND OPERATIONS, DAILY START AND END TIMES , DRILL RATE, REFUSALS, SAMPLING AND TESTING NOTES.
			2.5	SW	**WELL GRADED SAND w/ GRAVEL (SW)** - dr yellowish brn (10YR3/6), 30% gravel, 60% sand, 10% silty fines	Drilling smooth but preceeds less rapidly
40			10	SW	**WELL GRADED SAND w/ GRAVEL (SW)** - 40% subang met gravel up to 6cm, 55% subrnd to ang sand, 5% fines - more gravel below 38' - gravel is mostly fine	
45, 50				SW	**WELL GRADED SAND w/ GRAVEL (SW)** - Pale brn (10YR6/3), 30% subang met gravel up to 5cm, 60% subrnd to subang m to c met sand, 10% silty fines, wet	Soil sample collected
			10	SP	**POORLY GRADED SAND w/ GRAVEL (SP)** - pale brn (10TR6/3), 30% f subang gravel up to 2 cm, 65% mostly c sand, =2% fines	
55				SW	**WELL GRADED SAND w/ GRAVEL (SW)** - yellowish brn (10YR5/4), 40% subang met gravel up to 9cm, 55% f to c met sand, 5% silty fines, clast supported, m density, wet	
60, 65			9.5	GW	**WELL GRADED GRAVEL w/ SILT AND SAND (GW)** - brn (7.5YR5/4), 55% subang to ang met gravel up to 4cm, 25% f to c sand, 20% silty fines, dense, moist to dry - soil dries out - lt grey (10YR7/2) and powder dry - moist sandy zone, 55% gravel, 35% sand, 10% fines - dry silty lt grey GW below 65'	Collected Isoflow sample Drill rate slows to 2' / min
70				SW	**WELL GRADED SAND w/ GRAVEL (SW)** - yellowish brn (10YR5/4), 35% subang met gravel up to 4cm, 60% subrnd sand, 5% silty fines, loose, moist to wet	Moderate Drill Rate

SHEET 5 of 9	PROJECT NUMBER: 326128.01.16.EN	BORING NUMBER: *MW-47*

SOIL BORING LOG - DRAFT FOR DISCUSSION

PROJECT NAME: IMPM Drill Program	**HOLE DEPTH (ft):** 288.0	**DRILLING CONTRACTOR:** Prosonic Corp. Phoenix, AZ

SURFACE ELEVATION: 482.6 ft. MSL	**NORTHING (CCS NAD 27 Z 5):** 2,103,450.05	**EASTING (CCS NAD 27 Z 5):** 7,615,629.49	**DATE STARTED:** 02/27/2006	**DATE COMPLETED:** 03/13/2006

DRILLING METHOD: Rotosonic	**DRILLING EQUIPMENT:** Sonic AT (track mounted)
LOCATION: PG&E Compressor Station - Flood Plain, Topock, California	**LOGGED BY:** B. Moayyad, K. Ebel

DEPTH BGS (feet)	SAMPLE INTERVAL	SAMPLE TYPE/ NUMBER	SAMPLE RECOVERY (ft)	USCS CODE	SOIL DESCRIPTION (SOIL NAME, USCS SYMBOL, COLOR, PERCENT COMPOSITION, GRADING, GRAIN SHAPE, MINERALOGY, DENSITY/CONSISTENCY, STRUCTURE, MOISTURE.)	COMMENTS (DRILLING OBSERVATIONS AND OPERATIONS, DAILY START AND END TIMES , DRILL RATE, REFUSALS, SAMPLING AND TESTING NOTES.)
			6	SP	**POORLY GRADED SAND w/ SILT (SP)** - brn (7.5YR4/4), 5% subrnd to subang met gravel up to 4cm, 85% f to c sand, 10% fines, poorly graded, wet, no odor	
145			3	SM	**SILTY SAND W/ GRAVEL (SM)** - brn (7.5YR4/4), 20% subang to subrnd gravel up to 6cm, 60% f to c sand, 20% silty fines, well graded, m consolidated, met, wet, no odor	
150			5	SM	**SILTY SAND w/ GRAVEL (SM)** - dk yellowish brn (10YR4/4), 25% subang to subrnd up to 4cm met gravel, 60% well graded f to c sand, 15% fines, wet, no odor	
155			4	SW	**WELL GRADED SAND w/ SILT AND SAND (SW)** - dr yellowish brn (10YR4/4), 10% subang to subrnd up to 3cm met gravel, 75%well graded f to c sand, 15% fines, moist to wet	
			2	SW	**SILTY SAND (SM)** - brn (7.5YR4/4), 5% ang to subrnd met gravel up to 1.5cm increasing with depth, 85% poorly graded m to c sand, 10% fines, loose, wet	
			2	SM	**SILTY SAND w/ GRAVEL (SM)** - dk yellowish brn (10YR4/4), 15% subang to subrnd up to 2.5cm met gravel, 75% well graded f to c sand, 10% fines, mostly met, trace chert, loose, wet, no odor	Collected Isoflow sample
160			4	SM	**SILTY SAND W/ GRAVEL (SM)** - brn (7.5YR4/4), 25% subang to subrnd gravel up to 6.5cm, 60% m to c sand, 15% silty fines, well graded, m consolidated, met, wet, no odor	Drill rate = 0.75' to 1.5' / min
165			4	SW	**SILTY SAND (SW)** - mottled dk reddish brn (5YR3/4), 10% subang to subrnd gravel up to 2.5cm, 50% well graded f to m sand, 40% silt, metamorphic, dry to damp, no odor, interbedded sandy silt laminations	
170			5.5	SW	**SAND w/ GRAVEL (SW)** - dk reddish brn (5YR3/4), 20% subang to subrnd gravel up to 5cm, 75% f to c sand, 5% fines, well graded, loose, met, wet	
175			2.5	SM	**SILTY SAND w/ GRAVEL (SM)** - brn (7.5YR4/4), 15% subang to subrnd gravel, 70% f to m sand, 15% fines, poorly graded, met,increasingly consolidated, slightly to moderately calcareous, moist to wet	

CH2MHILL

PROJECT NUMBER:	BORING NUMBER:
326128.01.16.EN	*MW-47*

SOIL BORING LOG - DRAFT FOR DISCUSSION

PROJECT NAME: IMPM Drill Program		**HOLE DEPTH (ft):** 288.0	**DRILLING CONTRACTOR:** Prosonic Corp. Phoenix, AZ
SURFACE ELEVATION: 482.6 ft. MSL	**NORTHING (CCS NAD 27 Z 5):** 2,103,450.05	**EASTING (CCS NAD 27 Z 5):** 7,615,629.49	**DATE STARTED:** 02/27/2006 / **DATE COMPLETED:** 03/13/2006
DRILLING METHOD: Rotosonic			**DRILLING EQUIPMENT:** Sonic AT (track mounted)
LOCATION: PG&E Compressor Station - Flood Plain, Topock, California			**LOGGED BY:** B. Moayyad, K. Ebel

DEPTH BGS (feet)	SAMPLE INTERVAL	SAMPLE TYPE/NUMBER	SAMPLE RECOVERY (ft)	USCS CODE	SOIL DESCRIPTION: SOIL NAME, USCS SYMBOL, COLOR, PERCENT COMPOSITION, GRADING, GRAIN SHAPE, MINERALOGY, DENSITY/CONSISTENCY, STRUCTURE, MOISTURE.	COMMENTS: DRILLING OBSERVATIONS AND OPERATIONS, DAILY START AND END TIMES , DRILL RATE, REFUSALS, SAMPLING AND TESTING NOTES.
285			0	BR	**MIOCENE CONGLOMERATE BEDROCK (BR)** - 60% well graded subang to rnd gravel up to 10cm, 30% well graded sand, 10% fines, very calcareous, well consolidated to mostly hard, mod to very altered locally, mostly met, dry to moist	

Boring Terminated at 288 ft

ABBREVIATIONS

cc = continuous core run
brn = brown
lt = light
dk = dark
vf = very fine-grained
f = fine-grained
m = medium-grained
c = coarse-grained
vc = very coarse-grained
ang = angular
subang = subangular
subrnd = subrounded
rnd = rounded
br = bedrock formation
ss = sandstone
conglom = conglomerate
comptd = compacted
qtz = quartz

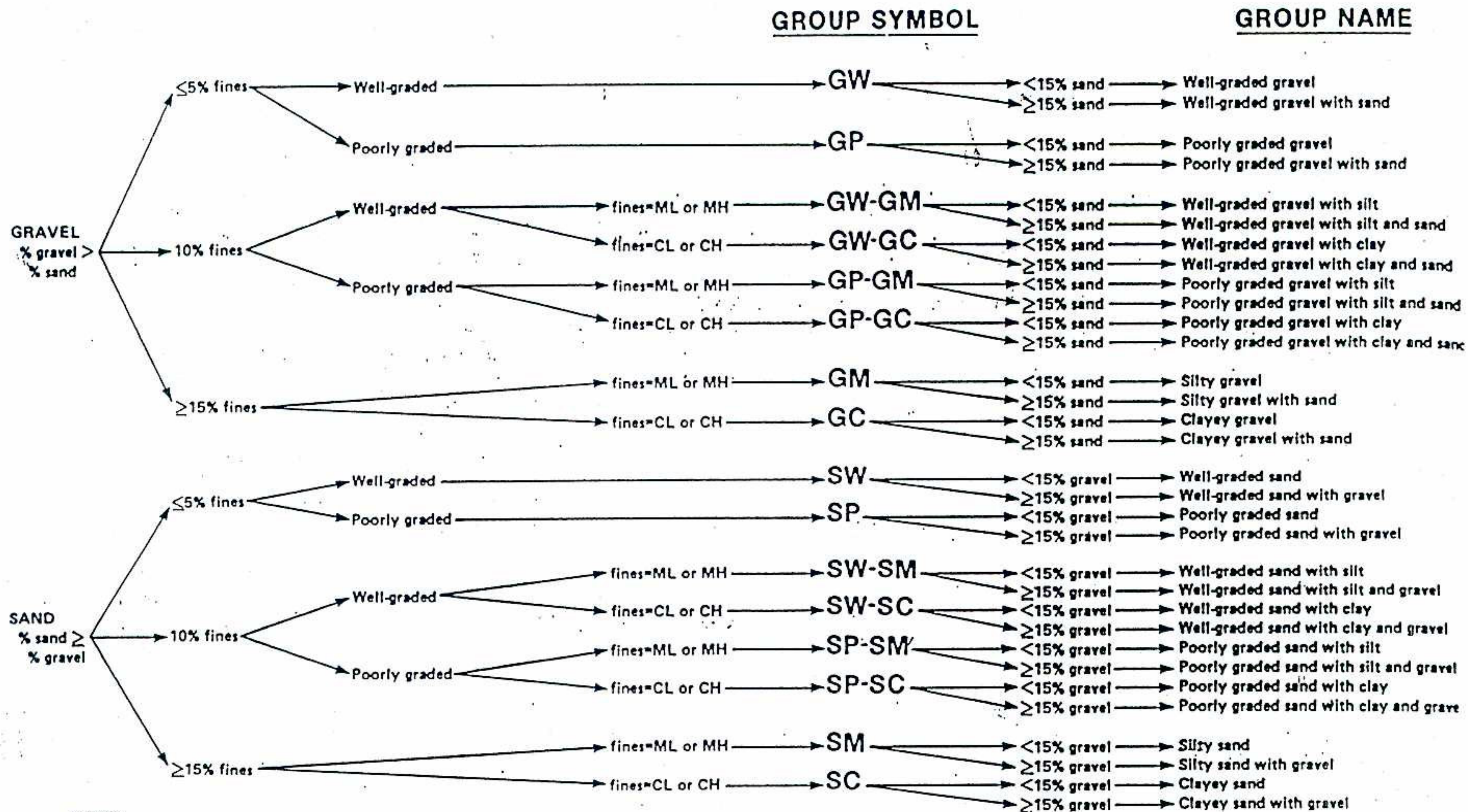
ATTACHMENT B

Unified Soil Classification System and Logging Criteria

GENERAL SOIL CATEGORIES			SYMBOLS	TYPICAL SOIL TYPES
COARSE GRAINED SOILS More than half is larger than No. 200 sieve	**GRAVEL** More than half coarse fraction is larger than No. 4 sieve size	Clean Gravel with little or no fines	GW	Well Graded Gravel, Gravel-Sand Mixtures
			GP	Poorly Graded Gravel, Gravel-Sand Mixtures
		Gravel with more than 12% fines	GM	Silty Gravel, Poorly Graded Gravel-Sand-Silt Mixtures
			GC	Clayey Gravel, Poorly Graded Gravel-Sand-Clay Mixtures
	SAND More than half coarse fraction is smaller than No. 4 sieve size	Clean sand with little or no fines	SW	Well Graded Sand, Gravelly Sand
			SP	Poorly Graded Sand, Gravelly Sand
		Sand with more than 12% fines	SM	Silty Sand, Poorly Graded Sand-Silt Mixtures
			SC	Clayey Sand, Poorly Graded Sand-Clay Mixtures
FINE GRAINED SOILS More than half is smaller than No. 200 sieve	**SILT AND CLAY** Liquid Limit Less than 50%		ML	Inorganic Silt and Very Fine Sand, Rock Flour, Silty or Clayey Fine Sand, or Clayey Silt with Slight Plasticity
			CL	Inorganic Clay of Low to Medium Plasticity, Gravelly Clay, Sandy Clay, Silty Clay, Lean Clay
			OL	Organic Clay and Organic Silty Clay of Low Plasticity
	SILT AND CLAY Liquid Limit Greater than 50%		MH	Inorganic Silt, Micaceous or Diatomaceous Fine Sandy or Silty Soils, Elastic Silt
			CH	Inorganic Clay of High Plasticity, Fat Clay
			OH	Organic Clay of Medium to High Plasticity, Organic Silt
HIGHLY ORGANIC SOILS			PT	Peat and Other Highly Organic Soils

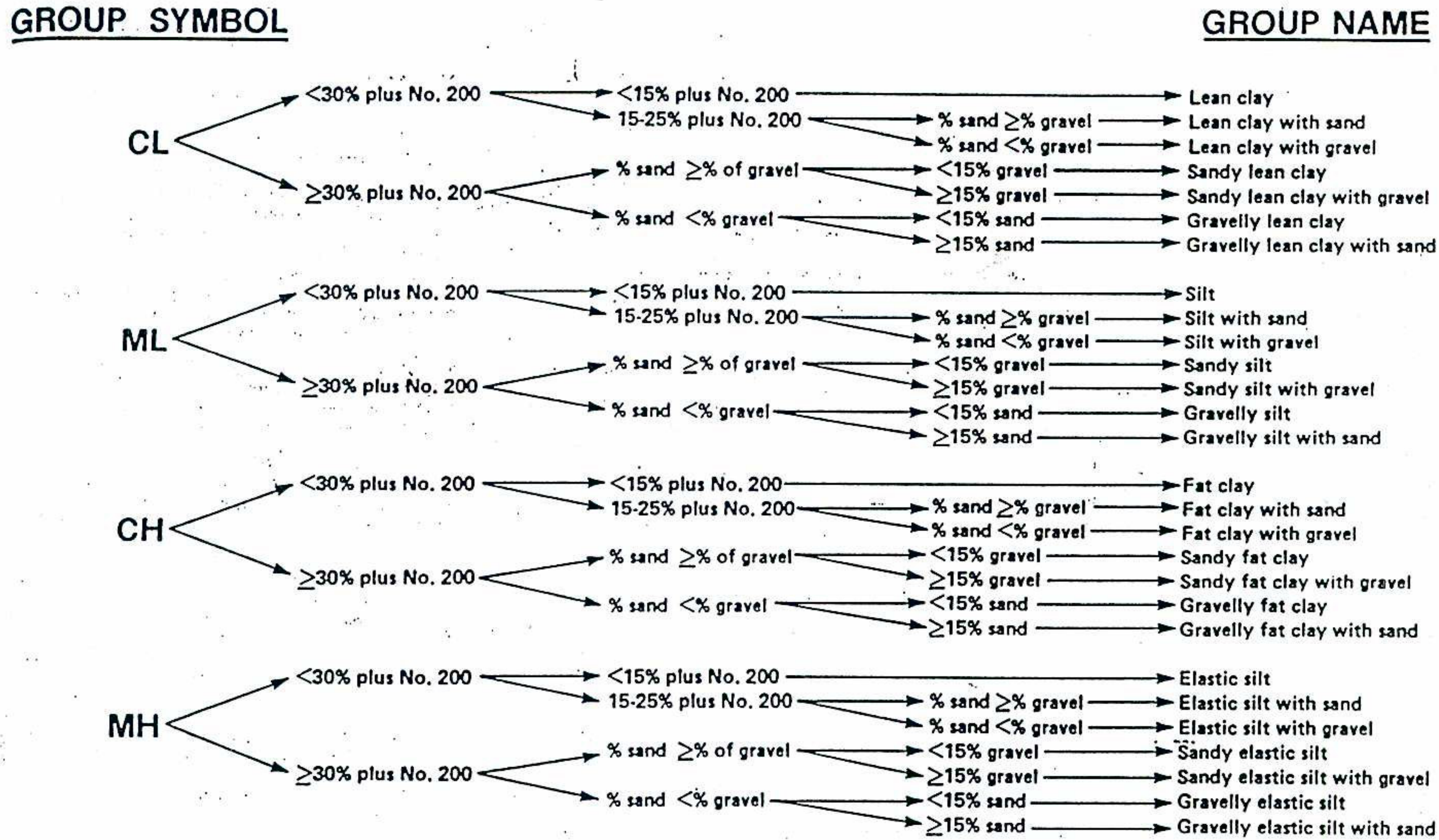
UNIFIED SOIL CLASSIFICATION SYSTEM

JOB NUMBER	DATE	APPROVED	PLATE



NOTE:
Percentages are based on estimating amounts of fines, sand, and gravel to the nearest 5%
(After ASTM Designation D2488 Standard Test Method for Classification of Soils for Engineering Purposes)

Flow Chart for Classifying Coarse-grained Soil
(50% or more retained on No. 200 sieve)
Field Guide for Soil Classification and Logging Procedures



NOTE:
Percentages are based on estimating amounts of fines, sand, and gravel to the nearest 5%
(After ASTM Designation D2488 Standard Test Method for Classification of Soils for Engineering Purposes)

Flow Chart for Classifying Fine-grained Soil
(50% or more passing No. 200 sieve)
Field Guide for Soil Classification and Logging Procedures

similar, the material is classified as poorly graded or well sorted. If fines represent less than 5 percent of the total mass, the symbol SP is used for a poorly-graded sand and SW for a well graded sand. If silts and/or clays exceed 12 percent, the symbols GC, SC, GM, and SM are used, respectively.

If the silts and clays are between 5 to 12 percent of the total sample weight, a dual classification with two group symbols is used. The first symbol is GW, GP, SW, or, SP, and the second is GC, GM, SC, or SM. The group name corresponds to the first group symbol plus the modifying words "with clay" or "with silt" to indicate the plasticity characteristics. If the fines plot on the CL-ML range on the plasticity chart (Figure 2-2), possible dual classification group names are:

GW-GM	well graded gravel with silt
GW-GC	well graded gravel with clay
GP-GM	poorly graded gravel with silt
GP-GC	poorly graded gravel with clay
SW-SM	well graded sand with silt
SW-SC	well graded sand with clay
SP-SM	poorly graded sand with silt
SP-SC	poorly graded sand with clay

If silts and clays exceed 12 percent of the total weight of sample, the modifiers "M" and "C" are used, respectively. If a sand or gravel has more than 15 percent of the other coarse-grained constituent, the words "with gravel" or "with sand" are added to the group name. A flow chart for classifying coarse-grained soils is presented in Figure 2-3.

2.2 Fine-grained Soils

Particles passing the No. 200 sieve are silts (M) and clays (C). These soils must undergo testing in order to differentiate between them. Typical tests used are: dry strength, dilatancy, toughness, and plasticity. These terms are further discussed in Tables 2-2 through Table 2-6. Silts have little or no dry strength when dry, while clays have considerable dry strength. Dry strength, dilatancy, and toughness are also used to identify the fine-grained fraction of coarse-grained soils.

TABLE 2-2
Criteria for Describing Dry Strength

Description	Criteria
None	The dry specimen crumbles into powder with the mere pressure of handling.
Low	The dry specimen crumbles into powder with some finger pressure.
Medium	The dry specimen breaks into pieces or crumbles with considerable finger pressure.
High	The dry specimen cannot be broken with finger pressure. The specimen will break into pieces between the thumb and a hard surface.
Very high	The dry specimen cannot be broken between the thumb and a hard surface.

TABLE 2-3
Criteria for Describing Dilatancy

Description	Criteria
None	There is no visible change in the specimen.
Slow	Water appears slowly on the surface of the specimen during shaking, and does not disappear, or disappears slowly upon squeezing.
Rapid	Water appears quickly on the surface of the specimen during shaking, and disappears quickly upon squeezing.

TABLE 2-4
Criteria for Describing Toughness

Description	Criteria
Low	Only slight pressure is required to roll the thread near the plastic limit. The thread and the lump are weak and soft.
Medium	Medium pressure is required to roll the thread to near the plastic limit. The thread and the lump have medium stiffness.
High	Considerable pressure is required to roll the thread to near the plastic limit. The thread and the lump have very high stiffness.

TABLE 2-5
Identification of Inorganic Fine-grained Soils from Manual Tests

Soil Symbol	Dry Strength	Dilatancy	Toughness
ML	None to low	Slow to rapid	Low or thread cannot form
CL	Medium to high	None to slow	Medium
MH	Low to medium	None to slow	Low to medium
CH	High to very high	None	High

TABLE 2-6
Criteria for Describing Plasticity

Description	Criteria
Nonplastic	A 1/8-inch (3-mm) thread cannot be rolled at any water content.
Low	The thread can barely be rolled, and the lump cannot be formed when drier than the plastic limit.
Medium	The thread is easy to roll, and not much time is required to read the plastic limit. The thread cannot be re-rolled after reaching the plastic limit. The lump crumbles when drier than the plastic limit.
High	It takes considerable time rolling and kneading to reach the plastic limit. The thread can be re-rolled several times after reaching the plastic limit. The lump can be formed without crumbling when drier that the plastic limit.

Fine-grained soils are accurately determined in the laboratory using the Atterberg Limits test. This test include liquid limit, plastic limit, and plasticity index measurements. The liquid limit is the water content of a soil at the point of transition from a plastic to a liquid state. The plastic limit is the water content of a soil at the point of transition from a semisolid to a plastic state. The plasticity index is the difference between the liquid limit and the plastic limit.

As shown in the Figure 2-2, five fields have been identified. These include:

- Silty Clays (CL), Organic Silts (OL) or Organic Silty Clays (OL) of low plasticity
- Fat Clays (CH) and Organic Clays (OH)
- Inorganic Silts (ML) and Organic Silty Clays (OL) of low plasticity
- Silts (MH) and Organic Clays (OH) of a high plasticity
- Silty Clays to Clayey Silt (CL-ML) of low plasticity

Fine-grained soils with a liquid limit > 50 are modified by the symbol H (MH or CH), and those with a liquid limit < 50 are modified by the symbol L (ML or CL). Fine-grained soils containing 30 percent or more coarse-grained fraction should be modified by descriptive terms, such as "gravelly" or "sandy." If the coarse fraction is between 15 and 30 percent, the words" with sand and/or gravel" should be added to the group name. A flow chart for classifying fine-grained soils is presented in Figure 2-4.

2.3 Organic Soils

To classify organic soils, the percentage organic material present in the soil as well as the non-organic fines must be estimated. When the organic content ranges from 18 to 36 percent, the material is an organic clay or an organic silt, depending on the nature of the fine-grained constituents. When the organic content is between 36 and 90 percent, the material is designated a muck or peaty muck (OL or OH). A flow chart for classifying organic soil is presented in Figure 2-4. The term "peaty" is added if the organic remains are

SOP-B3

Borehole Sampling and Logging of Soil Borings
Standard Operating Procedures for PG&E Topock Program

This standard operating procedure (SOP) provides guidance for sample collection from soil borings during the drilling process, and proper documentation necessary. Detailed guidance for sample collection, preservation and handling is provided in Section 4.0 of the site Quality Assurance Project Plan (QAPP) and in the Topock Program *Sampling, Analysis, and Field Procedures Manual* (Procedures Manual). SOP-B2 provides detailed guidance for soil characterization and logging.

REQUIRED DOCUMENTS

1) Event-specific sampling and analysis plan (SAP), work plan or event-specific field instructions. Planned borehole depth, proposed well construction/specifications, and field sampling summary table, if available.
2) Applicable project work plan or monitoring plan. Refer to the Procedures Manual and QAPP, as required.
3) Topock Program Health and Safety Plan (HSP).
4) Previous sampling, drilling, or well construction logs from other boreholes or wells in the vicinity, if available.
5) Blank sampling log and field notebook.

PREPARATION AND SETUP

1) Review event-specific work plan or event-specific field instructions, previous sampling logs, Procedures Manual, and HSP.
2) Initiate field logbook for sampling activity.
3) Review sampling procedures and equipment, and planned sample depths with drilling contractor and field crew.

Equipment List

- Field logbook
- Borehole log
- Blue or black waterproof or permanent ink pens
- Trash bags
- Plastic sandwich bags
- Paper towels

- Stainless steel sampling equipment (provided by driller)
- Decontamination equipment (Alconox® solution in spray bottle, brushes, buckets, rinse water spray bottle)
- Soil sample containers appropriate for sample analysis and preservation as called for in SAP and QAPP (glass jars, brass sleeves, Encore® containers, sandwich bags, etc.)
- Soil sampling equipment not provided by driller (spatula or putty knife, stainless steel compositing bowl, hand auger, etc.)
- Groundwater sample containers appropriate for sample analysis and preservation as called for in SAP and QAPP (glass jars, VOA vials, plastic jars, etc.)
- Groundwater sample equipment not provided by driller (pump, filters, tubing, power supply, etc.)
- Water quality meters
- Water level indicator
- Distilled water
- Coolers with ice
- Protective waterproof gloves (nitrile or latex)

GUIDELINES

Soil Boring Logs Documentation

Soil boring logs will be completed on the soil boring log forms during the drilling activities at the time of the logging and soil descriptions. Information collected will be consistent with the standard CH2M HILL form (See SOP-B2 attachment A). Sample data may also be documented in the comments section of the boring log.

Items documented on the borehole log include:

1) **Sample Interval:** The top and bottom depth of each sample run should be recorded on the borelog. Sampling includes samples collected for analysis as well as core retrieved for logging purposes.

2) **Sample Type and Number:** Enter the sample type and number consistent with the sampling and analysis plan at the correct depth intervals. An "x" should be placed across the vertical interval where the environmental soil, grab groundwater, or geotechnical sample was collected.

3) **Sample Recovery:** Enter the length of retrieved core to the nearest 0.1 foot of sample recovered, and record the value in feet. Do not count slough or caved material as part of the total recovered length of core. Record total length and percent of sample recovered. If using a 5-foot sample barrel, multiply the total length by 2 and 100 to get a percentage number. Similarly, if using a 2.5-foot sampler, multiply by 4 and 100 to get the percent recovery.

4) **Sampling:** Sampling difficulties shall be noted. Disturbed samples shall be noted on the log as well as the sample recovery. The top of the sample shall be marked on the container.

5) **Water Levels:** Water-level measurements, where groundwater is encountered, are required for each boring. Changes in soil moisture shall be noted and, if there is no water encountered, a note to that effect shall be included on the borehole log. The date and time of water-level measurements shall be documented.

At a minimum, sample identifiers (IDs) should be noted on boring logs at the depth collected. When time and space allows, a summary of analytical sample information can be included. When inclusion of these data prevents documentation of drilling information, sample data should be omitted in order to document drilling.

Borehole Sampling by Drilling—General Procedure

Split-spoon sampling procedures shall be executed in accordance with American Society for Testing and Materials (ASTM) D1586, "Standard Method for Penetration Test and Split-barrel Sampling of Soils" (ASTM 1984). California (2-inch) or Modified California (2.5-inch) split-barrel samplers may also be used.

1) The split-spoon or split-barrel sampler shall be advanced to the top of the sampling interval using a wire-line or sample rods such as A or AW. The larger-diameter samplers may be fitted with three 6-inch-long stainless-steel sleeves. The sampler shall be driven 18 inches or to refusal, with a 140-pound hammer dropping repeatedly 30 inches. Refusal shall be defined as requiring 50 blows with the hammer to advance the sampler less than 6 inches.

2) The number of blows required to drive the sampler each 6 inches shall be recorded on the borelog.

3) As the sample tubes are disassembled, an organic vapor monitor probe shall be inserted into the gap between two sample liners, and the liner exhibiting the highest reading shall be selected for analysis.

4) In general, the middle liner is collected for laboratory analysis, and 10 percent of the bottom liners are collected for quality assurance testing. A sample of the soil in the top liner typically is placed in a re-sealable plastic bag or 8-ounce clear glass jar and left in the sun for approximately 15 minutes to allow any volatile organic compounds (VOC) to volatilize.

5) After the 15 minute volatilization period, the soil vapor in the plastic bag is then measured for VOCs by taking a reading of the headspace. Background VOCs for the bag are determined by monitoring the air in an empty bag.

6) Results of the organic vapor monitoring are recorded on the boring log.

7) Small portions of soil at the ends of the sleeve are scraped off for classification.

Borehole Sampling by Drilling—Split Spoon Sampling

1) Samples collected for laboratory analysis using split spoon sampling device will be separated and transferred from the split-spoon halves into sample jars by clean stainless-steel utensils.
2) Samples for VOCs will be separated and collected first, followed by semivolatile organic compounds samples.
3) For VOC samples, avoid mixing the soil before sampling and sample directly from the split spoon. See SOPs for guidance on homogenizing soil samples and for VOC sampling using EnCore samplers, respectively.

Borehole Sampling by Drilling—Direct-push Sampling

1) Samples collected for laboratory analysis using a direct-push sampling drill rig will be handled by either opening the tube and placing the soil in sample jars or cutting the acetate tube and submitting it the laboratory directly.
2) For samples that will be removed from the acetate tube, the tube will be cut open longitudinally using a double-bladed razor knife.
    - Soil will be inspected and logged prior to removal of soil samples.
    - A short section of soil will be removed from the acetate sleeve using a stainless-steel utensil, homogenized in a clean stainless-steel bowl, and placed in sample jars.
    - Soil collected for VOC analysis will be sampled directly from the split acetate sleeve using EnCore samplers.
3) Alternatively, a short (6-inch) length of liner will be cut from the acetate sleeve and collected directly for laboratory analysis.
    - The section of acetate liner will be removed, capped with Teflon sheeting and plastic end caps at both ends, and taped with clear label or packing tape.
    - Labels shall be affixed to the liners with job designation, time, boring number, sample depth interval, sample number, date sampled, and the initials of the sampler clearly marked.
    - The samples shall then be enclosed in a plastic bag and stored in a cooler maintained at 4°C.
    - Sample information shall be placed on the chain-of-custody, the borelog, and the field logbook. All samples shall be handled in accordance with *Chain of Custody Procedures*.

Borehole Sampling by Drilling—Split-barrel Sampling

Soil samples can also be collected using a 3-foot-long or 5-foot-long split-barrel sampler. The split-barrel sampler is similar to the split-spoon sampler that is used to hold steel or brass sampling sleeves, but the split-barrel sampler typically is not used to hold sample sleeves.

1) The sampler is lowered to the base of the drill bit and is advanced slightly ahead of the drill bit and augers (or conductor casing). The weight of the drill string and sample barrel along with the drilling and cutting action of the drill bit advances the face of the split-barrel sampler into the formation.
2) Once the desired depth interval is reached, the split-barrel sampler is retrieved using a cable or tool steel sections.
3) The retrieved sampler is unscrewed, and one or both halves are laid on the sample table. The soil typically will form a continuous column of soil in one of the split-barrel halves.
4) The soil column is split longitudinally for soil descriptions using a putty knife or spatula.
5) Samples for VOC analysis are collected immediately directly from the soil column.
6) Other soil samples are collected after the core section has been described and logged. The soil is described following the procedures in the following sections.

Groundwater Sampling

1) Groundwater samples can be collected by hydropunch by bailer or by pumping from an isolated zone. Collection of groundwater by bailing is not an accurate method of collection depth discrete groundwater samples, as the zone sampled is poorly isolated.
2) Hydropunch samples are collected below the bit of the drill stem, in relatively undisturbed soil zone. This method of sample collection may be difficult in fine-textured soils and in very rocky soils. To collect these samples, a point is driven below the depth of the drill bit, then a screen zone is opened within this point and water allowed to flow in. The hydropunch tool must be decontaminated between samples.

Groundwater can also be collected from the open or cased borehole with a bailer. A disposable or decontaminated stainless-steel bailer is lowered into the boring, and water is collected. This method is preferable for collection of groundwater from the water table. Attempts can be made to collect discrete groundwater samples beneath the water table; however, the boring must be cased with watertight, stainless-steel pipe, and the boring must be evacuated prior to collection of samples.

Alternatively, discrete groundwater samples can be collected by isolating a zone with casing and packers. To collect these samples, the borehole is first advanced to the depth at which a sample is required. Then casing is advanced to within 20 feet of the sample zone. Next, a pump and packers are lowered into the hole. The zone from which samples are to be collected is isolated with a packer, and water is pumped directly from the target zone.

Sample Handling

Sample preservation and sampling procedures are detailed in Section 4.0 of the QAPP. Additional information is provided in the Procedures Manual and in the appropriate SAP.

KEY CHECKS AND ITEMS

- Check entries to the soil boring log and field logbook in the field during sampling activities because the samples will be disposed at the end of the fieldwork, confirmation and corrections cannot be made later.

- Check that the sample numbers and intervals are properly specified.
- Ensure that drilling equipment is decontaminated prior to the beginning of work and between each borehole.
- All materials generated during sampling (debris, PPE, decontamination liquids, etc.) will be placed in 55-gallon drums or roll-off bins for storage pending analysis and disposal off site, as outlined in SOP 39, Standard of Practice H-83, and Appendix D of the project *Soil and Groundwater Management Plan*.

ATTACHMENT A

Examples of Soil Bore Logs

CH2MHILL

PROJECT NUMBER	BORING NUMBER SHEET OF

SOIL BORING LOG

PROJECT ______ LOCATION ______

ELEVATION ______ DRILLING CONTRACTOR ______

DRILLING METHOD AND EQUIPMENT ______

WATER LEVELS ______ START ______ FINISH ______ LOGGER ______

DEPTH BELOW SURFACE (FT)	SAMPLE			STANDARD PENETRATION TEST RESULTS	SOIL DESCRIPTION	COMMENTS
	INTERVAL	NUMBER AND TYPE	RECOVERY (FT)	6"-6"-6" (N)	SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS AND INSTRUMENTATION

REV 9/96 FORM D1586

PROJECT NUMBER:	BORING NUMBER:
326128.01.16.EN	*MW-47*

SOIL BORING LOG - DRAFT FOR DISCUSSION

PROJECT NAME: IMPM Drill Program		**HOLE DEPTH (ft):** 288.0	**DRILLING CONTRACTOR:** Prosonic Corp. Phoenix, AZ	
SURFACE ELEVATION: 482.6 ft. MSL	**NORTHING (CCS NAD 27 Z 5):** 2,103,450.05	**EASTING (CCS NAD 27 Z 5):** 7,615,629.49	**DATE STARTED:** 02/27/2006	**DATE COMPLETED:** 03/13/2006
DRILLING METHOD: Rotosonic			**DRILLING EQUIPMENT:** Sonic AT (track mounted)	
LOCATION: PG&E Compressor Station - Flood Plain, Topock, California			**LOGGED BY:** B. Moayyad, K. Ebel	

DEPTH BGS (feet)	SAMPLE INTERVAL	SAMPLE TYPE/ NUMBER	SAMPLE RECOVERY (ft)	USCS CODE	SOIL DESCRIPTION: SOIL NAME, USCS SYMBOL, COLOR, PERCENT COMPOSITION, GRADING, GRAIN SHAPE, MINERALOGY, DENSITY/CONSISTENCY, STRUCTURE, MOISTURE.	COMMENTS: DRILLING OBSERVATIONS AND OPERATIONS, DAILY START AND END TIMES , DRILL RATE, REFUSALS, SAMPLING AND TESTING NOTES.
0–5			6	SP	**POORLY GRADED SAND (SP)** - very lt brn (10YR7/3), =2% fines, 98% f to m lithic quartz sand, subang to subrnd, dry - fine roots, iron staining, some iron oxide coating on grains	Hand augured to 5' bgs
5–15			10	SP	- slightly moist - dry	Rapid drill rate, no chatter
15–25			16	SW	**WELL GRADED SAND w/ GRAVEL (SW)** - lt yellowish brn (10YR6/4), 45% gravel up to 7cm, 50% f to m sand, 5% fines, loose, met subang gravel, dry(moist@ 17') - cobble present in slough - one subrnd chert gravel - Possible Fluvially Reworked Alluvium - lt grey (10YR7/2), subang to rnd met gravel up to 9cm, 2% to 5% fines - dk yellowish brn (10YR4/4), mostly c sand subang to ang, met, some Miocene conglomerate gravel - 65% sand, 30% gravel up to 4cm, 5% fines	
25–30				SW	**WELL GRADED SAND w/ GRAVEL (SW)** - dk yellowish brn (10YR3/6), 35% gravel up to 4cm, 55% m to c sand, 10% silty fines, met clasts are grain supported some mm siltstone - some oxide staining	
30–34				SW	**WELL GRADED SAND w/ GRAVEL AND CLAY (SW)** - dk yellowish brn (10YR3/6), 30% subang met gravel up to 7 cm, 55% subrnd to subang m to c sand, 15% clayey fines, m density, moist	Drill rate slowed to clean out 8" pipe
35						

CH2MHILL

PROJECT NUMBER: 326128.01.16.EN

BORING NUMBER: *MW-47*

SOIL BORING LOG - DRAFT FOR DISCUSSION

PROJECT NAME: IMPM Drill Program		**HOLE DEPTH (ft):** 288.0	**DRILLING CONTRACTOR:** Prosonic Corp. Phoenix, AZ
SURFACE ELEVATION: 482.6 ft. MSL	**NORTHING (CCS NAD 27 Z 5):** 2,103,450.05	**EASTING (CCS NAD 27 Z 5):** 7,615,629.49	**DATE STARTED:** 02/27/2006 / **DATE COMPLETED:** 03/13/2006
DRILLING METHOD: Rotosonic			**DRILLING EQUIPMENT:** Sonic AT (track mounted)
LOCATION: PG&E Compressor Station - Flood Plain, Topock, California			**LOGGED BY:** B. Moayyad, K. Ebel

DEPTH BGS (feet)	SAMPLE INTERVAL	SAMPLE TYPE/NUMBER	SAMPLE RECOVERY (ft)	USCS CODE	SOIL DESCRIPTION: SOIL NAME, USCS SYMBOL, COLOR, PERCENT COMPOSITION, GRADING, GRAIN SHAPE, MINERALOGY, DENSITY/CONSISTENCY, STRUCTURE, MOISTURE.	COMMENTS: DRILLING OBSERVATIONS AND OPERATIONS, DAILY START AND END TIMES , DRILL RATE, REFUSALS, SAMPLING AND TESTING NOTES.
			2.5	SW	**WELL GRADED SAND w/ GRAVEL (SW)** - dr yellowish brn (10YR3/6), 30% gravel, 60% sand, 10% silty fines	Drilling smooth but preceeds less rapidly
40			10	SW	**WELL GRADED SAND w/ GRAVEL (SW)** - 40% subang met gravel up to 6cm, 55% subrnd to ang sand, 5% fines - more gravel below 38' - gravel is mostly fine	
45						
50			10	SW	**WELL GRADED SAND w/ GRAVEL (SW)** - Pale brn (10YR6/3), 30% subang met gravel up to 5cm, 60% subrnd to subang m to c met sand, 10% silty fines, wet	Soil sample collected
				SP	**POORLY GRADED SAND w/ GRAVEL (SP)** - pale brn (10TR6/3), 30% f subang gravel up to 2 cm, 65% mostly c sand, =2% fines	
55				SW	**WELL GRADED SAND w/ GRAVEL (SW)** - yellowish brn (10YR5/4), 40% subang met gravel up to 9cm, 55% f to c met sand, 5% silty fines, clast supported, m density, wet	
60			9.5	GW	**WELL GRADED GRAVEL w/ SILT AND SAND (GW)** - brn (7.5YR5/4), 55% subang to ang met gravel up to 4cm, 25% f to c sand, 20% silty fines, dense, moist to dry - soil dries out - lt grey (10YR7/2) and powder dry - moist sandy zone, 55% gravel, 35% sand, 10% fines - dry silty lt grey GW below 65'	Collected Isoflow sample Drill rate slows to 2' / min
65						
70				SW	**WELL GRADED SAND w/ GRAVEL (SW)** - yellowish brn (10YR5/4), 35% subang met gravel up to 4cm, 60% subrnd sand, 5% silty fines, loose, moist to wet	Moderate Drill Rate

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SHEET 5 of 9		PROJECT NUMBER: 326128.01.16.EN	BORING NUMBER: *MW-47*

SOIL BORING LOG - DRAFT FOR DISCUSSION

PROJECT NAME: IMPM Drill Program		**HOLE DEPTH (ft):** 288.0	**DRILLING CONTRACTOR:** Prosonic Corp. Phoenix, AZ	
SURFACE ELEVATION: 482.6 ft. MSL	**NORTHING (CCS NAD 27 Z 5):** 2,103,450.05	**EASTING (CCS NAD 27 Z 5):** 7,615,629.49	**DATE STARTED:** 02/27/2006	**DATE COMPLETED:** 03/13/2006
DRILLING METHOD: Rotosonic			**DRILLING EQUIPMENT:** Sonic AT (track mounted)	
LOCATION: PG&E Compressor Station - Flood Plain, Topock, California			**LOGGED BY:** B. Moayyad, K. Ebel	

DEPTH BGS (feet)	SAMPLE INTERVAL	SAMPLE TYPE/NUMBER	SAMPLE RECOVERY (ft)	USCS CODE	SOIL DESCRIPTION: SOIL NAME, USCS SYMBOL, COLOR, PERCENT COMPOSITION, GRADING, GRAIN SHAPE, MINERALOGY, DENSITY/CONSISTENCY, STRUCTURE, MOISTURE.	COMMENTS: DRILLING OBSERVATIONS AND OPERATIONS, DAILY START AND END TIMES , DRILL RATE, REFUSALS, SAMPLING AND TESTING NOTES.
			6	SP	**POORLY GRADED SAND w/ SILT (SP)** - brn (7.5YR4/4), 5% subrnd to subang met gravel up to 4cm, 85% f to c sand, 10% fines, poorly graded, wet, no odor	
145			3	SM	**SILTY SAND W/ GRAVEL (SM)** - brn (7.5YR4/4), 20% subang to subrnd gravel up to 6cm, 60% f to c sand, 20% silty fines, well graded, m consolidated, met, wet, no odor	
150			5	SM	**SILTY SAND w/ GRAVEL (SM)** - dk yellowish brn (10YR4/4), 25% subang to subrnd up to 4cm met gravel, 60% well graded f to c sand, 15% fines, wet, no odor	
155			4	SW	**WELL GRADED SAND w/ SILT AND SAND (SW)** - dr yellowish brn (10YR4/4), 10% subang to subrnd up to 3cm met gravel, 75%well graded f to c sand, 15% fines, moist to wet	
			2	SW	**SILTY SAND (SM)** - brn (7.5YR4/4), 5% ang to subrnd met gravel up to 1.5cm increasing with depth, 85% poorly graded m to c sand, 10% fines, loose, wet	
			2	SM	**SILTY SAND w/ GRAVEL (SM)** - dk yellowish brn (10YR4/4), 15% subang to subrnd up to 2.5cm met gravel, 75% well graded f to c sand, 10% fines, mostly met, trace chert, loose, wet, no odor	Collected Isoflow sample
160			4	SM	**SILTY SAND W/ GRAVEL (SM)** - brn (7.5YR4/4), 25% subang to subrnd gravel up to 6.5cm, 60% m to c sand, 15% silty fines, well graded, m consolidated, met, wet, no odor	Drill rate = 0.75' to 1.5' / min
165			4	SW	**SILTY SAND (SW)** - mottled dk reddish brn (5YR3/4), 10% subang to subrnd gravel up to 2.5cm, 50% well graded f to m sand, 40% silt, metamorphic, dry to damp, no odor, interbedded sandy silt laminations	
170			5.5	SW	**SAND w/ GRAVEL (SW)** - dk reddish brn (5YR3/4), 20% subang to subrnd gravel up to 5cm, 75% f to c sand, 5% fines, well graded, loose, met, wet	
175			2.5	SM	**SILTY SAND w/ GRAVEL (SM)** - brn (7.5YR4/4), 15% subang to subrnd gravel, 70% f to m sand, 15% fines, poorly graded, met,increasingly consolidated, slightly to moderately calcareous, moist to wet	

PROJECT NUMBER:	BORING NUMBER:
326128.01.16.EN	*MW-47*

SOIL BORING LOG - DRAFT FOR DISCUSSION

PROJECT NAME: IMPM Drill Program		HOLE DEPTH (ft): 288.0	DRILLING CONTRACTOR: Prosonic Corp. Phoenix, AZ	
SURFACE ELEVATION: 482.6 ft. MSL	NORTHING (CCS NAD 27 Z 5): 2,103,450.05	EASTING (CCS NAD 27 Z 5): 7,615,629.49	DATE STARTED: 02/27/2006	DATE COMPLETED: 03/13/2006
DRILLING METHOD: Rotosonic			DRILLING EQUIPMENT: Sonic AT (track mounted)	
LOCATION: PG&E Compressor Station - Flood Plain, Topock, California			LOGGED BY: B. Moayyad, K. Ebel	

DEPTH BGS (feet)	SAMPLE INTERVAL	SAMPLE TYPE/ NUMBER	SAMPLE RECOVERY (ft)	USCS CODE	SOIL DESCRIPTION SOIL NAME, USCS SYMBOL, COLOR, PERCENT COMPOSITION, GRADING, GRAIN SHAPE, MINERALOGY, DENSITY/CONSISTENCY, STRUCTURE, MOISTURE.	COMMENTS DRILLING OBSERVATIONS AND OPERATIONS, DAILY START AND END TIMES , DRILL RATE, REFUSALS, SAMPLING AND TESTING NOTES.
285			0	BR	**MIOCENE CONGLOMERATE BEDROCK (BR)** - 60% well graded subang to rnd gravel up to 10cm, 30% well graded sand, 10% fines, very calcareous, well consolidated to mostly hard, mod to very altered locally, mostly met, dry to moist	

Boring Terminated at 288 ft

ABBREVIATIONS

cc = continuous core run
brn = brown
lt = light
dk = dark
vf = very fine-grained
f = fine-grained
m = medium-grained
c = coarse-grained
vc = very coarse-grained
ang = angular
subang = subangular
subrnd = subrounded
rnd = rounded
br = bedrock formation
ss = sandstone
conglom = conglomerate
comptd = compacted
qtz = quartz

CH2MHILL

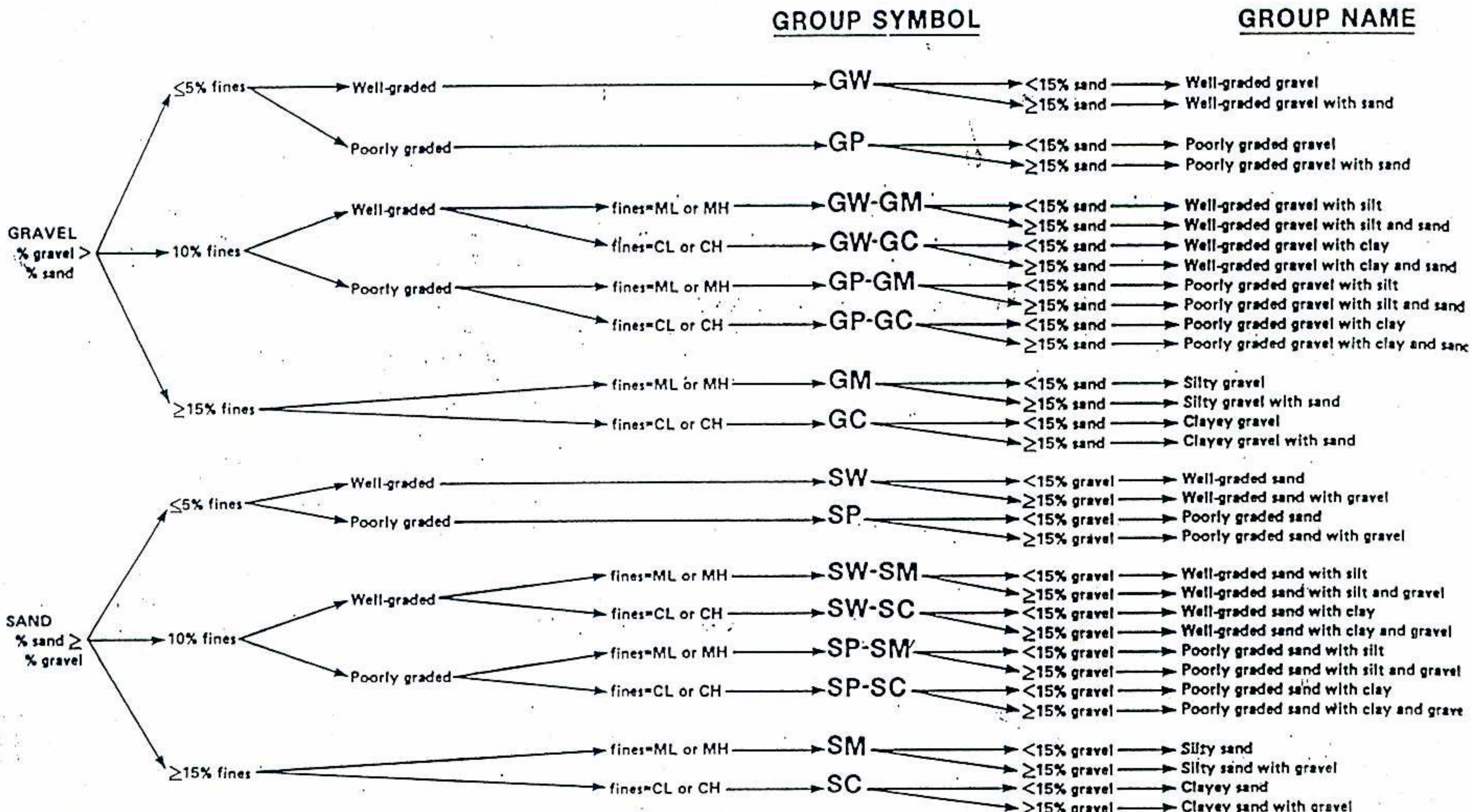
ATTACHMENT B

Unified Soil Classification System and Logging Criteria

GENERAL SOIL CATEGORIES			SYMBOLS	TYPICAL SOIL TYPES
COARSE GRAINED SOILS More than half is larger than No. 200 sieve	GRAVEL More than half coarse fraction is larger than No. 4 sieve size	Clean Gravel with little or no fines	GW	Well Graded Gravel, Gravel-Sand Mixtures
			GP	Poorly Graded Gravel, Gravel-Sand Mixtures
		Gravel with more than 12% fines	GM	Silty Gravel, Poorly Graded Gravel-Sand-Silt Mixtures
			GC	Clayey Gravel, Poorly Graded Gravel-Sand-Clay Mixtures
	SAND More than half coarse fraction is smaller than No. 4 sieve size	Clean sand with little or no fines	SW	Well Graded Sand, Gravelly Sand
			SP	Poorly Graded Sand, Gravelly Sand
		Sand with more than 12% fines	SM	Silty Sand, Poorly Graded Sand-Silt Mixtures
			SC	Clayey Sand, Poorly Graded Sand-Clay Mixtures
FINE GRAINED SOILS More than half is smaller than No. 200 sieve	SILT AND CLAY Liquid Limit Less than 50%		ML	Inorganic Silt and Very Fine Sand, Rock Flour, Silty or Clayey Fine Sand, or Clayey Silt with Slight Plasticity
			CL	Inorganic Clay of Low to Medium Plasticity, Gravelly Clay, Sandy Clay, Silty Clay, Lean Clay
			OL	Organic Clay and Organic Silty Clay of Low Plasticity
	SILT AND CLAY Liquid Limit Greater than 50%		MH	Inorganic Silt, Micaceous or Diatomaceous Fine Sandy or Silty Soils, Elastic Silt
			CH	Inorganic Clay of High Plasticity, Fat Clay
			OH	Organic Clay of Medium to High Plasticity, Organic Silt
HIGHLY ORGANIC SOILS			PT	Peat and Other Highly Organic Soils

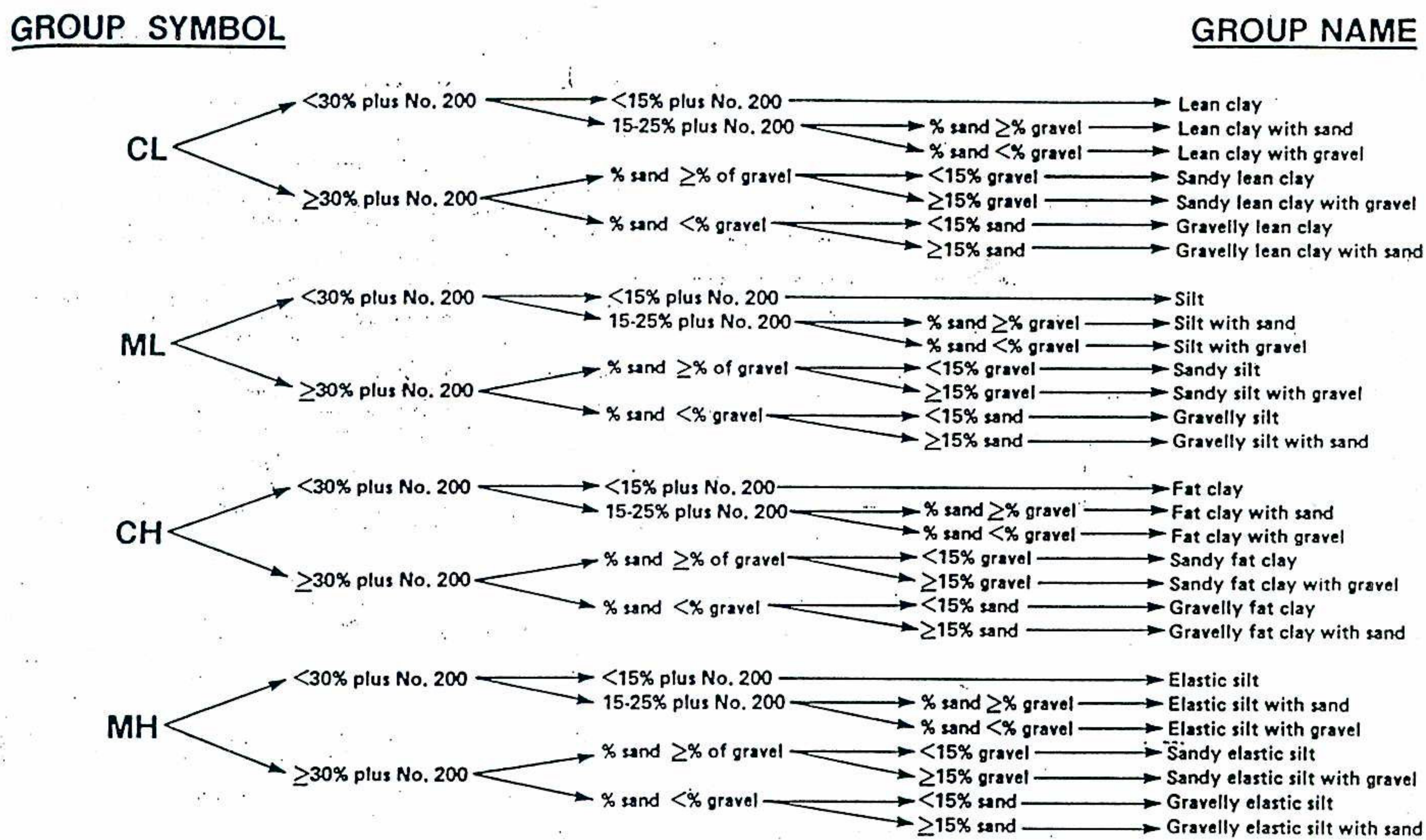
UNIFIED SOIL CLASSIFICATION SYSTEM

JOB NUMBER	DATE	APPROVED	PLATE



NOTE:
Percentages are based on estimating amounts of fines, sand, and gravel to the nearest 5%
(After ASTM Designation D2488 Standard Test Method for Classification of Soils for Engineering Purposes)

Flow Chart for Classifying Coarse-grained Soil
(50% or more retained on No. 200 sieve)
Field Guide for Soil Classification and Logging Procedures



NOTE:
Percentages are based on estimating amounts of fines, sand, and gravel to the nearest 5%
(After ASTM Designation D2488 Standard Test Method for Classification of Soils for Engineering Purposes)

Flow Chart for Classifying Fine-grained Soil
(50% or more passing No. 200 sieve)
Field Guide for Soil Classification and Logging Procedures

similar, the material is classified as poorly graded or well sorted. If fines represent less than 5 percent of the total mass, the symbol SP is used for a poorly-graded sand and SW for a well graded sand. If silts and/or clays exceed 12 percent, the symbols GC, SC, GM, and SM are used, respectively.

If the silts and clays are between 5 to 12 percent of the total sample weight, a dual classification with two group symbols is used. The first symbol is GW, GP, SW, or, SP, and the second is GC, GM, SC, or SM. The group name corresponds to the first group symbol plus the modifying words "with clay" or "with silt" to indicate the plasticity characteristics. If the fines plot on the CL-ML range on the plasticity chart (Figure 2-2), possible dual classification group names are:

GW-GM	well graded gravel with silt
GW-GC	well graded gravel with clay
GP-GM	poorly graded gravel with silt
GP-GC	poorly graded gravel with clay
SW-SM	well graded sand with silt
SW-SC	well graded sand with clay
SP-SM	poorly graded sand with silt
SP-SC	poorly graded sand with clay

If silts and clays exceed 12 percent of the total weight of sample, the modifiers "M" and "C" are used, respectively. If a sand or gravel has more than 15 percent of the other coarse-grained constituent, the words "with gravel" or "with sand" are added to the group name. A flow chart for classifying coarse-grained soils is presented in Figure 2-3.

2.2 Fine-grained Soils

Particles passing the No. 200 sieve are silts (M) and clays (C). These soils must undergo testing in order to differentiate between them. Typical tests used are: dry strength, dilatancy, toughness, and plasticity. These terms are further discussed in Tables 2-2 through Table 2-6. Silts have little or no dry strength when dry, while clays have considerable dry strength. Dry strength, dilatancy, and toughness are also used to identify the fine-grained fraction of coarse-grained soils.

TABLE 2-2
Criteria for Describing Dry Strength

Description	Criteria
None	The dry specimen crumbles into powder with the mere pressure of handling.
Low	The dry specimen crumbles into powder with some finger pressure.
Medium	The dry specimen breaks into pieces or crumbles with considerable finger pressure.
High	The dry specimen cannot be broken with finger pressure. The specimen will break into pieces between the thumb and a hard surface.
Very high	The dry specimen cannot be broken between the thumb and a hard surface.

TABLE 2-3
Criteria for Describing Dilatancy

Description	Criteria
None	There is no visible change in the specimen.
Slow	Water appears slowly on the surface of the specimen during shaking, and does not disappear, or disappears slowly upon squeezing.
Rapid	Water appears quickly on the surface of the specimen during shaking, and disappears quickly upon squeezing.

TABLE 2-4
Criteria for Describing Toughness

Description	Criteria
Low	Only slight pressure is required to roll the thread near the plastic limit. The thread and the lump are weak and soft.
Medium	Medium pressure is required to roll the thread to near the plastic limit. The thread and the lump have medium stiffness.
High	Considerable pressure is required to roll the thread to near the plastic limit. The thread and the lump have very high stiffness.

TABLE 2-5
Identification of Inorganic Fine-grained Soils from Manual Tests

Soil Symbol	Dry Strength	Dilatancy	Toughness
ML	None to low	Slow to rapid	Low or thread cannot form
CL	Medium to high	None to slow	Medium
MH	Low to medium	None to slow	Low to medium
CH	High to very high	None	High

TABLE 2-6
Criteria for Describing Plasticity

Description	Criteria
Nonplastic	A 1/8-inch (3-mm) thread cannot be rolled at any water content.
Low	The thread can barely be rolled, and the lump cannot be formed when drier than the plastic limit.
Medium	The thread is easy to roll, and not much time is required to read the plastic limit. The thread cannot be re-rolled after reaching the plastic limit. The lump crumbles when drier than the plastic limit.
High	It takes considerable time rolling and kneading to reach the plastic limit. The thread can be re-rolled several times after reaching the plastic limit. The lump can be formed without crumbling when drier that the plastic limit.

Fine-grained soils are accurately determined in the laboratory using the Atterberg Limits test. This test include liquid limit, plastic limit, and plasticity index measurements. The liquid limit is the water content of a soil at the point of transition from a plastic to a liquid state. The plastic limit is the water content of a soil at the point of transition from a semisolid to a plastic state. The plasticity index is the difference between the liquid limit and the plastic limit.

As shown in the Figure 2-2, five fields have been identified. These include:

- Silty Clays (CL), Organic Silts (OL) or Organic Silty Clays (OL) of low plasticity
- Fat Clays (CH) and Organic Clays (OH)
- Inorganic Silts (ML) and Organic Silty Clays (OL) of low plasticity
- Silts (MH) and Organic Clays (OH) of a high plasticity
- Silty Clays to Clayey Silt (CL-ML) of low plasticity

Fine-grained soils with a liquid limit > 50 are modified by the symbol H (MH or CH), and those with a liquid limit < 50 are modified by the symbol L (ML or CL). Fine-grained soils containing 30 percent or more coarse-grained fraction should be modified by descriptive terms, such as "gravelly" or "sandy." If the coarse fraction is between 15 and 30 percent, the words" with sand and/or gravel" should be added to the group name. A flow chart for classifying fine-grained soils is presented in Figure 2-4.

2.3 Organic Soils

To classify organic soils, the percentage organic material present in the soil as well as the non-organic fines must be estimated. When the organic content ranges from 18 to 36 percent, the material is an organic clay or an organic silt, depending on the nature of the fine-grained constituents. When the organic content is between 36 and 90 percent, the material is designated a muck or peaty muck (OL or OH). A flow chart for classifying organic soil is presented in Figure 2-4. The term "peaty" is added if the organic remains are

SOP-B5

Decontamination of Personnel and Equipment, Well Drilling, and Subsurface Sampling and Investigations
Standard Operating Procedures for PG&E Topock Program

This standard operating procedure provides general guidelines for the decontamination of personnel, sampling equipment, and monitoring equipment used in potentially-contaminated areas.

REQUIRED DOCUMENTS

1) Event-specific sampling and analysis plan (SAP).
2) Applicable project work plan or monitoring plan, which includes a health and safety plan. Refer to Topock Program *Sampling, Analysis, and Field Procedures Manual* and *Quality Assurance Project Plan*, as required.

PREPARATION AND SETUP

1) Initiate field log sampling book for activity.
2) Inspect all equipment necessary to carry out activities detailed in event-specific SAP.
3) Review decontamination guidelines for equipment necessary to carry out activities.

Equipment List

- Demonstrated analyte-free, deionized water (specifically, ASTM Type II water)
- Distilled water
- Potable water; must be from a municipal water supplier, otherwise an analysis must be run for appropriate volatile and semivolatile organic compounds and inorganic chemicals (e.g., Target Compound List and Target Analyte List chemicals)
- 2.5% (W/W) Liquinox® and water solution
- Large plastic pails or tubs for Liquinox® and water, scrub brushes, spray or squirt bottles for Liquinox® solution, and distilled or deionized water, plastic bags, and sheets
- Department of Transportation (DOT)-approved 55-gallon drum for disposal of waste
- Nitrile or latex gloves
- Decontamination pad and steam cleaner/high pressure cleaner for large equipment

GUIDELINES

Personnel Decontamination

Decontamination should be performed after completion of tasks whenever personnel come in contact with contaminated (or potentially-contaminated) soils or fluids. Full or emergency decontamination should be performed when contaminant concentrations are not known and when potentially-contaminated fluids come into contact with skin beneath clothing, eyes, nose, or ears.

Procedures for full/emergency decontamination are to:

1) Remove contaminated clothing.
2) Step into containment area (decontamination pad or large pail).
3) Rinse away fluids and soil.
4) Wash skin with Liquinox® solution in such a way as to not abrade skin. (Liquinox® solution should be made with potable water and sufficient detergent to create foamy suds.) Eyes and mucus membranes in contact with contaminants must be washed with eye wash or drinking water continuously for at least 15 minutes.
5) Rinse with potable water.
6) If no other clothes are available, wash affected clothes in Liquinox® solution prior to donning. If other clothes are available, contaminated clothes may be isolated for later wash or disposed of along with personal protective equipment (PPE).
7) Any PPE worn (including disposable latex booties, gloves, and disposable coveralls) should be discarded into DOT-approved 55-gallon drum located at the MW-20 bench.
8) Dispose of wash and rinseate water in an appropriate container with other chromium contaminated fluids. These fluids may be taken to the MW-20 bench for treatment or to a Baker® tank within the PG&E facility for containerization.
9) Replace all appropriate clothing and PPE before resuming work or departing site.

Moist soil or water containing known concentrations of hexavalent chromium less than 50 parts per billion that comes into contact with hands need not require full decontamination. Dry soil containing chromium that comes into contact with clothing can also be decontaminated in an abbreviated manner.

Daily decontamination and minor exposure contact decontamination procedures are to:

1) Wash hands and skin that comes in contact with soils or water that may contain small concentrations of chromium as soon as possible after contact. Wash with Liquinox® solution and rinse with potable water.
2) If contaminated soil or water contacts hands through hole or over lip of gloves, remove gloves and wash hands thoroughly before donning new gloves.
3) Discard gloves into DOT-approved 55-gallon drum located on the MW-20 bench at the end of the day or event.

4) Remove coveralls or dry soils from clothing before leaving site. Clothing contaminated by moist soil or water containing hexavalent chromium should be removed and promptly washed.

5) At the end of the work day, shower entire body, including hair, either at the work site or at hotel.

Sampling Equipment Decontamination—Groundwater Sampling Pumps

Sampling pumps are decontaminated after each use as follows:

1) Don waterproof (nitrile or latex) gloves.

2) Run pump and reusable tubing through with Liquinox® solution (made with potable water) so that the pump and all portions or the tubing have been flushed with the solution for at least 30 to 60 seconds. More time is required if water is present in the tubing. If unsure, run for 2.5 minutes. Outside of the tubing should also be submerged and washed in the solution.

3) Run pump and reusable tubing through first rinse (with potable or distilled water) so that the pump and all portions or the tubing have been flushed with the solution for at least 60 seconds. More time is required if any suds are present in the pump or tubing.

4) Run pump and reusable tubing through second rinse (with distilled water) so that the pump and all portions or the tubing have been flushed with the solution for at least 30 seconds. More time is required if water from first rinse is present in tubing.

5) Equipment blank samples may be taken at this point using ASTM Type II water or distilled water as required by laboratory.

Sampling Equipment Decontamination—Other Equipment

Reusable sampling equipment is decontaminated after each use as follows:

1) Don nitrile or latex gloves.

2) Wash all equipment surfaces that contacted the potentially contaminated soil/water with Liquinox® solution (made from potable water). Water quality meters that are not placed within wells should not be washed with detergent, as this will degrade sensors; these meters should be double-rinsed. Any portion of equipment that is placed inside wells (including cables and pipe) and that comes in contact with moisture should be washed with detergent.

3) Rinse equipment and supplies with potable water, if the equipment is not used to collect groundwater or soil samples. Equipment used to collect samples or take water quality parameters should be rinsed with distilled water.

4) Air dry or towel dry with paper towels.

5) Collect all rinseate and dispose of in Baker® tank within the PG&E facility or Denbeste® tank at the MW-20 bench.

6) Decontamination materials (e.g., plastic sheeting, tubing, etc.) that have come in contact with used decontamination fluids or sampling equipment will be disposed of in DOT-approved 55-gallon drums if highly contaminated. If not contaminated, equipment can be washed and disposed of in trash.

7) Preserved bottles may need to be washed before being packed or handed without gloves. The outsides of filled bottles should be rinsed and toweled dry to prevent contact with strong acids or based.

Heavy Equipment and Tools

Heavy equipment such as drilling rigs, drilling rods/tools, and the backhoe will be decontaminated upon arrival at the site and between locations as follows:

1) Set up a decontamination pad in designated area.

2) Steam clean heavy equipment until no visible signs of dirt are observed. This may require wire or stiff brushes to dislodge dirt from some areas.

KEY CHECKS AND ITEMS

- Clean with solutions of Liquinox® and potable water. Rinse with distilled or deionized water if equipment is used to collect samples or water readings; otherwise, rinse with potable water.
- Equipment placed within wells should be thoroughly decontaminated and before being placed in a well. All potions of this equipment that come into contact with moisture should be decontaminated.
- Decontaminate filled sample bottles before relinquishing them to anyone.

SOP-B7

Homogenization of Soil and Sediment Samples
Standard Operating Procedures for PG&E Topock Program

The homogenization of soil and sediment samples is performed to minimize any bias of sample representativeness introduced by the natural stratification of constituents within the sample. Standard techniques for soil and sediment homogenization and equipment are provided in this SOP. These procedures do not apply to aliquots collected for volatile organic compounds (VOCs) or field gas chromography screening; samples for these analyses should NOT be homogenized.

REQUIRED DOCUMENTS

1) Event-specific sampling and analysis plan (SAP).
2) Applicable project work plan or monitoring plan. Refer to Topock Program *Sampling, Analysis, and Field Procedures Manual* and *Quality Assurance Project Plan,* as required.
3) Topock Program Health and Safety Plan (HSP).
4) Previous sampling logs.
5) Blank sampling logs and field notebook.

PREPARATION AND SETUP

1) Review event-specific SAP or event-specific field instructions, previous sampling logs, Procedures Manual, and HSP.
2) Initiate field logbook for sampling activity.

EQUIPMENT LIST

- Sample containers
- Stainless-steel spoons or spatulas
- Stainless-steel pans
- Phthalate-free gloves

PROCEDURES

Sample Homogenization

1) Soil and sediment samples to be analyzed for semivolatiles, pesticides, polychlorinated biphenyls, metals, cyanide, or field x-ray fluorescence screening should be homogenized in the field.
2) After a sample is taken, a stainless-steel spatula should be used to remove the sample from the split spoon or other sampling device. The sampler should not use fingers to do this, as gloves may introduce organic interferences into the sample.

3) Samples for VOCs should be taken immediately upon opening the spoon and should not be homogenized.

4) Prior to homogenizing the soil or sediment sample, any rocks, twigs, leaves, or other debris should be removed from the sample.

5) The sample should be placed in a decontaminated stainless-steel pan and thoroughly mixed using a stainless-steel spoon. The soil or sediment material in the pan should be scraped from the sides, corners, and bottom, rolled into the middle of the pan, and initially mixed.

6) The sample should then be quartered and moved to the four corners of the pan. Each quarter of the sample should be mixed individually, then rolled to the center of the pan and mixed with the entire sample again.

Equipment Decontamination

1) All stainless-steel spoons, spatulas, and pans must be decontaminated following procedures specified in SOP *Decontamination of Personnel and Equipment* prior to homogenizing the sample.

2) A composite equipment rinse blank of homogenization equipment should be taken each day it is used.

SOP-B8

General Guidance for Well Surveying
Standard Operating Procedures for PG&E Topock Program

To provide site personnel with a review of the procedures necessary to perform a proper survey of monitoring wells and other site features at the Topock site. These procedures are to be considered general guidelines only and are in no way intended to supplement or replace the PG&E guidelines.

REQUIRED DOCUMENTS

1) Topock Program Health and Safety Plan (HSP)
2) Topographic map(s) of the Topock station and surrounding sites.
3) Maps that show features to be surveyed and reference landmarks.
4) Soil Boring Log and or other lithologic descriptions of the local area
5) Well construction logs/specifications for wells to be surveyed.
6) Blank survey logs and field notebook

EQUIPMENT LISTS

The equipment needed for surveying are simply the survey or global positioning equipment, and the vehicle and keys needed to access each site.

DEFINITIONS

The following terms are defined to clarify discussion in this SOP:

- North American Datum (NAD) -The standard geodetic datum on the North American continent.
- North American Vertical Datum (NAVD) 1983 - The vertical-control datum used by the National Geodetic Survey for all new vertical control.
- Horizontal Control - Horizontal location of an object from surveyed corners or other features on permanent land monuments in the immediate site area. Will be based on North American Datum (NAD) 1983 and state plane grid systems (California State Plane Coordinate System, Zone 5).
- Vertical Control - Vertical location of an object compared to the adjacent ground surface.
- Bench Mark - Precisely determined elevation above or below sea level. May also have horizontal control (northing, easting) determined for location.

PROCEEDURES

Record Keeping

All field notes should be kept in bound books. Each book should have an index. Each page of field notes should be numbered and dated and should show the initials of all crew members. The person taking field notes will be identified in the log. Information on weather (wind speed/wind direction, cloud cover, etc.) and on other site conditions should also be entered in the notes. Notes should also include instrument field identification number and environmental settings. Graphite pencils should be used. Erasing is not acceptable; use a single-strike-through and initial it. The note keeping format should conform to the *Handbook of Survey Note keeping* by William Pafford. A survey work drawing with grid lines and at the scale of the topographic map should be prepared for all survey field work in AutoCAD or Microstation (depending on client specifications).

Horizontal Survey

Horizontal angular measurements shall be made with a 5-second or better total station. All angles shall be doubled (once each direct and inverted), with the mean of the second angle within 5 seconds of the first angle. The minimum length of any traverse courses shall be 300 feet.

Distance measurements shall be made with a total station. When using a total station the parts per million (PPM), curvature and refraction corrections shall be made. Vertical angle measurements used for distance slope corrections shall be recorded to the nearest 5 seconds of arc deviation from the horizontal plane. Horizontal locations will be surveyed to within 0.05-foot of the true location.

Horizontal traverse stations shall be established and referenced for future use. All stations shall be described in the field notes with sufficient detail to facilitate their recovery at a later date. The station shall consist of a permanent mark scribed on facilities such as sidewalks, curbs, concrete slabs, or iron rod and cap.

The horizontal location will be referenced to NAD83 and California Zone 5 in the state plane grid system.

Some horizontal coordinates will be measured using Geographic Positioning System (GPS) equipment. This approach will be used in particular for determining the coordinates of surface-water and sediment sampling locations, and may be used also for determining the locations of piezometers and monitoring wells. The GPS survey will be performed by staff trained in the use of the equipment and will conform to guidance provided by the manufacturer.

Vertical Survey

When practical, vertical control will be referenced to the North American Vertical Datum (NAVD) of 1988, obtained from a permanent benchmark. If practical, level circuits should close on a known benchmark other than the starting benchmark. The following criteria shall be met in conducting the survey:

Using a Conventional Level

- Instruments shall be pegged weekly or after any time it is dropped or severely jolted.
- Foresight and backsight distances shall be reasonably balanced and shall not be greater than 250 feet in length.
- No side shot shall be used as a beginning or ending point in another level loop.

- Rod readings shall be made to 0.01-foot and estimated to 0.005-foot.
- Elevations shall be adjusted and recorded to 0.01-foot.

Using an electronic Digital Level

- Use the electronic level per the instructions for the specific instrument.
- Balance forsight and backsight distances per instrument specifications.
- Elevations shall be adjusted and recorded to 0.01-foot.

Using a Total Station (Trig levels)

- From each instrument station readings will be taken both with a direct scope and an inverted scope.
- Direct and inverted measurements will be meaned and than meaned again with the adjacent stations.
- The level loop will be closed to another known monument or back on the beginning monument.
- Elevations shall be adjusted and recorded to 0.01-foot.

Using Global Positioning Systems (GPS)

- The GPS survey will be performed staff trained in the use of the equipment.
- All monuments to be used for Vertical Control will be tied from two existing vertical control monuments.
- Geoid03 model will be used.
- Elevations shall be adjusted and recorded to 0.01-foot.

Temporary benchmarks (TBM's) shall be established and referenced for future use. All TBM's shall be described in the field notes with sufficient detail to facilitate their recovery at a later date. The TBM's shall consist of a permanent mark scribed on facilities such as sidewalks, curbs, concrete slabs, etc. or spikes set in the base of trees (not power poles), or tops of anchor bolts for transmission line towers, etc. (If suitable Horizontal traverse stations can be used as a TBM's .)

Traverse Computations and Adjustments

Traverses will be closed and adjusted in the following manner:

1) Coordinate closures will be computed using unadjusted bearings and unadjusted field distances.
2) Coordinate positions will be adjusted (if the traverse closes within the specified limits) using the compass rule or a Least Square Adjustment Program.
3) Final adjusted coordinates will be labeled as "adjusted coordinates." Field coordinates should be specifically identified as such.

4) The direction and length of the unadjusted error of closure, the ratio of error, and the method of adjustment shall be printed with the final adjusted coordinates.

5) The adjustment shall meet 3rd order specifications.

Level Circuit Computations and Adjustments

Level circuits will be closed and adjusted in the following manner:

- For a single circuit, elevations will be adjusted proportionally, provided the raw closure is within the prescribed limits for the circuit.
- In a level net where the elevation of a point is established by more than one circuit, the method of adjustment should consider the length of each circuit, the closure of each circuit, and the combined effect of all the separate circuit closures on the total net adjustments.

Piezometer and Monitoring-Well Surveys

Piezometer and monitoring-well locations will be surveyed only after the installation of the protective casing, which is set in concrete. The horizontal plane survey accuracy is ±0.05-foot and is measured to any point on the protective-casing cover. The vertical plane survey must be accurate to ±0.01-foot. The following two elevations will be measured at piezometers and monitoring wells:

- Top of the piezometer or well riser (not on the protective casing), preferably on the north side
- Ground surface, preferably on the north side of the well

If no notch or mark exists, the point at which the elevation was measured on the inner casing shall be described and marked so that water-level measurements may be taken from the same location.

Grid Surveys

Selected soil boring locations may be located by the survey crew after the soil borings are complete. The selected borings will be staked in the field by the field team leader. The stake will be marked with the boring number for reference. The horizontal plane survey accuracy is ± 1 foot and is measured to any point on the ground surface immediately adjacent to the stake.

KEY CHECK

STANDARDS FOR MODIFIED THIRD-ORDER PLANE SURVEYS

Traverse

Max Number of bearing courses between azimuth checks	30
Astronomical bearings standard error of results:	6"
Azimuth closure at azimuth checkpoint not to exceed	20" $\sqrt{N}$
Standard error of the mean for length measurements	1 in 50,000
Position closure per loop in feet before azimuth adjustment	1:10,000

Leveling

Levels error of closure per loop in feet $0.05\sqrt{M}$

N = the number of stations for carrying bearing
M = the distance in miles

SOP-B9

Drilling--Sonic Method
Standard Operating Procedures for PG&E Topock Program

REQUIRED DOCUMENTS

1) Event-specific sampling and analysis plan (SAP), Work Plan or event-specific field instructions. Planned borehole depth, proposed well construction/specifications, and field sampling summary table, if available.

2) Applicable project work plan or monitoring plan. Refer to Topock Program Sampling, Analysis, and Field Procedures Manual and QAPP (Procedures Manual), as required.

3) Topock Program Health and Safety Plan (HSP)

4) Previous sampling, drilling, or well construction logs from other boreholes or wells in the vicinity, if available

5) Blank sampling log and field notebook

Equipment List:

- Drilling rig (Sonic)
- Drill rods and core barrel

GUIDELINES

PRIOR TO INTRUSIVE ACTIVITIES AT ANY DRILLING LOCATION THE AREA WILL HAVE BEEN CLEARED OF ALL UTILITIES AND THE CLEARANCE RECORDED IN THE FIELD LOGBOOK. It is also the field team leader's responsibility to confirm that all required access permits are in place.

Prior to the start of drilling, the area of site activity will be identified and delineated using stakes and/or flagging. The extent of impact will be mineralized at all times and the delineated area of activity decreased when possible. All sensitive vegetation or habitats will be delineated with stakes and/or flagging and no impact will occur in these areas.

Sampling depths and total depths of holes shall be determined by temporary marking of drill equipment, by reference to standard equipment dimensions (for example, 5-foot hollow-stem auger flights), or by measurement using a fiberglass tape. Final total depth measurements will be confirmed using a weighted fiberglass tape. Observations by the field geologist or engineer shall be recorded directly in the borehole log.

The field borehole log is the standard form used to document subsurface geologic conditions. The borehole log is divided into two areas. One portion contains spaces for noting information on the drilling and sampling methods. The second portion contains space for noting lithologic descriptions. All sheets shall be filled out completely, legibly, and in ink. The borehole log will be filled out in the field at the time of the drilling and sampling. The original logs shall be permanent records, and information on the logs may not be erased. If corrections are needed, information shall be crossed out with a single line and the correction shall be initialed and dated.

The use of water and drilling fluid to assist in sonic drilling for monitoring well installation will be avoided, unless required for such conditions as running sands or drilling bedrock formations.

Temporary outer casing, drill rods, core barrels, and other downhole drilling tools will be properly decontaminated prior to the initiation of drilling activities and between each borehole location. Core barrels and other downhole soil sampling equipment will also be properly decontaminated before and after each use.

Sonic inner casing (sample tube) will have an inside diameter of at least 3.25 inches. Samples may be collected for chemical analysis. For sonic drilling, these samples are collected in a metal trough. A continuous core is collected and the sample interval is selected from the length of core run.

Surface casing may be installed where soil borings will penetrate a confining layer or when there is risk of eroding soil during the drilling process if water is used.

PROCEDURES

Instructions for Completing Soil Boring Logs

Soil boring logs will be completed in the field log books. Information collected will be consistent with that required for Form D1586 (attached), a standard CH2M HILL form or an equivalent form that supplies the same information. Procedures will follow the SOP "*Soil*

Non-Core Collection Drilling

At locations or depths from which core collection is not required, drilling may proceed without the recovery of soil cores. The drilling will include advancing the larger outer casing and the use of water to facilitate cuttings removal from the boring. The inner casing drill rods may or may not be used, depending on the cuttings recovery when drilling with the larger outer casing.

Continuous Core Drilling

At locations or depths when core collection is required, drilling will proceed using an outer casing and an inner core sample tube. The inner core sampling tube will be advanced first without the use of water. Before removal of the sampling tube, the outer casing will be advanced, using water only as needed for cuttings removal, to the same total depth as the inner casing. The outer casing will stabilize the boring when the sampling tube is removed. The process is repeated in 10 to 20 foot intervals, as the lithology of the boring permits.

The length of each drilling interval should be adjusted depending on the lithology and the quality and recovery percentage of the sample cores retrieved. At locations with very hard drilling (i.e. with large cobbles or hard materials) or when percent recovery decreases, the drilling interval should be decreased until such time that the conditions change.

After retrieval of the inner sampling core tube, the minimally disturbed sample cores will be collected into plastic liner sleeves in intervals of 2 to 3 feet. The plastic sleeves will be immediately sealed on both ends. The cores will be used for visual descriptions and may be used for analysis for geochemical and geotechnical parameters.

KEY CHECKS AND ITEMS

- Check entries to the soil boring log and field logbook in the field during sampling activities because the cores will be disposed at the end of the fieldwork, confirmation and corrections cannot be made later.
- Check that the sample numbers and intervals are properly specified.
- Ensure that drilling equipment is decontaminated prior to the beginning of work and between each borehole.
- All materials generated during sampling (debris, PPE, decontamination liquids, etc.) will be placed in approved IDW storage containers pending analysis and disposal off site as outlined in SOP-B6, *Disposal of Waste Fluids and Solids (IDW)*.

SOP-B11

Site Clearance and Permitting
Standard Operating Procedures for PG&E Topock Program

This standard operating procedure (SOP) addresses the procedures for site clearance and permitting at the Topock site. This SOP should be used to obtain proper site clearance and permits before any work is performed at a site.

REQUIRED DOCUMENTS

1) Applicable project work plan, event-specific sampling and analysis plan (SAP), and/or Procedures Manual, if applicable.
2) Topock Program Health and Safety Plan (HSP).
3) Site map with work locations identified.

PREPARATION AND SETUP

1) Review applicable project work plan, event-specific SAP, Procedures Manual, and HSP.
2) Identify locations where work will be performed, determine if any subsurface work will be needed.
3) Before the start of any work obtain approval by the appropriate land agencies (such as BLM, USFWS, County of San Bernardino). Activities located on PG&E property fall under the jurisdiction of the County; however, approval may also be required from BLM and/or USFWS for activities such as access, waste management, etc. Work in Topock, Arizona falls under the jurisdiction of the Arizona Department of Water Resources.
4) Before the start of any work obtain appropriate approval by the regulatory agencies. These include at a minimum the DTSC if in California, and ADEQ is in Arizona. Other regulatory approvals that may be required include, but are not limited to CDFG, USFWS, USACE and RWQCB. Approval from the Arizona Land Department may also be required for wells drilled in Arizona.

If subsurface work will be involved, follow the following steps:

1) Follow the guidelines of the Southern California Underground Service Alert (USA) agency to mark the edges of the work location as outlined on their web page (http://www.digalert.org). If in Arizona, the Arizona Blue Stake should be contacted for location of buried facilities (www.azbluestake.com). Make sure to:
   - Identify delineated areas with white markings with the requesters company name or logo within the pre-marked zones
   - Delineate the exact area of excavation with white paint through the use of dots or dashes, or a continuous solid line. Limit the size of each dash to approximately 6" in length and 1" width with interval spacing not less that approximately 4 feet. Dots of

approximately 1" diameter are typically used to define arcs or radii and may be placed at closer intervals in lieu of dashes. Limit width of lines to 1".

- For point locations (such as a soil boring or well) mark the exact location in the USA or Blue Stake box with a stake. Make sure the delineated area around the stake is of adequate radius (50 to 100 feet is appropriate for drilling).

2) Call USA at 1-800-227-2600 or Arizona Blue Stake at 1-800-782-5348 at least three working days before the start of work at the identified location and provide them with the information requested on the location request form. Be ready to give the location in terms of feet relative to I-40 and to Park Moabi Road when calling. You will be assigned a Dig Alert Number, file this number until work at the delineated area is complete. (The number does expire after two weeks and a new number may need to be obtained if work has been delayed.)

3) Mark the Dig Alert Number in the delineated area using white paint as soon as possible after calling USA or Arizona Blue Stake.

4) If the location is in a developed area, contact a private utility locator and have them perform a sweep of the delineated work area. Util-Locate at (866) 421-5325 is typically used for this service.

5) In some cases the utility companies may need to be contacted directly by CH2M HILL. If the following companies do not respond to the USA or Blue Stake ticket or if we are working in their easements, use the following contact information and procedures:

Southwest Gas: Main contact is Jim Default/702-365-2097
(The required minimum clearance distance from gas pipelines is 18-inches**.** Potholing may need to be performed in advance of design completion Southwest Gas should be called prior to construction activities). If Southwest Gas does not come to the site after the USA call, contact them at their Bullhead City office at (928) 763-7766

Southern California Gas Co.: Main contact is Frank Castro/818-701-4566; secondary contact is Martin Woodsworth/818-701-4543. If we need to work in their easement, we must provide a letter from BLM giving us permission to be on the property. Southern California Gas Co. also requires advance notification of construction activities. They may also require a copy of the design drawing, potholing activities, and the issuance of a "Non-Interference" letter, if applicable, before work can proceed. One of their representatives may need to be in the field when digging is occurring near their pipeline.

TransWestern Pipeline Co.: Main contacts are Ron Westbrook (ROW Department)/713-345-3067 and Mike Baxter (Operations)/928-757-3620. They may require potholing if proposed construction activities are near their pipelines. Crossing pipeline requires filling out a simple form.

Burlington Northern Santa Fe Railroad: Main contact is Greg Rousseau (BNSF)/909-386-4079. Prior to work in their easements submit the proper application with the $250 fee to the Staubach Company.

City of Needles Utility Dept: Main contact is Ron Myers/760-326-5700 (ext. 7 for the utilities department). Work activities may need to be a minimum of 10 to 15 feet from their utility poles.

6) Do not start subsurface work at the site until the delineated area has been marked or cleared by the appropriate utility agencies.

If the work includes a performing a well installation or abandonment, or drilling a boring in California:

1) Apply for a San Bernardino County well permit two to three weeks before the start of drilling (one permit per well; cost is /$212.00 per well). Obtain a permit application by calling the Environmental Health Services Department at 1-909-387-4666 (open Monday through Friday, 8:00 a.m. to 5:00 p.m. The fee schedule for permits is located at http://www.sbcounty.gov/ dehs/FEESCHEDULE/feeschedule.htm#wateranchor. Fill out the appropriate permit form and provide it to the California-licensed driller contracted to perform the well installation. The driller is expected to review and file the permit with the San Bernardino County Department of Environmental Health Services (Steve Sesler), address below.

   Environmental Health Services
   385 N. Arrowhead, 2nd Floor
   San Bernardino, CA 92415-0160

2) A well permit needs to be obtained from San Bernardino County for well abandonment by the same procedure described in #11. Check the 'destruction' box on the same permit form used for well installation.

3) A permit also needs to be obtained from San Bernardino County for any boring that reaches to or below the water table, even if a well is not actually installed. The permit process is the same as described in #11.

If the work includes a performing a well installation or abandonment, or drilling a boring in Arizona:

1) Apply for an Arizona Department of Water Resources (DWR) well permit two to three weeks before the start of drilling (one permit per well; cost is /$150.00 per well). Obtain a permit application by calling the DWR at 1-(602) 771-8500 (open Monday through Friday, 8:00 a.m. to 5:00 p.m. MST). All ADW permits and instructions can be found at http://www.azwater.gov/dwr/Content/Find_by_Category/Permits_Forms_Applications/default.htm
   Fill out the appropriate permit form (55-44A) and provide it to the Arizona-licensed driller contracted to perform the well installation. The driller is expected to review and file the permit with the Arizona Department of Water Resources address below.

   Arizona Department of Water Resources
   3550 N. Central Avenue
   Phoenix, AZ 85012

   Upon completion of the well, the driller must submit a Driller Report and Well Log (Form 55-55) to the DWR within 30 days. The form and instructions can be found on the DWR webpage.

2) A well abandonment permit needs to be obtained from the Arizona Department of Water Resources prior to well abandonment (form 55-38). Exploratory wells that are abandoned before the drill rig leaves the site are exempt from the well abandonment permit requirements. The well abandonment form and instructions are included as Attachment 4 and can be found at the ADW webpage . No fee is required for filing this form.

   Within 30 days of well abandonment a Well Abandonment Completion Report (Form 55-58) must be filed with the DWR.

SOP-B12

General Guidance for Wireline Geophysical Logging Standard Operating Procedures for PG&E Topock Program

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This standard operating procedure (SOP) addresses the procedures and equipment to be used for oversight of down-hole geophysical surveys performed during drilling and well inspection operations at the Topock site. These procedures are to be considered general guidelines only and are in no way intended to supplement or replace the contractual specifications in the subcontractor's agreements.

REQUIRED DOCUMENTS

1) Applicable project work plan or monitoring plan. Refer to Topock Program Sampling, Analysis, and Field Procedures Manual and QAPP (Procedures Manual), as required.
2) Topock Program Health and Safety Plan (HSP)
3) Soil Boring Log and or other lithologic descriptions of the local area
4) Well construction logs/specifications (if performed in cased borehole)
5) Available soil and groundwater sample results or field parameter measurements
6) Blank geophysical survey logs and field notebook

EQUIPMENT LISTS

Equipment may vary considerably depending on the scope of work and site conditions. The following pieces of equipment are common, however, the logging contractor typically brings only what is necessary to complete their scope of work.

- Contractor rig or winch system (equipment with proper mast arm and stabilization equipment necessary to lower and raise geophysical equipment within borehole or well)
- Caliper logging tool (for caliper logging)
- Temperature logging tool (for temperature logging)
- Electric logging tools (for spontaneous potential and resistivity logging)
- Brine injection apparatus (for brine tracer test)
- Fluid conductivity logging tool (for brine tracer test)
- Gamma ray logging tool (for gamma ray logging)
- Acoustic spectrum tool (for acoustic imaging)
- Electromagnetic borehole flowmeter (for flow characterization)
- Video-camera logging tool (for video imaging)

- Decontamination materials
- Electrical power supply
- Appropriate data logging, data analysis and computer equipment

GUIDELINES

Various down-hole geophysical methods are available for subsurface investigation. Some common methods are listed in this section. They can be used to: (i) characterize subsurface lithology, aquifers, or groundwater, (ii) characterize the borehole or well, and (iii) assist in design of wells. This section provides summary information on method applicability and basic guidelines.

Caliper Logging

The caliper log is a record of the average diameter of the borehole. Caliper logs primarily are run to determine annular volumes prior to well construction, locate fractures or other openings might intersect the borehole and assess whether or not squeezing or other effects may have reduced the diameter of the borehole. Caliper logs may be either three-arm or four-arm (X-Y) types. Four-arm caliper logging tools are capable of measuring borehole deviation and direction.

Guidelines:

1) A caliper log must be performed in uncased boreholes.
2) A caliper log featuring arm-type devices is preferable to one featuring bow springs because of greater sensitivity of the arms.
3) Logs should have at least 1 inch of chart width per inch of hole diameter to provide adequate sensitivity of recording.
4) Several feet of casing should be logged so that the accuracy of the tool can be checked.

Electric Logs (E-Logs)

The most common suite of e-logs run in boreholes during well drilling and/or exploration operations include spontaneous potential, sing point resistivity, 16-inch normal, 64-inch normal and guard resistivity. They are all based on the same principals of electrical conductivity, but can be used to extract different sorts of subsurface information. Resistance is measured between two electrodes. When electrodes are closely spaced and boreholes are large, the resistance is affected primarily by borehole fluids. When electrodes are spaced farther apart, the resistance is largely affected by lithology and stratigraphy. The logging records are taken continuously in units of ohm-meters.

Single-point resistance logs record the electrical resistance from points within the borehole to an electrical ground at land surface. In general, resistance increases with increasing grain size and decreases with increasing borehole diameter, fracture density, and dissolved-solids concentration of the water. Single-point resistance logs are useful in the determination of lithology, water quality, and location of fracture zones.

Normal resistance logs record the electrical resistivity of the borehole environment and surrounding rocks and water as measured by variably spaced potential electrodes on the logging probe. Typical spacing for potential electrodes is 16 inches for short-normal resistivity and 64 inches for long-normal resistivity. Normal-resistivity logs are affected by bed thickness, borehole diameter, and borehole fluid and can only be collected in water- or mud-filled open holes

Fluid-resistivity logging provides a measurement of the resistivity of the borehole fluid between closely spaced electrodes in the probe. Abrupt and significant changes in fluid resistivity in the borehole may indicate the entry of groundwater of differing resistivity into the borehole via fractures and other openings in the geologic materials surrounding the borehole.

The fluid-resistivity log should be one of the first logs run because other logging methods will disturb the water in the borehole.

Temperature Logging

The temperature log measures the temperature and temperature gradient of the fluid in the boreholes. It can provide information on the source and movement of groundwater into and out of the borehole. Generally the temperature of the groundwater in the borehole will increase with depth. Deviations from this general trend may indicate where groundwater is flowing up, down, into, or out of the borehole. The presence of water producing zones in the borehole can be inferred from the temperature log data and correlated with other borehole flow data to determine the best well construction parameters for monitoring wells and potential extraction wells.

The temperature log may be made using the same tool as the fluid-resistivity log.

Guidelines:

1) A temperature log can be performed in uncased boreholes or wells.
2) Drilling, pumping and disruption to the fluid column will disturb the temperature gradient. For best results, the borehole needs to stabilize for at least 5 days before temperature logging.
3) The temperature log should be one of the first logs run because other logging methods will disturb the water in the borehole.
4) All temperature sensors have an inherent response lag, or time constant, so that the logging speed must be constant and slow enough that the temperatures are accurately reflected at the true depths on the log.

Flow Logging

Borehole flow logging is performed using an electromagnetic borehole flowmeter. Flow logging can identify the zones with the highest flow rate. These data are correlated with other flow data and fracture data using Geostatistics and used to evaluate the most permeable portions of the rock formation.

Guidelines:

1) Flow logging can be performed in uncased borings or wells.

2) This method may not be accurate in a boring drilled using the mud rotary method since drilling fluids may disrupt the natural flow patterns, and inhibit flow from permeable zones.

3) Results of flow logging may be biased by differing gradients at various zones. To determine the response of various zones to specific aquifer units, flow logging can be performed in an observation borehole or well during a pump test. To determine hydraulic properties, flow logging should be performed in boreholes where horizontal gradients are relatively equivalent with depth.

Brine Tracing

Brine tracing is used to measure natural or artificially induced flow within a borehole. Data on borehole flow is related to well construction, vertical differences in hydraulic head within the open or screened interval in the well, and the relative magnitude or permeability of the water-bearing units open to the well.

Guidelines:

1) Brine tracing can be performed in uncased borings or though the screened zones of cased borings or wells.

2) The fluid conductivity of the borehole should be profiled previous to the injection of brine. Low conductivity fluids, with a flat conductivity profile are ideal.

3) Lithologic stratigraphy data should be detailed enough to determine if conductivity anomalies are caused by stratigraphic changes.

4) The conductivity difference between the brine and borehole fluids needs to be large enough to easily distinguish between dilution caused by brine moving downwards though the borehole, and dilution caused by fluid movement from the aquifer.

5) The brine should be more dense than the borehole fluid, in order to move downward through the borehole from the injection point near the surface of the borehole fluid.

6) The dilution and movement are monitored by moving the detector slowly up and down through the tracer. Care is required so that the movement of the detector does not cause excessive spreading of the tracer; this effect can be minimized by using the smallest-diameter probe available.

Gamma Ray Log

The gamma ray log is used to measure the naturally occurring gamma emissions in counts per second (cps) from the formation surrounding the boreholes, due to potassium and elements of the uranium and thorium series present in the rocks. The log is a single trace of measured average radiation versus depth. Changes in the amount of gamma emissions result in significant changes in the single trace which will display measured average radiation versus depth. The presence of lithological changes in the borehole can be inferred from the gamma ray log data and correlated with other lithological data derived from formation samples.

Guidelines:

1) Gamma ray logs can be performed in cased and uncased borings or wells.
2) The logging tool will need to be moved at a constant rate in order for counts to be weighed accurately to various depths.
3) For a given site, the rate of movement may have to be adjusted to the geologic materials present in the borehole walls. In general, the smaller the gamma counts, the slower the tool should be moved.
4) These logs may be biased by water with radiological contaminants
5) Gamma ray logging equipment does not contain radiological emission sources, as does some radiological methods (neutron probe). Therefore this equipment does not have to be treated as a hazard.

Video Logging

Video logging provides a real-time and recorded image of the actual conditions in the borehole. The video log typically is used to identify the depths of fractures and other openings in the borehole. Well videos can also be performed in order to assess damage and structure of wells. It is important to ensure the video log tool has side-scan capabilities.

Guidelines:

1) The log should be run at a sufficiently slow speed that features can be accurately recorded.
2) The field geologist (or technician), if possible, should observe the logging image so that the operator can be directed to stop or reduce logging speed at any critical locations, such as intervals where flow may be occurring as indicated by the movement of particles in the borehole.
3) If a non-aqueous phase liquid (NAPL), particularly one that floats on the surface, is present in the borehole, the image may be so adversely affected that the NAPL may have to be removed from the borehole before logging can be completed.
4) The field geologist (or technician) should obtain a copy of the video in VHS format while the operator is still in the field.\
5) A video log report containing photos of key features and their depths should be generated and provided to the CH2M HILL representative on site immediately following the logging.

Acoustic Televiewer/Spectrum System

The acoustic logs are used to measure the amplitude and pulse travel time of transmitted acoustic pulses returning from the borehole wall. The generated log is a pseudo log in waveform graphics. The pseudo log consists of an image oriented to the magnetic north as a two dimensional presentation of direction and depth. From left to right, the quadrants run north, east, south, west, and back again to north (360 degrees). The final image is a continuous picture of the borehole, with depths to the far right and the image, laid flat, to the left. From these pseudo logs, the depth, orientation, and dip of bedding intersecting the borehole can be determined. These data are correlated with other data using geostatistical analysis to determine the best location to monitor for groundwater contamination.

Guidelines:

1) This visualization method should be performed in an open borehole, with no opaque fluids.

2) The log should be run at a sufficiently slow speed that features can be accurately recorded.

EXECUTION/PROCEEDURES

Specific procedures vary according to the geophysical method used, and the specific equipment and software used. The general procedures are as follows:

1) Prior to commencement of down-hole measurements, the site should be evaluated to determine if the site conditions are safe and appropriate for the specific work to be performed.

2) Determine the proper order or combination of geophysical logs/tests that will provide the best data, and minimal interference.

3) Calibrate all down-hole instruments and check that all equipment is working in proper order. Calibration should be properly documented.

4) Collect preliminary measurements pertinent to all geophysical logs/tests.

5) Set up equipment, making sure that all electrical equipment is properly grounded, and all mechanical equipment is properly supported. Cables should not be positioned such that they may be entangled or cause tripping hazards.

6) The logging equipment should be adequately decontaminated before the first use on the site and between boreholes.

7) Perform down-hole geophysics with oversight of appropriately trained and experienced scientist or engineer, with appropriate documentation of field techniques.

8) Review each log, test or visualization prior to removal of instruments from boring to determine if, and where new data needs to be collected.

9) Allow borehole fluids to equilibrate as is necessary and practicable between logging runs.

10) Secure each boring or well prior to proceeding to another location. No instruments, cables or fluids should be suspended within unattended borehole.

11) Collect all available electronic and hardcopy data from subcontractor prior to departure.

KEY CHECK AND ITEMS

- Ensure that subcontractor follows their procedures, particularly those for calibration of the instruments and the rate of logging.
- Obtain copies of logs at the site.
- Temperature and fluid-resistivity logs should be run first so that the disturbance caused by the other logging methods does not disrupt the results of these two methods.
- Decontaminate as necessary.

DELIVERABLES

Geophysical logs should be run in the presence of a CH2M HILL representative and the results, including three field copies of each log, provided to a CH2M HILL representative immediately after completion. The logs become the property of CH2M HILL at the time the logging is completed. In addition to the three field copies, the logging specialist shall submit the following:

1) Five final copies of each geophysical log.
2) Digital ASCII files of all geophysical data on a compact disk.
3) Digital PDF files of all geophysical data on compact disk.

Upon receiving copies of the geophysical logs, the CH2M HILL representative in the field should distribute copies of the logs to the appropriate senior level staff in the office and field. Geophysical logs should also be reviewed by the driller (in the case of drilling operations) and in the presence of the logging specialist contracted to perform the wireline logging.

REFERENCES

The following are useful technical references:

Driscoll, F.G. 1995. *Groundwater and Wells*. Second Edition. St. Paul, MN: Johnson Screens.

Keyes, Scott W. 1989. *Borehole Geophysics Applied to Groundwater Investigations.* National Water Well Association.

Welenco Inc. 1996. *Water and Environmental Geophysical Well Logs*. Welenco, Inc., 8th Edition

Appendix D
Supplemental Information for Bedrock Characterization and Groundwater Sampling Methods

How to locate, and flow test, every major fracture in a borehole in one hour

Carl Keller, Flexible Liner Underground Technologies (FLUTe)

Abstract

A new method has been developed for measuring the flow paths intersected by a borehole. The method uses a flexible, everting liner to drive the water from the borehole. The velocity of the propagation of the liner down the hole decreases as the everting liner seals the flow paths sequentially from the top to the bottom of the hole. Using the velocity of propagation, the excess head driving the liner, and the other measurements of significant parameters, the flow rate into each flow path is calculated. That flow rate is used to define a transmissivity profile for the borehole. Results of measurements with the method are shown for numerous sites. This method is compared to traditional straddle packer techniques to illustrate the similarities and differences. The liner method compares very well to measurements made with packers. The main differences from straddle packer testing are: there are no concerns about bypass leakage, the technique uses 5-10% of the time typically required for packer testing, the spatial resolution of flow paths is far better than possible with packer testing, the liner is usually left in place to seal the entire hole against cross contamination, there is less risk of hole slough entrapping the liner. On the other hand, the liner method, by itself, does not produce water samples for testing. The time to perform a measurement depends more on the flow rate out of the hole than upon the depth of the hole. Small diameter holes are measured more quickly than large diameter holes. The limitations of the method are reviewed with respect to hole size, depths possible, differential pressure limits, and others. Generally, these are not very limiting to most environmental applications. The technique is being extended to possible use in direct push holes with flexible liners emplaced for other purposes*.

The Problem Addressed

Most ground water problems are aided by a good understanding of the existing flow paths. Measurement of those flow paths is central to the science, and the subject of this paper.

Flow path measurements range from simple slug or pumping tests to many other measurements, some of which are broadly collected under the term geophysical measurements. Examples are gamma, resistivity, sonic, and other logs related to the stratigraphy, but not really flow path measurements. Others like caliper, sonic tele-viewer, thermal, chemical, and optical logs tend to locate fractures and beds, but they also are not flow measurements. Natural velocity logs, pumped velocity logs, and packer tests are flow measurements. These measurements are all performed in boreholes, the common means of access to the subsurface.

The method described hereafter is offered as an alternative to pumped hole velocity logs and to straddle packer tests. The advantages are the lower cost, better spatial resolution and collateral benefits. The collateral benefit is the sealing of the borehole against the vertical migration of contamination.

The method in general

The long name for this method is the flexible liner hydraulic conductivity profiler, FHCP. The process is the forcing of water into every flow path, at a known pressure, and the measurement of the flow rate. That sounds like a straddle packer test. Throughout this paper, there will be a comparison with straddle packer methods to illustrate the similarities and the differences.

The process is to install a flexible, everting liner into the borehole. The liner is driven by an internal pressure. As the liner everts (a term that will be explained) down the hole, it forces the borehole water into the formation. The essence of the method is the measurement of the flow into every "significant" flow path as the liner progressively seals the borehole from the top to the bottom. The advantages are the location and hydraulic conductivity measurement of all significant flow paths in the borehole in one-half hour to several hours, relatively independent of the hole depth.

The method in detail

First, one must understand how an everting flexible liner is installed in a hole. The flexible liner installation procedure is shown in Fig. 1. The liner is fed, inside out, from a shipping reel at the wellhead. The open end of the liner is clamped to the casing and the liner is then pushed down into the well. Water is added to the concentric pocket formed by the liner. The water pressure forces the liner deeper into the hole. When the liner reaches the water table in the hole, the water in the hole is forced out of the hole by the pressure of the descending liner. Since the liner is everting (the opposite of inverting) as it rolls out against the hole wall, the liner does not slide against the hole wall. Rather, it grows in volume at the bottom end, which we call the *eversion point*. As the liner grows in length at the eversion point, it forces the water in the hole out the available flow paths. As the liner descends, it sequentially covers the flow paths. The liner descent rate is controlled by the rate that water can flow from the hole into the formation.

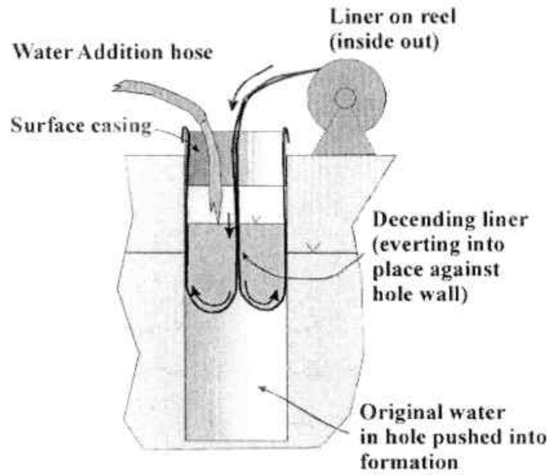


FIGURE 1. Blank liner installation

This blank liner installation is relatively simple and is often done by someone standing at the wellhead with a water hose to supply the water. Often a chair is desirable for that person to be comfortable while the liner descends, pulling itself off of the reel. It takes little effort on the part of the installer. (See Fig. 2 for an installation of a liner in Maine. The operator is switching a pump as needed to keep the liner filled to the top of the casing as the liner descends.) As the liner descends, it slows as the available flow paths are sealed and the remaining transmissivity decreases. The liner descent rate is usually dominated by the hole flow path distribution, the conductivity of those flow paths, and the rate at which water is supplied to the interior of the liner. The liners are removed by the reversal of the procedure.

FIGURE 2. Liner installation

By adding a distance meter to the liner installation, Fig. 3, and a measure of the excess head in the liner above the water table in the formation, we convert the normal blank sealing liner into a flow meter. The flow measured is the flow rate out of the hole. The liner of cross-section A, as shown in Fig. 4, is displacing the water downward with a velocity v_z. The flow rate out of the hole is $Q = v_z \times A$. As the liner propagates, it covers the flow paths sequentially. When the liner travels down the hole, the pressure distribution in the hole below the liner is that shown in Fig. 5A. It is a uniform overpressure throughout the open hole, and there is no overpressure where the liner has sealed the hole. Under the uniform overpressure, flow is occurring out of all unsealed flow paths below the liner. The transmissivity, T(z), below the liner is due to all the unsealed flow paths. As the liner eversion point depth, z,

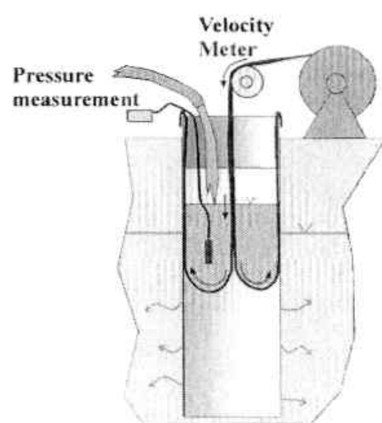


FIGURE 3. Additional measurements to convert a blank liner installation into a profiling device

increases, T decreases.

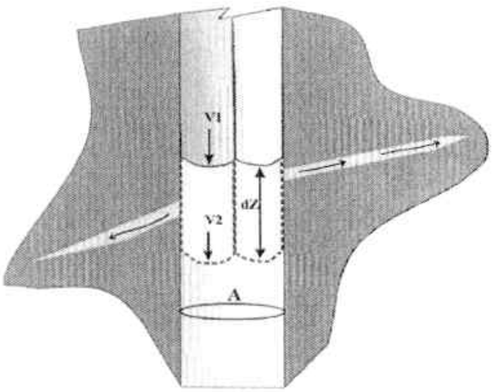
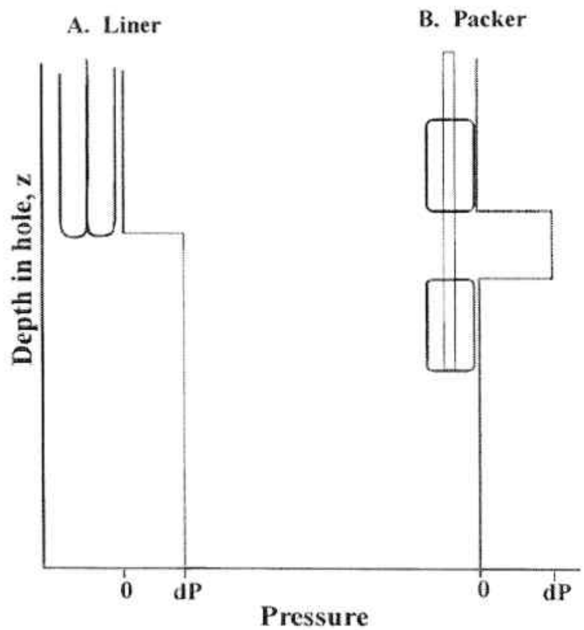


Fig. 4. Liner passing a fracture

We measure the velocity of the liner propagation down the hole to obtain a velocity with depth curve as seen in Fig. 6 (a hole in Paterson, NJ). The velocity is monotonically decreasing as the liner propagates to the bottom of the hole for a constant excess head in the liner. If the liner excess head is varying, the velocity will actually increase as the head increases and decrease as the head decreases. Since this is essentially a linear relationship, we simply divide the velocity by the driving head in the liner to get the velocity per unit driving pressure. That velocity is the one that should be monotonically decreasing. That is what is plotted in Fig. 6.

When the liner seals a flow path, the transmissivity drops by an amount dT. There is a corresponding drop in the flow rate out of the hole $dQ = A \times dv_z$, where dv_z is the drop in the velocity of the liner propagating down the hole. As the liner depth, z, increases, T decreases. Another way of saying that is that the velocity v(z) is monotonically decreasing as the liner moves more and more slowly down the hole.

Fig. 5. Pressure distribution with liner and packer



One can easily see in Fig. 6 where the step changes occur in the velocity. Each step is the location of a flow path. The magnitude of the velocity change is a direct measure of the flow rate into that flow path before it was sealed by the advancing liner.

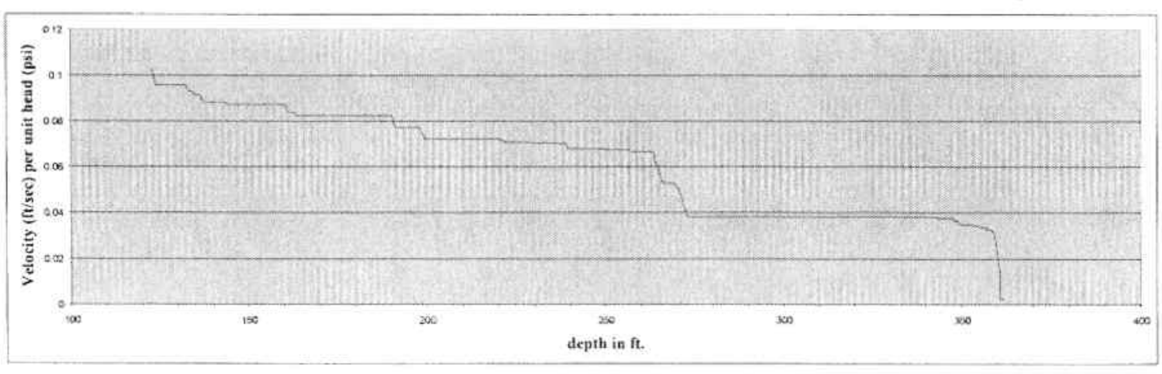


Figure 6. Liner velocity profile in hole

The liner velocity is typically measured every 2 seconds. The excess head, the liner driving force, is recorded at the same time. The pressure in the water below the liner is essentially that in the liner, if the liner is fed freely into the hole. In reality, the liner has some tension on it and the pressure below the liner is calculated as a function of the tension on the liner.

Once the flow rate, the driving pressure for the flow, and the location of the flow path are in hand, we can calculate either a transmissivity distribution (the preferred result) or a conductivity distribution in the hole, and plot it as seen in Fig. 7 (the conductivity). The transmissivity is independent of the liner velocity, but the length of hole assigned to the conductivity calculation depends upon the liner velocity. However, both are correct within the mathematical definition. As the liner passes a permeable bed, the velocity change will occur over a longer interval as a slope in the velocity curve rather than a step change. In the measurement, it is a series of small step changes.

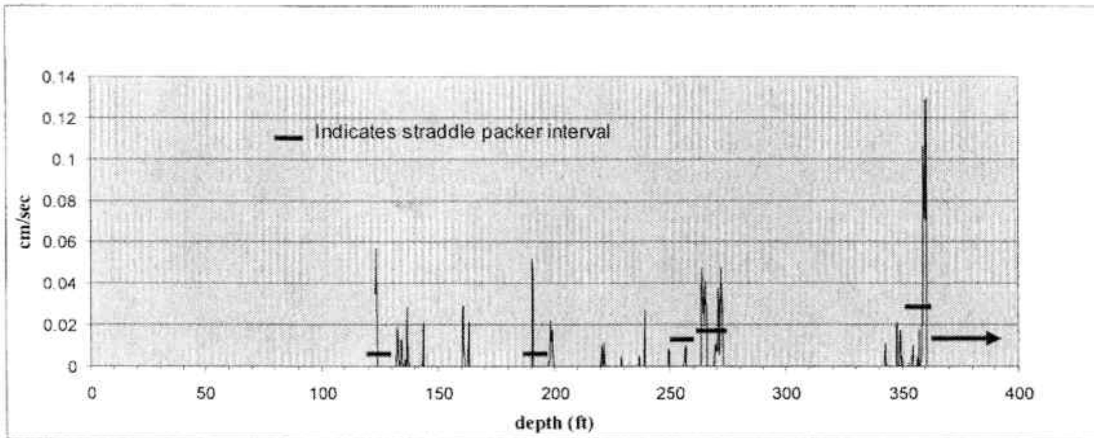


Figure 7. Conductivity profile from velocity profile

It is noteworthy that the conductivity plot of Fig. 7 calculated from a real velocity plot, Fig. 6, shows very fine spatial details of the flow path distribution as well as flow capacity. The very large flow path at 360 ft is obvious in the velocity curve.

Comparison with Straddle Packers

We were provided with straddle packer tests results after we performed the measurement in Fig. 6. The packer tests were done before the liner installation. Fig. 8 shows the integration of the detailed liner measurement over the same interval as the packer test, plotted with the packer test results. The results from this early test of the method were quite satisfying.

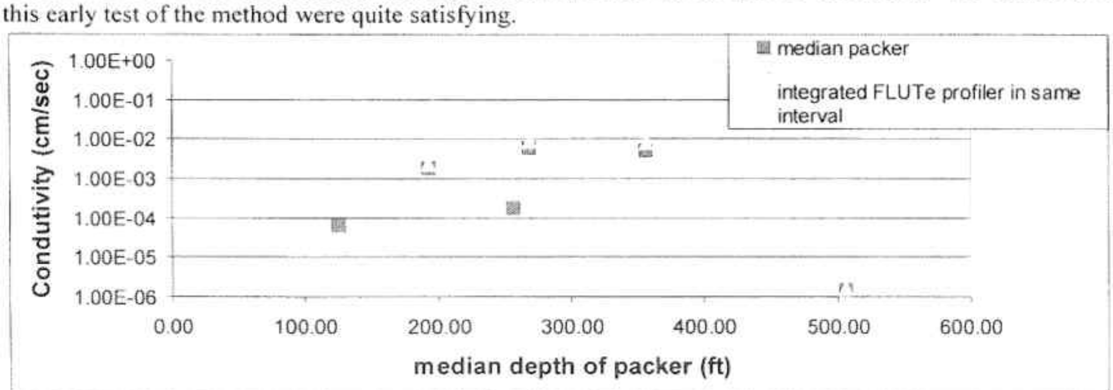


Figure 8. Comparison of straddle packer results to FHC Profiler results

So, what is different from a packer test? First, there is the time to perform the measurement. The measurement of the data in Fig. 6 was done in about 1.5 hr. for 370 ft of hole. A measurement of a hole in Cambridge, Ontario took ~36 min. for 328 ft. That same hole had a complete suite of packer tests over its entire length that took two people, four days. The set up time in each case is about an hour. In other words, it takes only 5-10% of the packer testing time to perform the blank liner installation. The longest liner profiling done to date is 4 hours. That was because of the desire to measure to very low transmissivity levels in a hole with very low flow out of the bottom quarter of a 400 foot hole (those results are shown in the Field Test Results section hereafter).

The time it takes to profile a hole is dependent upon the transmissivity of the hole. That factor is more important than the depth of the hole. Therefore deep holes are often measured in less time than some shallow holes.

Another difference from packer testing is that the liner can be sized to fit any size hole and an undersize hole (e.g., 7") can be measured using a larger liner (8-9") without significant effect. The smallest practical size is probably 2" diameter for the current liner fabrics and measurement equipment. The smallest done to date is less than 3.78 inches.

Another comparison with a straddle packer is shown in Fig. 5B. The pressure profile in a packer is high in the straddled interval and ambient above and below. Therefore, there is a tendency for the injected water to try to bypass the packer by flowing upwards or downwards into the open hole beyond the packers. That flow, called leakage, may be via the formation through fractures or matrix permeability, or between the packer and the hole wall (e.g., a rough hole wall). Such bypass is unlikely for a liner because there is no open hole above the bottom end of the propagating liner. The liner is far more flexible than packers, and therefore conforms quite well with the hole wall. Figure 9 is a snapshot from a video of the interior of a liner showing how very well the liner conforms. It looks like it is painted on the hole wall.

During the liner installation, the liner displaces only one hole-volume of water, no more or less. The integral of the flow measurement is correct. For packers, the total flow measured includes a leakage component that can be large, or small, depending upon hole ruguosity and/or formation permeability where the packer is set. Hence, the packer testing provides only an upper bound on the transmissivity of the straddled interval. If another set of guard packers is used (i.e., 4 packers) with pressure transducers, some of the leakage affects can be detected, but the correction for leakage is not practical

Fig. 9. Interior view of liner conforming to hole

In packer testing, one can inject water or extract water to perform the packer test. The highest extraction rate is usually limited by the size of the pump that can be placed down hole through the access pipe. There are no serious limits on the flow rates (conductivities) that can be measured with the liner system. The limit is how fast water can be poured down the open hole.

The installation of a liner is very gentle with respect to hole stability. The liner roles smoothly out against the hole wall, supporting the hole wall material against sloughing. When the liner is later removed by the reverse process (inversion), the liner is gone when the hole wall is no longer supported. The significance is that the liner is unlikely to be trapped in the hole by sloughing of the hole. In contrast, the scraping of the hole wall with the installation, inflation, deflation, and repositioning of the straddle packer assembly is much more likely to cause the hole wall to slough. Entrapment of a straddle packer assembly is a very real concern of straddle packer testing. The consequence is not only the loss of the packer assembly, but sometimes the loss of the hole.

One disadvantage of the liner method is that one can not obtain a sample from the blank liner measurement. However, there is no contaminated-water disposal cost either. There are flexible liner sampling systems available that do collect samples and measure the head at each sampling interval. That is the subject of other papers at this conference.

The realities of field tests and results

Whereas the concept of the liner measurement is quite simple, the implementation requires some diligence. The machine built to perform the measurements is shown in Fig. 10. This machine measures: the position of the liner, the tension on the liner in time, and controls the tension of the liner to a preset value. That data, plus the head measurement inside the liner, is recorded in a lap-top computer every 2 seconds, or as often as desired. A spreadsheet in the same computer converts the raw data to the plots which are shown in this paper.

Most of our customers purchase a blank liner to seal the hole against vertical flow and associated contaminant migration immediately after the hole is drilled. Measuring the velocity of the installation is a simple addition to the normal installation of a sealing liner.

Other results of actual field measurements are shown in Fig. 11 for a site in Paterson, NJ and in Figs. 12 and 13 at Media, Pennsylvania. The time to collect the data is shown on the graph. The velocity graph alone is a very good identification of the significant flow paths.

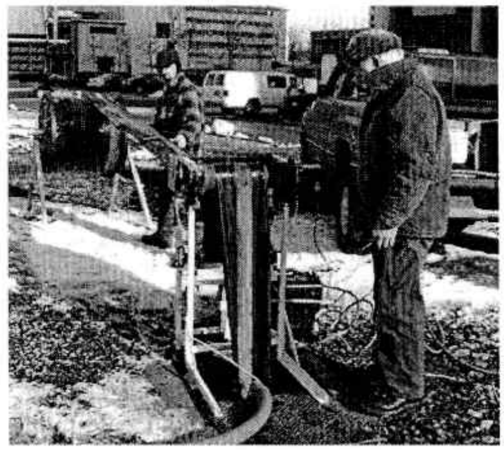


Fig. 10. Profiler machine over 8" hole

Like a pumped-hole velocity profile, the limit of the FHCP resolution is depth dependent. At the top of the hole, where the liner velocity is higher, the resolution is less than at the bottom of the hole. Fortunately, for many geologic sites, the upper most portion of the bedrock is also the most fractured with the largest flow rates and is not limited by the resolution of the method. At the bottom end of the hole, the resolution is extremely high (sub inch) in space and very low flows (< 0.001 gal/sec).

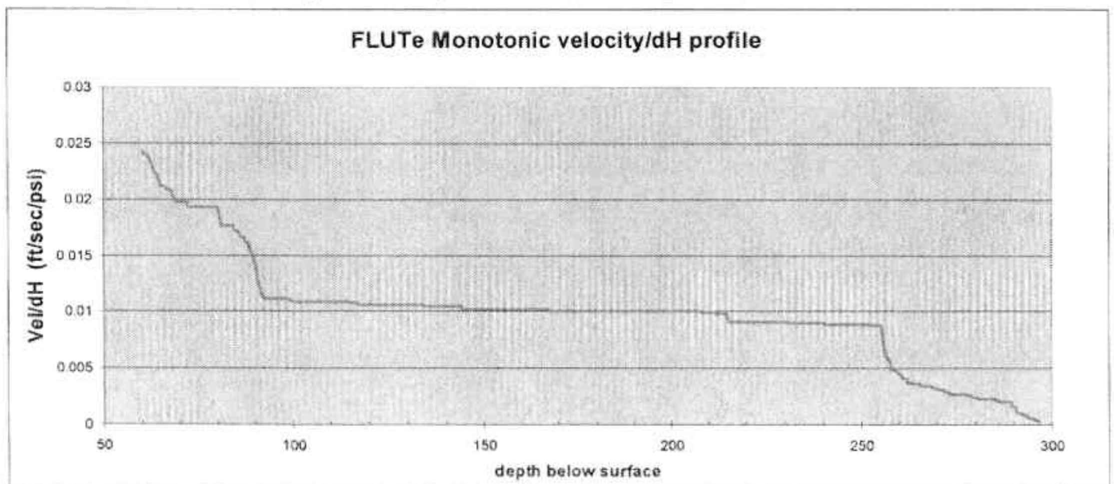


Fig. 11. Profile in 4" hole in Paterson, NJ

Unlike pumped hole velocity profiles, there is no limit on how fast the hole is "pumped" for the liner installation except for how fast water can be poured down the hole. This has an important significance in that the excess head typically is much higher in the liner than the natural head in the hole, and so all flows are outward from the hole with no confusing inflow zones to violate the model. The use of a water flow rate capable of maintaining at least 10 ft of excess head is desirable.

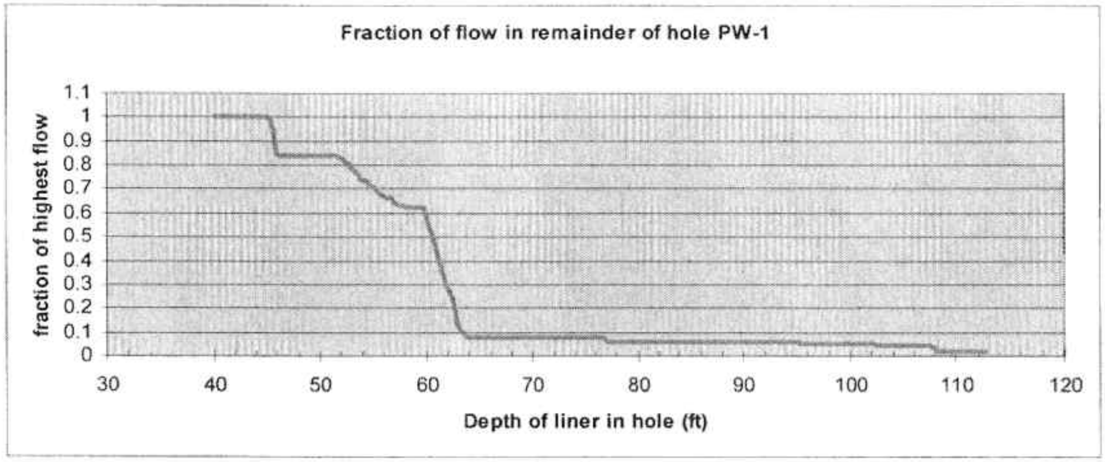


Fig. 12. Profile measured in 200 ft hole in ~3 hrs.

Later, measurements of actual head distribution in the formation (e.g., using a multi level system) can be incorporated into the calculation of a refined transmissivity distribution in the hole. The initial assumption is that the head in the formation is constant.

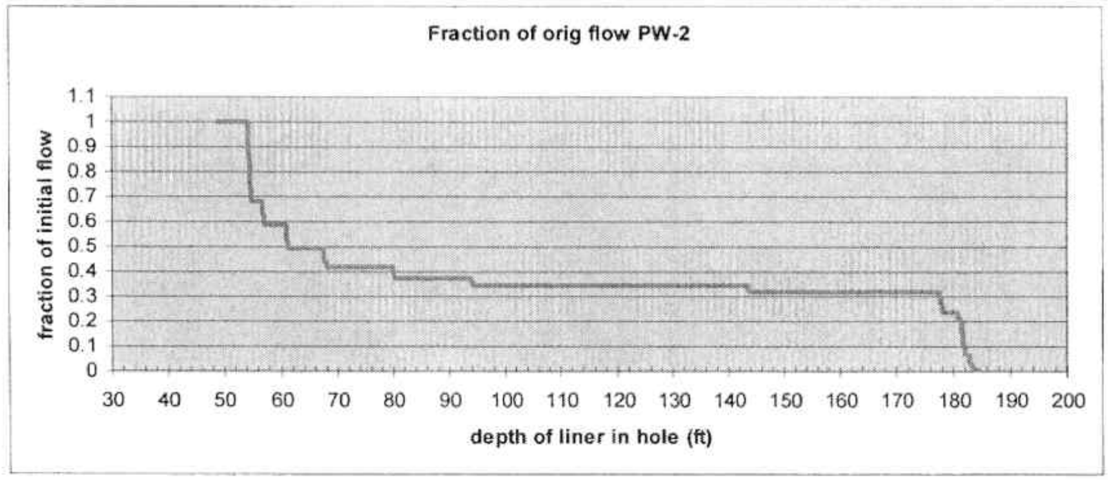


Fig. 13. Profile measured in 185 ft hole in ~30 minutes.

This kind of measurement was first done with our linear capstan system which can pull liners out of holes with 1000 lb of force while measuring the tension and velocity of the liner. Since then, there have been continuing improvements in the procedures and the hardware to obtain better and better sensitivity of the measurement. The data shown was obtained with the state of the art 6-12 months ago. Much has improved since then.

Mathematical models have been developed which can now predict the liner descent velocity based upon estimates of the conductivity profile. This is very useful in assessing the effects of the many variables on the installation such as hole diameter, depth, conductivity, excess head, and friction. Small diameter holes can be profiled more quickly than large diameter holes intersecting the same flow paths because the liner displaces one hole volume, or most thereof.

There is always a question of how this method will work with different conditions. There is no theoretical limit to how deep these liners can go in a hole. The practical limitations are the differential pressures that the liner may experience with great depths. The liner will burst at about 65 psi, if unsupported, in a 6 inch diameter. That is about 150 ft of excess head. Smaller diameter holes can withstand higher differential pressures. The liners propagate through most breakouts quite well. A very large, eccentric breakout with a flat floor can stop the liner, but rarely does. For very deep water tables, there is a certain amount of adhesion of the wet inverted liner against the everted liner. There are several procedures for reducing that effect. Overall there are a wide range of ordinary conditions in which this technique works very well.

Extensions of the method

We are currently working on an FHCP system which will measure the same flows while the liner is being withdrawn. This has an attractive application for our NAPL FLUTe system liners which are installed through direct push rods. Those slender (2.5-3") liners may allow the measurement of the hydraulic conductivity in soft sediments (i.e., no stable hole required) as the liners are being inverted out of the hole. The primary purpose of those liners is to map the DNAPL pure product distribution. The conductivity profiling would be helpful to the remediation design.

Conclusion

The FHCP is a simple concept that has been well tested in the field, and has been shown to be a very convenient and inexpensive means of measuring the significant flow paths intersected by a borehole. The data produced is much more detailed than is obtained with normal straddle packer tests. The limits of resolution are already very good and are getting better with refinements of procedures and hardware.

The largest cost of the method may be the liner. In clean holes, liners are easily reused (just pull/peel/invert it out of the hole). In contaminated holes, the liner is left in place to seal the hole as long as desired. Typically the flow data is used to select the sampling intervals for a multi level sampling system which can measure head and water quality. We often pull the blank and install our flexible liner multi level sampling system in the same day.

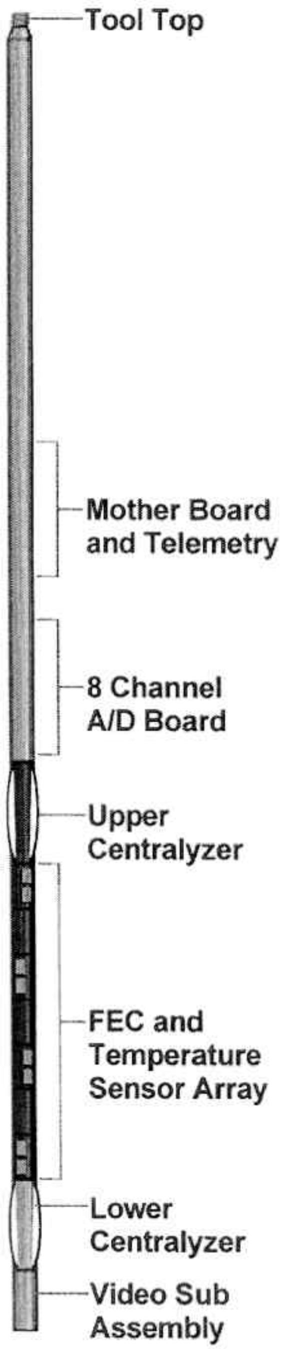
The characteristics of the FHCP make it a very attractive alternative to conventional packer testing. One does not need to select where in the hole the test is to be performed, because the whole hole is easily measured. In combination with the ability to provide a long term seal of the hole by leaving the liner in place, the system seems to have very good utility.

Acknowledgements:
We are very thankful to those who provided the holes for our initial tests and refinements. We are especially thankful to those who also provided other information like packer test results, and video logs of the holes for comparison with the FHCP measurements. These were mainly contaminated sites and not eager for public recognition, but we thank them none-the-less. One research site of the University of Waterloo has been especially useful to our testing of this concept.

* Patents are pending on this method and apparatus in the USA and abroad.

Carl Keller, received a BS in Physics and in Math from Valparaiso University and an MS in Engineering Science from Rensselaer Polytechnic Inst. He spent 3 years developing nuclear reactor calculation models and 25 years designing containment systems for underground nuclear tests. For 10 years he was in charge of all research and containment design for all DOD underground nuclear tests. For 15 years he has developed applications of flexible liners for underground measurements. He received the R&D 100 award in 1994, and holds 12 patents mainly on flexible liner methods. He is owner and principal scientist for Flexible Liner Underground Technologies, FLUTe, 6 Easy St., Santa Fe, NM 87506, carl@flut.com, 505-455-1300, fax 505-455-1400.

Hydrophysical Logging



SPECIFICATIONS	
TOTAL HYDRAULIC HEAD	2000 ft
MINIMUM HOLE DIAMETER	2 in
MAXIMUM HOLE DIAMETER	None
MAXIMUM TEMPERATURE	65°C

RAS provides an advanced method called hydrophysical logging for the hydraulic characterization of aquifers.

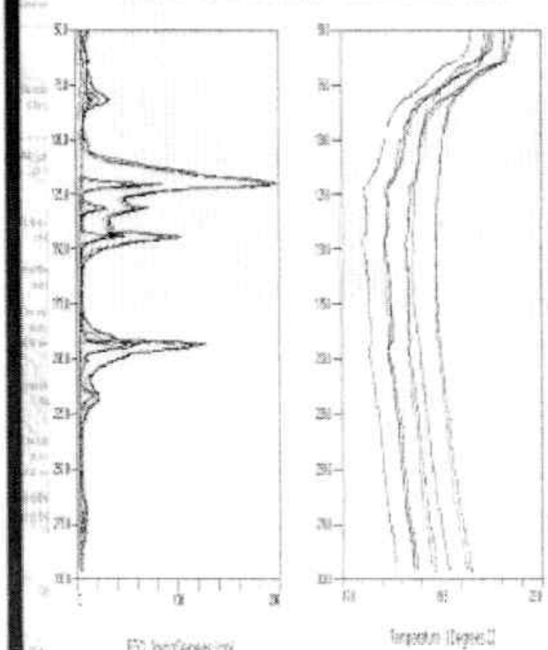
Data acquisition involves logging with RAS's proprietary multi-sensor tool which measures temperature and fluid electrical conductivity. Logging is conducted during procedures replacement of the native wellbore fluids with environmentally safe deionized water. The formation fluids contrast electrically with the deionized water and provide a means of establishing the location of formation fluids and quantifying flow rates in-situ.

The RAS hydrophysical tool is the only multi-FEC/T sensor tool available for the purpose of testing with this technique. Our instrumentation package has been developed as a result of extensive field experience as well as numerous laboratory/numerical simulations conducted in conjunction with several national DOE and USGS laboratories.

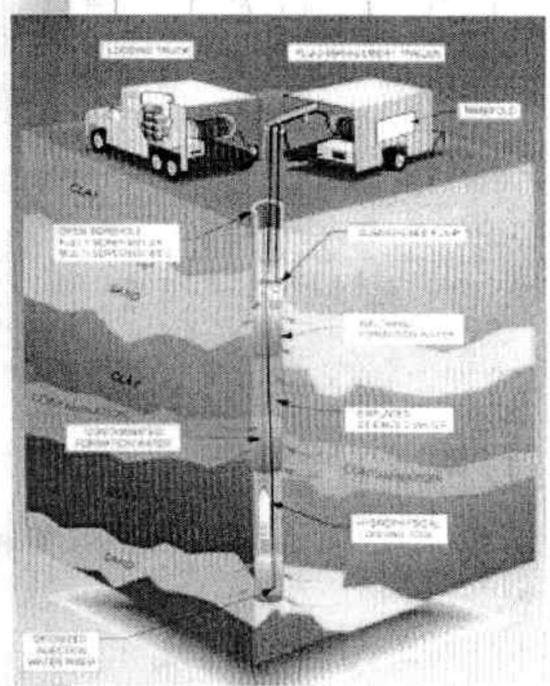
When the hydrophysical method is applied in multiple well investigations, critical data regarding intermediate to large scale permeability and aquifer parameters may be acquired. This information is critical for analyzing the extent of contamination, developing effective remediation plans, understanding groundwater system hydraulics, and calculating aquifer volumetrics/movement.

HYPROPHYSICAL LOGGING SUMMARY

- Technique applicable in a wide variety of hydrogeologic settings: low to high yield bedrock, alluvial/porous settings, karst and volcanic aquifers.
- Both open boreholes and completed wells can be characterized (2 inch minimum diameter).
- Water bearing intervals are identified to one borehole diameter resolution.
- A wide range of interval specific flow rates can be quantified (0.01 to 100+ gpm).
- Flow rates can be assessed independent of borehole diameter.
- Wellbore flow is evaluated under ambient or stressed aquifer conditions.
- A larger volume of aquifer is investigated than by traditional packer testing.
- Interval specific water quality can be evaluated.
- Single and cross-hole aquifer characterization (i.e. larger scale hydraulic connections between two or more wells) can be conducted.
- Data output equivalent to packer testing (Δp and Δq) for transmissivity and hydraulic conductivity can be calculated.



The hydrophysical logging method allows for identification of the water bearing intervals and quantification of the associated flow rates to a high degree of sensitivity.



Formation fluids are replaced with deionized water to allow characterization of in-situ parameters during ambient and pumping conditions.

RAS Integrated Subsurface Evaluation
311 Rock Avenue • Golden, CO 80401
http://www.rasinc.org
PH: 303.526.4432 • FAX: 303.526.4426

Integrated Subsurface Evaluation

HYPROPHYSICAL LOGGING SUMMARYof KEY POINTS

- **The technique is applicable in a wide variety of hydrogeologic settings: low to high yield bedrock, alluvial/porous settings, karst and volcanic aquifers.**
- **Both open boreholes and completed wells can be characterized (2 inch minimum diameter).**
- **Water bearing intervals are identified to within one borehole diameter resolution.**
- **A wide range of interval specific flow rates can be quantified (0.01 to 100+ gpm).**
- **Flow rates can be assessed independently of borehole diameter.**
- **Wellbore flow can be evaluated under ambient or stressed aquifer conditions.**
- **A larger volume of the aquifer is investigated than by traditional packer testing and is more time and cost effective than packer testing.**
- **Interval specific water quality can be evaluated.**
- **Single and cross-hole aquifer characterization (i.e. evaluate larger scale hydraulic connections between two or more wells) can be accomplished.**
- **Data output equivalent to packer testing** (Δp and Δq) **for transmissivity and hydraulic conductivity calculations.**

Click here to download a FTP program
E-mail:EmailfromRAS@aol.com
Office: (303) 526-4432
Fax: (303) 526-4426
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Golden, CO 80401 USA.
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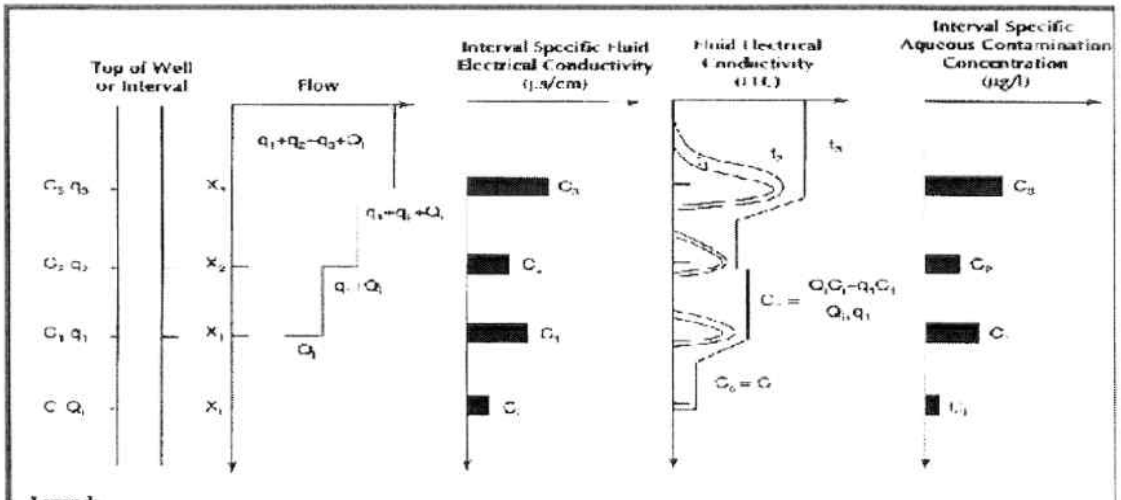
RAS
Integrated Subsurface Evaluation

PRINCIPLES OF HPL LOGGING



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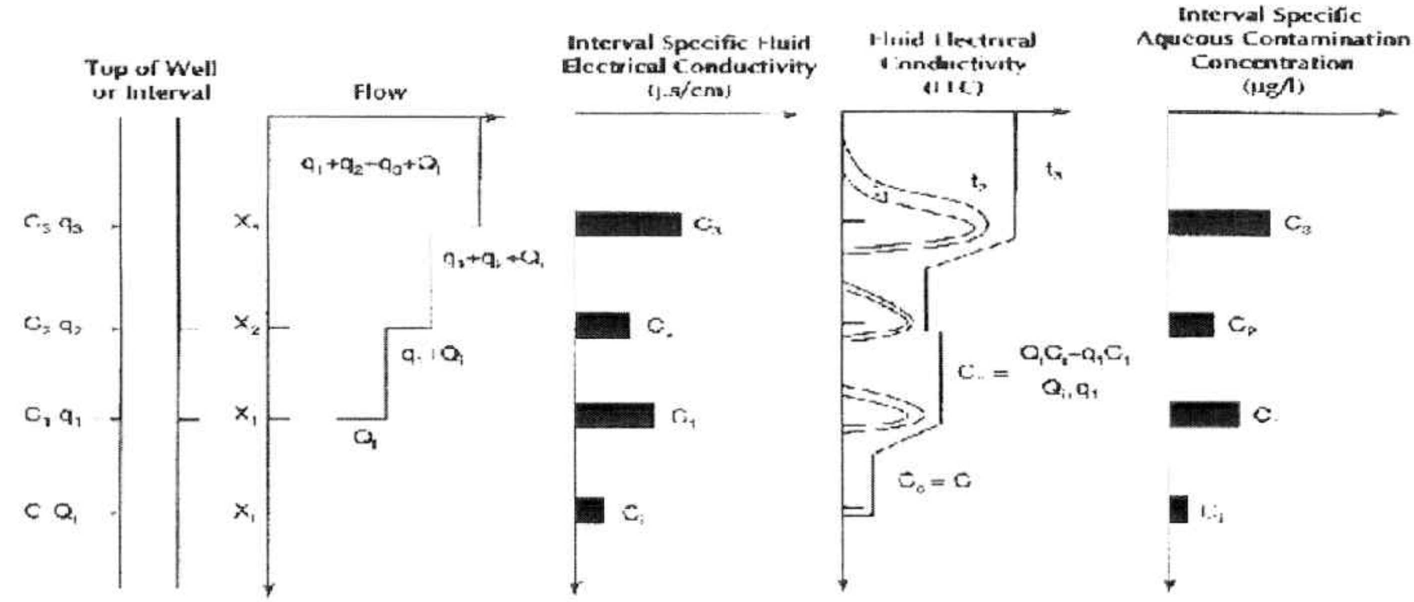
Schematic of well with multiple producing zones. During pumping/non-pumping conditions, each zone is characterized by two parameters: volumetric rate of inflow/outflow, qi, and interval specific concentration, Ci, of the constituent of interest. These constituents range from total dissolved solids (TDS), pH, and hardness (calcium,	Flow schematic with the pump set above the upper most producing intervals (e.g. fractures): a step change increase in flow will occur at each producing interval. As fluid moves from the bottommost interval toward the pump, the flow rate will increase in a step-like	In addition to quantification of flow, HpL evaluates interval specific fluid electrical conductivity (~ TDS).	The integrated relationship between flow and FEC results in a unique time series of electrical conductivity profiles during pumping after the borehole is flushed with deionized water.	As HpL can identity water bearing zones during pumping, a down hole discrete point fluid sampler can be used during flowing conditions to obtain samples above each interval. The observed concentrations generated by this hydrochemical analysis and the interval specific flow rates are used to calculate" actual" (pore water) concentrations

magnesium, iron) to aqueous phase VOCs, pesticides and radionuclides.	function until the point above X3 where total flow is observed.			of any aqueous phase contaminant.



Legend:
C=Concentration (mass/volume) q=Volumetric Flow Rate (gpm) X=Depth t=Time CiQi-Deionized Water injection

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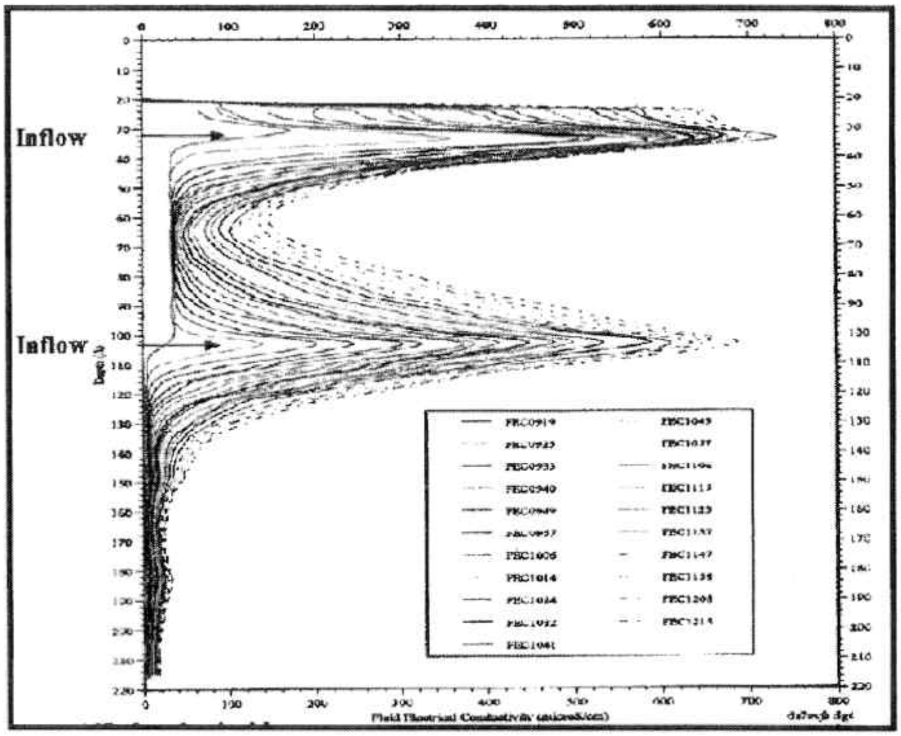
EXAMPLES OF HpL RESULTS

Ambient Horizontal Flow



This example shows hydrophysical logs acquired during ambient conditions in the well. Each log represents fluid conditions at a given time following deionized water emplacement. For ambient flow characterization, no pumping is conducted after deionized water emplacement. Based on these hydrophysical logs, it is determined that horizontal inflow is occurring at 32 and 104 feet.

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Office: (303) 526-4432
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Fax: (303) 526-4426
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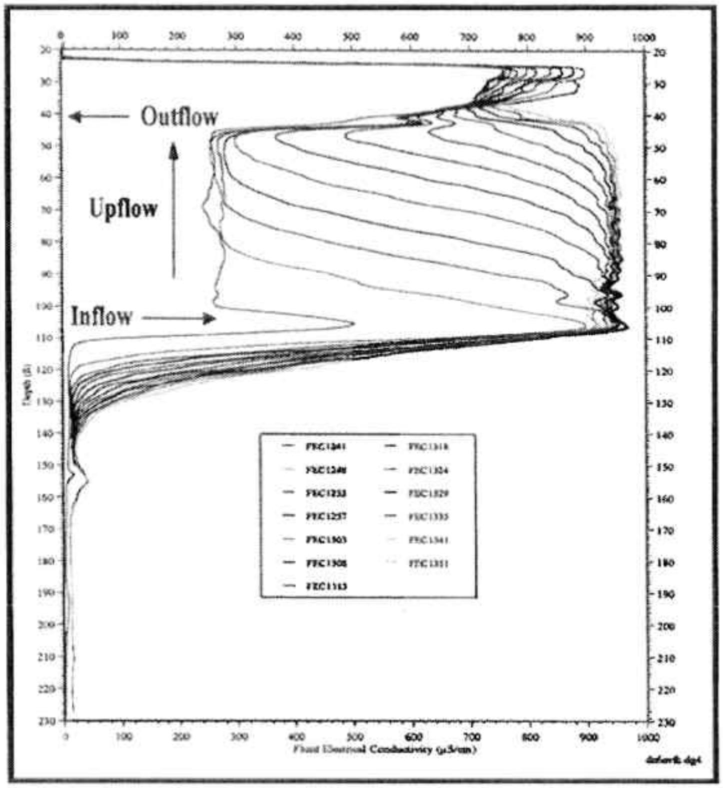
EXAMPLES OF HpL RESULTS

AMBIENT VERTICAL FLOW

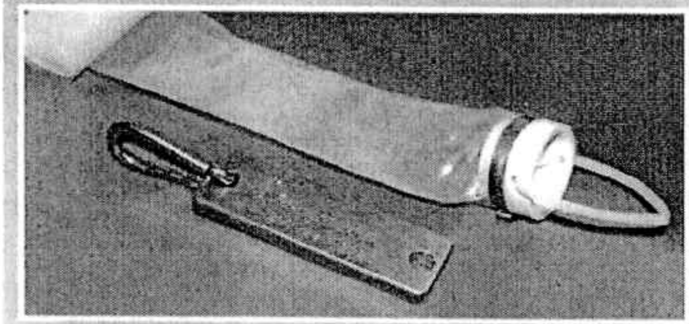


Example of hydrophysical logs during ambient vertical (upward) flow conditions. A series of fluid electrical conductivity logs is acquired after flushing the wellbore fluids with deionized water. For ambient flow characterization, the logging is conducted after deionized water is emplaced but before any pumping is initiated.

HYDRASleeve

U.S. Patent No. 6,481,300; others pending

Beats bailers for sampling accuracy, turbidity & cost



- Short and long term monitoring
- Low-yield wells
- UST applications
- Discrete interval sampling and vertical profiling

No-Purge Sampling

Cut groundwater sampling costs in half with HydraSleeve

U.S. Patent No. 6,481,300; others pending

No-Purge Groundwater Sampler

Unlike any other groundwater sampler, the HydraSleeve instantaneously "cores" a whole water sample from a defined vertical and horizontal interval (usually within the well screen). HydraSleeve samples do not blend fluid from different vertical zones or pull water in from outside the well screen, but instead sample via ambient and/or diffusive flow of groundwater through the well screen.

The sample is collected without purging and with very little downwell disturbance, providing excellent control of turbidity. This minimizes the time spent on filtration of turbid samples typically collected after purging with a bailer or submersible pump.

Samples can be collected at in-situ pressure with almost no aeration or degassing. This prevents alteration due to loss of volatiles or oxidation of sensitive parameters. Samples can be analyzed for all parameters.

HydraSleeve samplers are inexpensive, disposable, and very quick and easy to use, resulting in significant savings on startup and ongoing costs when compared to other sampling equipment such as bailers or pumps.

Applications

HydraSleeve is the best available technology for sampling low yield wells. It is suitable for both short and long term groundwater monitoring, and is especially useful in narrow, constricted, or damaged wells. It can also be used to sample discrete intervals from surface water bodies and tanks.

Cost savings of HydraSleeve sampling (typically 50 to 75%) make it an extremely effective option for monitoring UST leaks, dry cleaning plants, and other small-scale point-source contaminant sites.

Samples collected with the HydraSleeve correlate well to other sampling methods, and it can even be used for special challenges such as in-well vertical profiling of multilayered contaminant concentrations.

This photograph shows a HydraSleeve after collecting a simulated sample in a clear column of water with red oil floating on the surface. As shown, once the HydraSleeve is full, the closed check valve prevents mixing of any liquid from the upper part of the well into the sample.

HYDRASLEEVE FACTS

- HydraSleeve samplers are inexpensive, disposable, and easy to use.
- A discrete, instantaneous "core" of water is collected from a precisely defined vertical and horizontal interval.
- Samples are collected with little or no aeration, agitation, degassing, or displacement.
- Samples can be collected at in-situ pressure and analyzed for all parameters.
- HydraSleeve samples do not blend fluid from different vertical and/or horizontal zones.

Why No-Purge Sampling Is Better

Historically, the accepted protocol for sampling groundwater monitoring wells required removal of 3 to 5 times the volume of standing water in the well screen, casing, and surrounding filter pack prior to sampling. This "purging" was done to assure that samples came from the screened interval and did not contain stagnant water from the unscreened portion of the well.

Using bailers or pumps, this purging was a time-consuming, costly process; if the well was contaminated, purge water handling, containment, and disposal added expense and hazards to the sampling process.

Over the years, researchers interested in simplifying groundwater sampling have tried to find ways to reduce the burden of purging. Some recent advances in this effort include low-flow pumping and passive diffusion sampling.

The common underlying principle behind these methods and the HydraSleeve is the premise that the screened interval of the well is in dynamic equilibrium with the surrounding formation. Many studies have shown that the flow of groundwater through most well screens is primarily horizontal and laminar, with little or no mixing with the overlying water column.

The HydraSleeve collects a "core" from this water with minimal disturbance, thus delivering a highly representative sample quickly and easily, without generating purge water.

How It Works

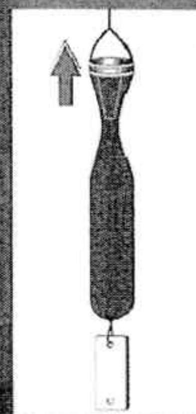
The HydraSleeve consists of three basic parts — a reusable weight, a long, flexible sample sleeve (usually a polyethylene tube creased to lay flat), and a check valve. The bottom of the flexible tube is sealed and the weight is attached to it. A top-loading check valve assembly includes an attachment point for the suspension line.

HydraSleeve use is simple and can be performed by one person. The sampler is lowered into the well; after the water column returns to equilibrium, the HydraSleeve is recovered with no mixing from the overlying water in the well.

USING THE HYDRASLEEVE

1 Sampler Placement
The reusable weight is attached and the HydraSleeve is lowered and placed at the desired position in the well screen. In-situ water pressure keeps the sleeve collapsed and check valve closed, preventing water from entering the sampler. Well is allowed to return to equilibrium.

2 Sample Collection
The check valve opens to allow filling when the sampler is moved upward faster than 1 foot per second, either in one continuous upward pull or by cycling the sampler up and down to sample a shorter interval. There is no change in water level, and minimal agitation during collection.



3 Sample Retrieval
When the flexible sleeve is full, the check valve closes and the sampler can be recovered without entry of extraneous overlying fluids. Samples are removed by puncturing the sleeve with the pointed discharge tube and draining the contents into sample containers or field filtration equipment.