Topock Project Executive Abstract

Document Title: Revised Final RCRA Facility Investigation/Remedial Investigation (RFI/RI), PG&E Topock Compressor Station, Needles, California Volume 2 - Hydrogeologic Characterization and Results of Groundwater and Surface Water Investigation Submitting Agency/Authored by: DTSC, DOI Final Document? ☒ Yes ☐ No	Date of Document: February 11, 2009 Who Created this Document?: (i.e. PG&E, DTSC, DOI, Other) PG&E
Priority Status: ☒ **HIGH** ☐ **MED** ☐ **LOW** Is this time critical? ☐ Yes ☒ No Type of Document: ☐ Draft ☒ Report ☐ Letter ☐ Memo ☐ Other / Explain:	Action Required: ☒ Information Only ☐ Review & Comment Return to: ______________________ By Date:__________________________ ☐ Other / Explain:
What does this information pertain to? ☐ Resource Conservation and Recovery Act (RCRA) Facility Assessment (RFA)/Preliminary Assessment (PA) ☒ RCRA Facility Investigation (RFI)/Remedial Investigation (RI) (including Risk Assessment) ☐ Corrective Measures Study (CMS)/Feasibility Study (FS) ☐ Corrective Measures Implementation (CMI)/Remedial Action ☐ California Environmental Quality Act (CEQA)/Environmental Impact Report (EIR) ☐ Interim Measures ☐ Other / Explain:	Is this a Regulatory Requirement? ☒ Yes ☐ No If no, why is the document needed?
What is the consequence of NOT doing this item? What is the consequence of DOING this item? Completion of the RFI/RI is required to proceed to the Corrective Measure Study/Feasibility Study (CMS/FS).	Other Justification/s: ☐ Permit ☐ Other / Explain:

Brief Summary of attached document:

The RCRA Facility Investigation/Remedial Investigation (RFI/RI) Volume 2 Report satisfies the characterization requirements of RCRA and CERCLA for past releases to groundwater from the former percolation bed in Bat Cave Wash (Solid Waste Management Unit (SWMU) 1 / Area Of Concern (AOC) 1) and the inactive injection well PGE-8 (SWMU 2).

This report defines the nature and extent of contamination in groundwater, surface water, pore water, and river sediment. Over 10 years of data (July 1997-October 2007) are presented. Based on the data and conclusions presented in this report, the only media affected by past releases to groundwater at the Topock Compressor Station is groundwater. The data show no effects on surface water, pore water, or river sediment in the vicinity of the site. The report recommends that 2 sites (SWMU 1 and AOC 1) be carried forward into the CMS/FS. It also concludes that the constituents of potential concerns (COPCs) in groundwater are hexavalent chromium (Cr(VI)), total chromium (Cr(T)), molybdenum, and selenium. For Cr(VI) and Cr(T) in groundwater that are related to the SWMU 1/AOC 1, the data in this report show that the extent of these COPCs is defined sufficiently well for the purpose of establishing remedial action objectives and for evaluating remedial alternatives. The conclusions regarding molybdenum and selenium will be addressed further in the forthcoming RFI/RI Volume 2 Addendum, which will also discuss the results of the Arizona groundwater investigation.

Written by: PG&E

Recommendations:
See above.

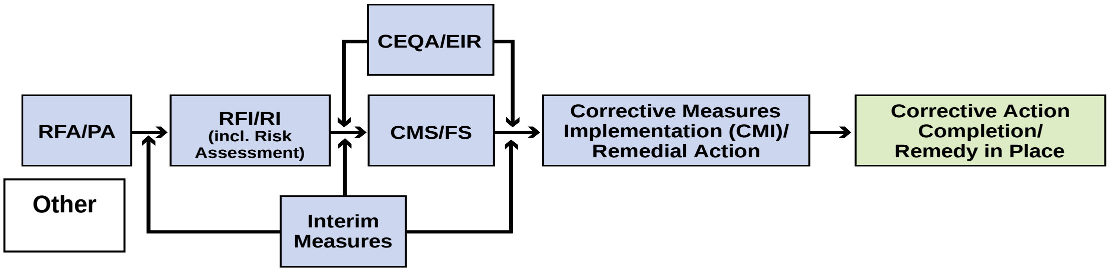
How is this information related to the Final Remedy or Regulatory Requirements:
Along with the groundwater risk assessment, the RFI/RI Volume 2 Report provides basic information for the evaluation of remedial alternatives for groundwater cleanup via the Groundwater CMS/FS.

Other requirements of this information?

The data in this report are used as input for the groundwater risk assessment and the CMS/FS.

Related Reports and Documents:

Click any boxes in the Regulatory Road Map (below) to be linked to the Documents Library on the DTSC Topock Web Site (www.dtsc-topock.com). **The link to the Documents Library is currently UNDER CONSTRUCTION.**



Legend
RFA/PA – RCRA Facility Assessment/Preliminary Assessment
RFI/RI – RCRA Facility Investigation/CERCLA Remedial Investigation (including Risk Assessment)
CMS/FS – RCRA Corrective Measure Study/CERCLA Feasibility Study
CEQA/EIR – California Environmental Quality Act/Environmental Impact Report

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February 11, 2009

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Subject: Revised Final RCRA Facility Investigation/Remedial Investigation Report, Volume 2—Hydrogeologic Characterization and Results of Groundwater and Surface Water Investigation, Pacific Gas and Electric Company, Topock Compressor Station, Needles, California (EPA ID NO. CAT080011729)

Dear Mr. Yue and Ms. Innis:

This letter transmits the Revised Final RCRA Facility Investigation/Remedial Investigation Report, Volume 2—Hydrogeologic Characterization and Results of Groundwater and Surface Water Investigation, Pacific Gas and Electric Company, Topock Compressor Station, Needles, California.

This report incorporates revisions made to the January 12, 2009 report and includes edits directed by DTSC in their February 4, 2009 conditional approval letter, and summarized by DOI in their February 9, 2009 approval letter. No additional changes have been made to the report.

Please contact me at (805) 234-2257 if you have any questions regarding the attached information or any other aspect of the RFI/RI activities.

Sincerely,

Yvonne Meeks

Yvonne Meeks
Topock Remediation Project Manager

Cc: Christopher Guerre, DTSC
Rick Newill, DOI

Enclosures

Final Report

RCRA Facility Investigation/Remedial Investigation Report PG&E Topock Compressor Station Needles, California

Volume 2 – Hydrogeologic Characterization and Results of Groundwater and Surface Water Investigation

Prepared for

Pacific Gas and Electric Company

February 11, 2009

CH2MHILL
155 Grand Avenue, Suite 100
Oakland, California 94612

Certification

RCRA Facility Investigation/Remedial Investigation Report

PG&E Topock Compressor Station
Needles, California

Volume 2

The information and results presented in this report are based on the review and compilation of available data obtained from numerous sources, including studies performed by others and data from independent laboratories. To the best of our knowledge, CH2M HILL has collected and incorporated the relevant data from these previous studies and reports into this document. This document and any interpretations, conclusions, and recommendations contained within are based upon those data.

This report was prepared by CH2M HILL under the supervision of the professionals whose seals and signatures appear hereon, in accordance with currently accepted professional practices; no warranty, expressed or implied, is made.

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Acronyms and Abbreviations

°F	degrees Fahrenheit
ADEQ	Arizona Department of Environmental Quality
afy	acre-feet per year
AOC	Area of Concern
APE	Area of Potential Effect
ARAR	applicable or relevant and appropriate requirement
bgs	below ground surface
BLM	United States Bureau of Land Management
BOR	United States Bureau of Reclamation
CACA	Corrective Action Consent Agreement
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980
cfs	cubic feet per second
CMP	Compliance Monitoring Program
CMS/FS	corrective measures study/feasibility study
COPC	constituent of potential concern
Cr(III)	trivalent chromium
Cr(T)	total chromium
Cr(VI)	hexavalent chromium
DOI	Department of Interior
DTSC	California Department of Toxic Substances Control
E&E	Ecology and Environment
ft/d	feet per day
GMP	Groundwater Monitoring Program
gpd	gallons per day
gpm	gallons per minute
HNWR	Havasu National Wildlife Refuge

HSU	hydrostratigraphic unit
I	Interstate
IM	Interim Measure
IM-3	Interim Measure Number 3
ISPT	*in-situ* pilot test
kg/m^3	kilograms per cubic meter
MCL	maximum contaminant level
µg/L	micrograms per liter
µS/cm	microSiemens per centimeter
mg/kg	milligrams per kilogram
mg/L	milligrams per liter
msl	mean sea level
m/s	meters per second
mV	millivolt
MWD	Metropolitan Water District
MWH	Montgomery Watson Harza
NOAA	National Oceanic and Atmospheric Administration
ORP	oxidation-reduction potential
OWS	oil/water separator
PAH	polynuclear aromatic hydrocarbon
PCB	polychlorinated biphenyl
PG&E	Pacific Gas and Electric Company
PMP	Performance Monitoring Program
ppm	parts per million
QA/QC	quality assurance/quality control
QAPP	quality assurance project plan
RCRA	Resource Conservation and Recovery Act
RFI/RI	Resource Conservation and Recovery Act facility investigation/remedial investigation
RMP	River Monitoring Program

scfd	standard cubic feet per day
SOW	Statement of Work
SQG	sediment quality guidelines
SVOC	semivolatile organic compound
SWMU	Solid Waste Management Unit
TDS	total dissolved solids
TPH	total petroleum hydrocarbons
TWG	Technical Work Group
USGS	United States Geological Survey
UTL	upper tolerance limit
VOC	volatile organic compound
VSMOW	Vienna Standard Mean Ocean Water
Water Board	California Regional Water Quality Control Board, Colorado River Basin Region

Executive Summary

Pacific Gas and Electric Company (PG&E) is conducting investigative and remedial activities at the Topock Compressor Station located in eastern San Bernardino County, California. The California Environmental Protection Agency, Department of Toxic Substances Control (DTSC) is the lead agency responsible for oversight of Resource Conservation and Recovery Act (RCRA) corrective action activities. The United States Department of the Interior (DOI) is the lead Federal agency on land under its jurisdiction, custody, or control and is responsible for oversight of response actions being conducted by PG&E pursuant to the Comprehensive Environmental Response, Compensation and Liability Act of 1980 (CERCLA). This document satisfies the requirements of a RCRA facility investigation (RFI) and a CERCLA remedial investigation (RI).

This document is Volume 2 of what is currently planned to be a three-volume RFI/RI document. Volume 2 contains the hydrogeologic characterization and results of groundwater and surface water investigations at the PG&E Topock site. The purpose of this document is to complete the characterization requirements of the RFI and CERCLA RI for past releases to groundwater from two specific historical operations at the Topock Compressor Station.

ES.1 RCRA Facility Investigation/CERCLA Remedial Investigation Overview

The compressor station occupies approximately 65 acres of PG&E-owned land located in eastern San Bernardino County, California, approximately 15 miles southeast of Needles. The compressor station is located approximately 1,500 feet from the Colorado River and the California and Arizona state border. The study area covers additional surrounding land owned and managed by a number of government agencies and private entities. The compressor station is located in a sparsely-populated, rural area. The surrounding land lies within an area of significant cultural and sacred tribal resources. The nearest communities are Moabi Regional Park (California); Topock, Arizona; and Golden Shores, Arizona. Existing infrastructure in the study area includes six natural gas transmission pipelines, the Burlington Northern Santa Fe Railway, Interstate 40, a former gravel quarry, the compressor station operation infrastructure including four operating evaporation ponds, and an interim remedial measures groundwater treatment plant and associated pipelines.

Investigative and remedial activities at the Topock Compressor Station date to the 1980s with the identification of solid waste management units (SWMUs) and areas of concern (AOCs) through a RCRA facility assessment. The RFI began in 1996 when PG&E and DTSC entered into a Corrective Action Consent Agreement, and numerous phases of data collection and evaluation have been implemented. Since 2005, investigative and remedial activities have been performed pursuant to both RCRA corrective action and CERCLA.

To date, major portions of the RFI/RI have been completed, Interim Measures have been implemented, and work toward the risk assessment, and RCRA corrective measures study

(CMS) is progressing. The CMS will be completed following the completion of the risk assessment, and will also meet the requirements of the feasibility study (FS) under CERCLA.

ES.2 Summary of Wastewater Discharge Activities Associated with Groundwater Contaminants

The Topock Compressor Station began operations in December 1951 to compress natural gas supplied from the southwestern United States for transport through pipelines to PG&E's service territory in central and northern California. The compressor station is still active and is anticipated to remain an active facility into the foreseeable future. Other than changes in waste management activities that have evolved with industry practice, current operations at the compressor station are very similar to the operations that occurred from the start of facility operations in 1951. A description of compressor station operation history is provided in Volume 1 of this RFI/RI Report (CH2M HILL, 2007a).

As defined by Volume 1 of the RFI/RI, the SWMUs and AOCs to be carried forward and addressed in Volume 2 of the RFI/RI are those associated with the historical discharge of wastewater from the facility. These include:

- SWMU 1/AOC 1 – Former percolation bed and area around former percolation bed
- SWMU 2 – Inactive Injection Well PGE-8

ES.2.1 SWMU 1/AOC 1 – Former Percolation Bed and Area around Former Percolation Bed

SWMU 1/AOC 1 includes that portion of Bat Cave Wash that lies just to the west of the facility and that was formerly occupied by the percolation bed. From 1951 to 1970, facility wastewater containing chromium was discharged to this area and was allowed to percolate into the ground and/or evaporate (beginning in 1964, discharged wastewater was treated to reduce hexavalent chromium [Cr(VI)] to trivalent chromium [Cr(III)].

Wastewater discharged to Bat Cave Wash consisted primarily of cooling tower blowdown (about 95 percent) and a minor volume of effluent from an oil/water separator (OWS) and other facility maintenance operations (about 5 percent). From 1951 until 1964, cooling tower blowdown was not treated prior to being released to the wash. The cooling tower blowdown contained Cr(VI). From 1964 to 1969, the cooling tower blowdown was treated with a one-step system to reduce Cr(VI) in the wastewater to Cr(III) prior to discharge to the wash. Beginning in late 1969, cooling tower blowdown was treated with a two-step system to reduce Cr(VI) to Cr(III) and then to remove Cr(III) from the wastewater prior to discharge to Bat Cave Wash. The continuous discharge of wastewater to Bat Cave Wash ceased in May 1970 when injection well PGE-8 was brought online. However, between May 1970 and September 1971, some treated wastewater may have been temporarily discharged to the percolation bed in Bat Cave Wash when injection well PGE-8 was offline for repairs or maintenance.

Cooling tower blowdown between 1951 and 1970 contained Cr(VI)-based products that were added to the cooling water to inhibit corrosion, minimize scale, and control biological growth. In addition, due to evaporation loss in the cooling towers, naturally-occurring inorganics (e.g., sodium chloride) in the cooling water were concentrated. In addition, copper, nickel, and zinc are wear metals that could have been released from the tubes in the heat exchangers and therefore may have been contained in the blowdown. The effluent from the OWS contained entrained heavy hydrocarbons derived from compressor oil and potentially other sources such as steam-cleaning operations.

As defined by a review of site history information in Volume 1 of the RFI/RI, the constituents of potential concern (COPCs) for groundwater at SWMU 1/AOC 1 consist of total chromium [Cr(T)], Cr(VI), copper, lead, nickel, zinc, pH, electrical conductivity, and total petroleum hydrocarbons (TPH). Additional COPCs in groundwater have been monitored during the RFI/RI period and are discussed in this report. Constituents that merit designation as SWMU 1/AOC 1 COPCs to be carried forward in the RCRA/CERCLA process are identified at the end of the report. Soil is also a media for SWMU 1/AOC 1 and will be addressed in RFI/RI Volume 3.

ES.2.2 SWMU 2 – Inactive Injection Well PGE-8

Inactive injection well PGE-8 was used for the subsurface injection of facility wastewater from 1970 to 1973. Treated wastewater was injected directly into groundwater at depths exceeding 405 feet below ground surface (bgs); therefore, groundwater is considered the medium of concern at this SWMU. Soil is not a media of concern at SWMU 2. Since December 1973, PGE-8 has been completely inactive; it has only been used for routine groundwater sample collection.

There were no significant modifications in the handling and treatment of the cooling tower blowdown and the OWS effluent during the operation of the injection well from 1970 to 1973. PG&E estimated that during the injection period (June 1970 through December 1973), approximately 29.4 million gallons of treated wastewater were injected into this well. Approximately 95 percent of the wastewater generated at the facility was from cooling tower blowdown, and the remaining 5 percent consisted of effluent from an OWS and other facility maintenance operations. Wastewater sent to PGE-8 for subsurface injection was treated and concentration levels were reduced to below 1 part per million of total chromium, according to reports of the time. Based on the reported treatment process, the chromium in the post-treatment water would have been Cr(III), and given the limited solubility of Cr(III) the concentrations were very likely much less than 1 part per million.

As defined by a review of site history information in Volume 1 of the RFI/RI, the COPCs for groundwater associated with SWMU 2 consist of Cr(T), Cr(VI), copper, lead, nickel, zinc, electrical conductivity, pH, and TPH. Additional COPCs in groundwater have been monitored during the RFI/RI period and are discussed in this report.

ES.3 Physical Characteristics and Hydrogeologic Setting

The RFI/RI study area is located in the southern portion of the Mohave Valley, along the California-Arizona border in eastern San Bernardino County, California. The approximate boundaries of the RFI/RI study area are defined by the Area of Potential Effect (APE). The study area encompasses approximately 3 square miles of north-sloping piedmont alluvial terrace and floodplain along the northern margin of the Chemehuevi Mountains.

Topography in the study area is abrupt, rising from the Colorado River in the east and north to the Chemehuevi Mountains in the south. Surface topography is characterized by alluvial terraces extending northward to the Colorado River floodplain, with incised drainage channels. One of the largest incised channels is Bat Cave Wash, a north-south trending desert wash adjacent to the Topock Compressor Station. Locally, a floodplain borders both sides of the Colorado River, though the river no longer floods due to flow regulation by upstream dams.

The climate is typical of low desert areas along the Lower Colorado River, with hot summer and mild winter seasons. The average daily maximum temperature exceeds 100°F during June, July, August, and September, and rarely does the temperature drop below freezing. Average precipitation from 1961 to 1990 was approximately 4.67 inches per year. The most prominent period of rain occurs during summer thunderstorms from July through early September, with some coming from occasional winter rains. The predominant wind direction is south-southwest based on data from the Needles airport. The second most predominant wind direction is north-northwest. Wind direction and speed are more variable at the compressor station site due to the pronounced topography and proximity to the river channel.

ES.3.1 Geology of the Study Area

The Topock site and study area are in the Basin and Range geomorphic province, characterized by roughly parallel north/south fault-block mountains, separated by alluvial valleys. The oldest rocks in the Topock area are exposed in the Chemehuevi Mountains and include Precambrian and Mesozoic-age metamorphic and igneous rocks. Miocene-age sedimentary and volcanic rocks, associated with the tectonic uplift and faulting in the region, were deposited on the metamorphic and plutonic bedrock complex. The bedrock basement formations are, in turn, overlain by younger Tertiary and Quaternary to Recent-age sedimentary deposits.

The most prominent geologic structural feature in the study area is the detachment fault that forms the northern boundary of the Chemehuevi Mountains. The Chemehuevi detachment fault is inferred to be low-angle (15 to 20 degree) northeast-dipping normal fault that has displaced pre-Tertiary metamorphic bedrock and Miocene sedimentary rocks (upper plate) across underlying, lower plate crystalline bedrock. The surface trace of the Chemehuevi detachment fault is mapped in western Mohave County, Arizona, approximately 2 miles southeast of the Topock site, indicating this regional fault extends eastward from California into Arizona.

ES.3.2 Hydrogeology of the Study Area

The study area is within the Mohave Valley groundwater basin, which is bisected by the Colorado River. Groundwater in the Mohave basin occurs in the Tertiary and younger alluvial basin deposits, which include the productive Pleistocene to recent fluvial deposits associated with the Colorado River. In the Basin, water-bearing zones may occur locally where bedrock formations are weathered or fractured although no areas have been identified in the Mohave groundwater basin where saturated bedrock formations are capable of yielding significant quantities of groundwater.

Groundwater occurs under unconfined to semi-confined conditions within the alluvial fan and fluvial sediments beneath most of the Topock site. The alluvial fan hydrostratigraphic units (HSUs) consist primarily of clayey/silty sand and clayey gravel deposits interbedded with more permeable sand and gravel deposits. The fluvial HSUs similarly consist of interbedded sand, sandy gravel, and silt/clay sediment. The saturated portion of the alluvial fan and fluvial sediments are collectively referred to as the Alluvial Aquifer. In the floodplain area adjacent to the Colorado River, the fluvial deposits interfinger with, and are hydraulically connected to, the alluvial fan deposits. The unconsolidated alluvial and fluvial deposits are underlain by the Miocene Conglomerate and pre-Tertiary metamorphic and igneous bedrock with very low permeability; therefore, groundwater movement occurs primarily in the overlying unconsolidated Alluvial Aquifer.

The water table in the Alluvial Aquifer has a very gently-sloping gradient throughout the study area and typically equilibrates to an elevation within 2 to 3 feet of the river level. Due to the variable topography at the site, the depth to groundwater ranges from as shallow as 5 feet bgs in floodplain wells next to the river to approximately 170 feet bgs at the upland alluvial terrace areas. The saturated thickness of the Alluvial Aquifer is about 100 feet in the floodplain and thins to the south, pinching out along the Miocene Conglomerate and bedrock outcrops. In the western portions of the study area, where the depth to bedrock increases, the saturated Alluvial Aquifer is over 200 feet thick.

ES.3.3 Surface Water Hydrology of the Study Area

The primary surface water feature at the site is the Colorado River and its adjacent wetlands and marshes. The two largest dry wash drainages in the study area are Bat Cave Wash and an unnamed surface drainage extending southwest of Park Moabi. The river system upstream of the site is characterized by the wide Mohave Valley floodplain, marsh, and alluvial valley. Downstream of Topock, the river traverses the exposed bedrock of the Chemehuevi Mountains of California and the northern portion of the Mohave Mountains in Arizona. Sacramento Wash is the principal dry wash surface drainage to the Colorado River from the Sacramento Valley in Mohave County, Arizona.

The Colorado River channel ranges from approximately 600 to 700 feet wide in the area upstream of the Interstate 40 bridge crossing at Topock. In 2005 the river depths ranged from four to 12 feet on two cross-river transects measured at and north of the Interstate 40 bridge. On the river transect measured at the I-3 gas pipeline bridge, the channel depths ranged from 5 feet near the Arizona shoreline to a maximum of 22 feet near the California shoreline.

Following the completion of Hoover Dam in 1936, the large spring floods were controlled. The completion of Parker Dam downstream from the site in 1938 marked the beginning of a period of rising river levels as Lake Havasu filled and the lower Mohave Valley aggraded. Dam releases are greatest in the late spring and early summer, producing higher river levels during this time (April through July). The portion of the aquifer adjacent to the river receives river water recharge during this time of year. Beginning in June, releases decrease, producing lower river levels and groundwater gradients trend towards the river except at the site where IM-3 pumping maintains the landward gradient. The lowest river levels are typically from October to January. River levels at the site fluctuate by 2 to 3 feet per day, and flows vary anywhere from 4,000 to 25,000 cubic feet per second according to the dam releases, producing a sinusoidal hydrograph each day.

The Colorado River is a net-gaining stream at the Topock site. Most of the groundwater discharge to the river in Mohave Valley occurs upstream of the site as supported by the site conceptual model, numerical modeling, and groundwater chemistry data. Water levels in Topock Marsh are maintained slightly higher than the river at Topock by diverting river water at an upstream location near Needles. The marsh is therefore an indirect source of river recharge by groundwater in the study area. Smaller sources of recharge in Mohave Valley are precipitation recharge in bordering mountains, irrigation return flow, and groundwater underflow from adjacent groundwater basins such as Sacramento Valley (Arizona). To a lesser extent, groundwater discharge in Mohave Valley includes evapotranspiration along the river floodplain; underflow beneath the river in Topock Gorge; and pumping for municipal, industrial, and agricultural use.

ES.4 Summary of RFI/RI Hydrogeologic Investigations

RFI/RI field activities began in June 1997, and six phases of work were completed through October 2007. The scope of work for each phase was determined by using the findings from previous investigation phases. The work plans were implemented after approval by DTSC and (since 2004) by DOI agencies. Other state and local agency approvals were obtained prior to work plan implementation, as required by corresponding regulations. Data included in this report are data collected within the Area of Potential Effect, between 1997 and 2007, by PG&E and its consultants in accordance with agency-approved plans and procedures and in conformance with data quality control programs.

Field activities included drilling and hydrogeologic investigations, hydraulic testing, groundwater monitoring well installation, groundwater sample collection, surface water sampling, pore water sampling, and river sediment sampling. Sample collection and management under the RFI/RI program was performed in accordance with the RFI work plan, the RFI work plan amendments, and several additional matrix-specific sampling and analysis plans. Quality assurance/quality control programs were also implemented to ensure that the data were of high quality and met the purpose and objectives of the RFI/RI.

ES.5 Hydrogeologic Conditions and Conceptual Site Model

The Topock site is located at the southern downstream end of the Mohave Valley groundwater basin. The hydrogeologic setting consists of unconsolidated alluvial and fluvial deposits (the Alluvial Aquifer) underlain by the Miocene Conglomerate and pre-Tertiary metamorphic and igneous bedrock. The alluvial deposits include several HSUs that exhibit considerable variability in hydraulic conductivity within the individual units. The fluvial sediments were deposited by the Colorado River and include interbedded sand and sandy gravel deposits and lower-permeability silt and clay-rich sediments. In the floodplain area, the fluvial deposits interfinger with, and are hydraulically connected to, the alluvial fan deposits. The interface between alluvial and fluvial units occurs near the western edge of the floodplain. The Topock Compressor Station is located in the upland alluvial terrace portion of the site, near the southern edge of the Alluvial Aquifer.

The hydrogeologic and hydrogeochemical features that comprise the site's conceptual model are summarized below.

- Under natural conditions, groundwater flows from west/southwest to east/northeast across the site. Gradients are very small due to the limited recharge, with a typical value of 0.0005 feet/foot in the alluvial area. Under average conditions groundwater velocity is about 45 feet/year. Localized areas of northward flow likely occur along the mountain front to the south of the compressor station.
- Under ambient conditions, the river recharges groundwater during the spring months and groundwater discharges to the river during the months of lower river stages. Since 2004, the Interim Measures (IM) groundwater extraction has maintained a consistent landward gradient in the plume floodplain area year round.
- Mineral content of site groundwater is variable but is mostly brackish water with total dissolved solids (TDS) between 1,000 and 15,000 milligram per liter. In general, TDS increases with depth, with the highest TDS found in deepest alluvial and bedrock wells. The TDS in fluvial groundwater increases with distance away from the river and with depth, becoming similar to alluvial groundwater quality in deeper fluvial wells west of the floodplain.
- Stable isotopes of oxygen and hydrogen have been used to generally identify three water groups: (1) river water and river-influenced groundwater, (2) local alluvial groundwater, and (3) industrial water from historical facility discharges. The groups are intermixed to varying degrees, especially in the floodplain. IM groundwater extraction has drawn river-influenced groundwater westward and downward, causing it to mix with the groundwater underlying the edge of the floodplain.
- The Cr(VI) groundwater plume extends from the former percolation bed in Bat Cave Wash to the floodplain area north of the railroad tracks. Within the plume, Cr(VI) is typically present at all depth intervals of the alluvial portion of the aquifer but is generally limited to deep wells in the fluvial portion of the aquifer near the river. The Cr(VI) groundwater plume is characterized by higher oxidation-reduction potential and a heavier oxygen/deuterium isotopic signature compared to river-influenced fluvial zone groundwater. Reducing conditions have been documented in most shallow to mid-depth fluvial wells and sediments near and underlying the river. South of the railroad tracks, these reducing conditions are also encountered in deep wells near and beneath the river. The observed reducing conditions are characterized by the presence of organic carbon, dissolved iron, dissolved manganese, and ammonia in groundwater samples. Under non-pumping conditions, as Cr(VI) migrates in groundwater from non-reducing conditions in the alluvial and deep fluvial sediments to reducing conditions near and beneath the river, it undergoes chemical reduction and reverts to Cr(III) which is immobilized in the sediments, as evidenced by its absence in groundwater samples collected from fluvial wells screened in reducing material. Stable isotope data from floodplain monitoring wells indicate that the decrease in Cr(VI) concentration does not occur by dilution, and laboratory testing of fluvial anaerobic core samples provides direct evidence of the reduction reaction.

- The general absence of Cr(VI) in reducing groundwater, and the results of laboratory testing in fluvial core samples indicate that there is significant capacity in the fluvial deposits underlying the river to reduce and remove Cr(VI) from groundwater (CH2M HILL, 2008a). This process is a beneficial factor limiting Cr(VI) migration to the river under current conditions. Uncertainties remain regarding the extent to which reducing conditions in fluvial deposits provide a pervasive and permanent barrier to Cr(VI) contaminant migration to the river.

ES.6 Groundwater Characterization Results

Groundwater characterization of the Topock site is based on multiple phases of groundwater investigation, sampling, and monitoring data collected from July 1997 through October 2007. The RFI/RI groundwater investigations included six phases of well installation, which has produced a large network of groundwater wells available for water quality monitoring. The current well network consists of approximately 110 groundwater monitoring wells, eight IM extraction and test wells, and 32 *in-situ* pilot test/monitoring wells.

ES.6.1 Nature and Extent of Contamination in Groundwater

The RFI/RI sampling and investigation and the ongoing site groundwater monitoring programs have produced a comprehensive chemical analytical data set for characterizing groundwater conditions. This section summarizes the characterization findings and conclusions for the COPCs related to SWMU 1/AOC 1 and other constituents of interest.

ES.6.1.1 Electrical Conductivity (Specific Conductance) and pH

Electrical conductivity (equivalent and referred to herein as specific conductance) was identified as a COPC in the CACA and the RFI/RI Report Volume 1. The groundwater specific conductance readings for the recent 2006 to 2007 monitoring period range from approximately 1,100 microSiemens per centimeter (µS/cm) for shallow wells next to the Colorado River to values in the range of 40,000 to 65,000 µS/cm in shallow and deep wells that monitor brackish to saline groundwater zones. The RFI/RI data show that many wells in areas outside of the groundwater plume associated with SWMU 1/AOC 1 have average specific conductance values above 15,000 µS/cm, and these values are believed to represent natural groundwater conditions. Elevated specific conductance is interpreted to be a natural property of the deep alluvial and bedrock groundwater, and is also found in some shallow fluvial zones. Specific conductance is strongly correlated to the proximity of the well screens to bedrock. Many wells within the plume have been screened closer to the bedrock, and therefore exhibit higher specific conductance. Once the data set is corrected for this difference in screened interval, there is no statistically significant difference in specific conductance measured inside and outside of the plume. It is therefore recommended that specific conductance (electrical conductivity) not be considered a COPC in groundwater related to SWMU 1/AOC 1.

Groundwater pH readings range from 6.79 to 8.98 for the sampling period. The vast majority of site groundwater samples have pH values within the federal secondary drinking water standard range of 6.5 to 8.5. The few slightly elevated pH values do not appear to be associated with the groundwater plume or any site activity; therefore, pH should not be not be considered a COPC in groundwater related to SWMU 1/AOC 1.

ES.6.1.2 Copper, Nickel, Lead, and Zinc

The concentrations of copper, lead, nickel, and zinc in some site wells exceed the calculated statistical upper tolerance limit (UTL) concentrations for regional background conditions and/or the groundwater applicable or relevant and appropriate requirements (ARARs). It is expected that at least 5% would exceed the UTL, based on the statistical methods described in the Background Study. The occurrence and distribution of these COPC exceedances do not coincide with the historical discharges to Bat Cave Wash, the inactive injection well PGE-8, or with other identifiable sources. The distribution of these exceedances does not form a plume that suggests a site-related source area. The conclusion is that these exceedances reflect local variability of naturally occurring groundwater in the basin, and in some cases likely represent solid colloidal material that passed through the sample filter. On the basis of these observations, none of the four metals are recommended for further consideration as COPCs in groundwater related to SWMU 1/AOC 1.

ES.6.1.3 Total Petroleum Hydrocarbons

Selected shallow monitoring wells in the vicinity and downgradient of SMWUs 1 and 2 were sampled for TPH gasoline, diesel, and motor oil in May 2007. The TPH analytes were not detected at or above the analytical reporting limits in these samples. These sampling results for selected wells in the vicinity of SMWUs 1 and 2 indicate no impacts to groundwater by petroleum hydrocarbons, and therefore, it is recommended that TPH not be considered a COPC in groundwater related to SWMU 1/AOC 1.

ES.6.1.4 Other Trace Metals

Additional trace metals have been sampled during the groundwater characterization. Aluminum, arsenic, beryllium, molybdenum, selenium, vanadium and antimony are present in groundwater above the site background UTL concentrations in some wells and arsenic is found in several locations at concentrations exceeding ARARs. With the possible exception of arsenic at well MW-10 (as postulated by DTSC), the arsenic, vanadium, and antimony exceedances are discontinuous and do not coincide with the historical discharges to Bat Cave Wash or the inactive injection well PGE-8. The sampling data generally suggest either natural elevated concentrations or localized, anomalous detections. Based on the discontinuous distribution or localized occurrence, along with the lack of identifiable sources or association with facility operations, arsenic, vanadium, antimony, beryllium, aluminum, and manganese are not recommended for consideration as COPCs in groundwater related to SWMU 1/AOC 1. Molybdenum has been used at the compressor station and was identified in a facility wastewater sample from 2005. For these reasons, molybdenum cannot be ruled out as a COPC in groundwater from SWMU 1/AOC 1. Elevated selenium concentration has been documented in well TW-1, adjacent to and downgradient from the facility. DTSC has concluded that selenium is a COPC, and there is not sufficient evidence to refute this conclusion. Additional Title 22 metals data have been collected and will be reported in the RFI/RI Volume 2 Addendum Report to verify these conclusions.

ES.6.1.5 Other Constituents Analyzed

Additional constituents analyzed during the groundwater characterization include organic compounds (volatile organic compounds, semivolatile organic compounds, and polychlorinated biphenyls) and perchlorate. The sampling and analysis for these constituents in selected wells was requested by the DTSC to assess potential presence and occurrence in site groundwater.

Fluoride was originally analyzed to help characterize general groundwater chemistry, yet concentrations are elevated above ARAR in both site and Background Study wells. Average concentrations exceeding the background UTL for fluoride are limited to only three site wells: MW-10 near the compressor station, MW-33-40 in the floodplain, and MW-6 near the current evaporation ponds. Fluoride is a geochemically conservative element that would be expected to move as freely through the aquifer as Cr(VI). Due to the inconsistent, non-plume-like nature of the concentration distribution, fluoride should not be considered a COPC in groundwater from SWMU 1/AOC 1.

Sampling for organic compounds was conducted in 2004, 2005, and 2007 in selected wells in the vicinity and downgradient of SMWUs 1 and 2. The analyses from this supplemental sampling indicated no impacts to groundwater by organic compounds.

Perchlorate was never used or stored at the site; however, perchlorate from sources near Las Vegas had been detected in water samples from the Colorado River. Perchlorate was not detected in the 2003-2004 groundwater samples collected at selected wells. In two additional sampling events at the New Ponds wells in 2005, perchlorate was reported in samples at two of the monitoring wells at concentrations ranging from 2.43 to 3.77 micrograms per liter (µg/L). Based on site history and the distance of these wells from the Colorado River, the 2005 perchlorate detections are considered anomalous and potentially false-positive analytical results. No additional perchlorate sampling was conducted.

ES.6.1.6 Hexavalent and Total Chromium

The sampling results from the October 2007 comprehensive, sitewide groundwater monitoring event were used to define the present distribution of chromium in groundwater at the site. These data are shown on Figures 6-12a, 6-12b, and 6-12c. For this sampling event, 118 groundwater wells were sampled for Cr(VI) and Cr(T), as well as for other chemical parameters.

The chromium plume is defined as that part of the Alluvial Aquifer where Cr(VI) concentrations exceed natural background levels, following the subsurface flowpath along which the original industrial discharge passed. The calculated statistical UTL of natural background levels for Cr(VI) in groundwater, obtained from sampling monitor and water supply wells surrounding the Topock site, is 31.8 µg/L (CH2M HILL, 2008b). This value was rounded to 32 µg/L as the definition of the Cr(VI) plume at the Topock site.

In each of the Alluvial Aquifer depth monitoring zones, the location of Cr(VI) concentrations for groundwater greater than or equal to 32 µg/L follows Bat Cave Wash northward approximately 2,000 feet from the compressor station. For shallow and mid-depth wells, the 32 µg/L concentration limit is located eastward from Bat Cave Wash and extends eastward into the western portion of the floodplain. In the deep zone of the Alluvial Aquifer, the 32 µg/L concentration limit is also located eastward from Bat Cave

Wash and extends further eastward into the floodplain especially in the area between monitoring wells MW-27 and MW-28. Non-reducing conditions are still prevalent in deep fluvial wells within the plume flowpath at this location, and Cr(VI) concentrations are correspondingly elevated. The variability in the vertical distribution and trends for chromium within the aquifer are believed to result from the combined effects of: (1) proximity to the source area, (2) heterogeneity and permeability variations (vertical and lateral) of the aquifer media, (3) long-term groundwater gradients within the aquifer, and (4) site-specific geochemical conditions affecting the stability of Cr(VI). Density-driven flow may have played a role in the early stages of plume development, when blowdown water discharged to Bat Cave Wash was more saline than in later years. Whatever effect this had was likely diminished by the homogenizing action of the original site water supply wells, which were located near where I-40 crosses Bat Cave Wash, and by the facility limiting the number of cooling water cycles, thus lowering the discharge salinity.

In the sampling data that predate the March 2004 startup of IM groundwater extraction, Cr(VI) concentrations were generally stable in the deep zone, whereas a seasonally-fluctuating trend was observed in the shallow zone. The initial response to full-time groundwater extraction was an increase in Cr(VI) concentrations in the mid-depth and deep wells and declining concentrations in the shallow, water table monitoring wells. The sampling data since July 2006 show declining or stable concentration trends for floodplain wells.

ES.6.1.7 Chromium Distribution in Bedrock Units

Dissolved Cr(T) has typically been detected at trace to low concentrations (typical range 2 to 10 µg/L) in groundwater samples from the bedrock wells. In the RFI/RI sampling from March 2001 to October 2007, Cr(VI) has not been detected in any of the groundwater samples from bedrock wells, with the exception of well MW-23. Beginning in March 2004, Cr(VI) has been detected in groundwater samples at MW-23. The Cr(VI) concentrations observed in the March 2004 through October 2006 sampling of MW-23 ranged from 1.1 to 16.8 µg/L. The Cr(VI) concentration for MW-23 in December 2006 was reported to be 1,920 µg/L; however, this result was rejected for decision purposes following standard QA/QC practice due to inconsistency with field duplicate sample results. The March 2007 sample showed a similar anomalously elevated Cr(VI) concentration (1,020 µg/L). Subsequent MW-23 samples in May and October 2007 were at lower concentrations (13 and 19.2 µg/L), consistent with the 2005 and 2006 results. The distribution of Cr(VI) in the vicinity of bedrock well MW-23 will be further characterized in the East Ravine groundwater investigation to be submitted in a supplementing investigation report.

ES.6.2 Fate and Transport of Chromium in Groundwater

Hexavalent chromium is relatively stable under the non-reducing conditions of the alluvial aquifer beneath the Topock site. It is in the form of the chromate anion, CrO_4^{2-}, in the pH range of site groundwater. This anion is a relatively mobile ion that does not form insoluble precipitates nor does it adsorb strongly to mineral surfaces (Hering and Harmon, 2004). This stability is evidenced by the persistence of Cr(VI) from the original discharge area in Bat Cave Wash throughout all the predicted flowpaths in the non-reducing alluvial material.

Once Cr(VI) encounters a sufficiently reducing environment as is found in portions of fluvial materials, it quickly reverts to Cr(III). Trivalent chromium is essentially immobile except either under highly acidic pH conditions or in the presence of strong complexing agents, neither of which is present at the Topock site. Wherever the natural reducing capacity of the fluvial material is present, chromium is converted to its stable form of Cr(III) and is essentially immobile.

The capacity of the reducing fluvial material to reduce Cr(VI) has been investigated by conducting two phases of the anaerobic core study. Laboratory analysis has confirmed that fluvial material in reducing groundwater zones demonstrates a strong capacity to remove Cr(VI) from plume groundwater. The reduction capacity and extent of the reducing zone are not precisely known. Calculation and review of this capacity are currently in progress, and the estimated range of natural reducing capacity will be used in the CMS/FS.

Movement of chromium by density-driven flow is not currently a significant transport mechanism. The difference in fluid density between brackish blowdown water and fresh or brackish groundwater is small, and the resultant density-driven flow would not be significant when compared to advective gradients and advective flow. It is noted that during the earlier years of the operation of the compressor station, the cooling towers were operated differently than in later years. During this initial period of operations, the water was kept in the cooling towers longer between blowdown cycles, resulting in higher salinity. During the initial period of discharge to Bat Cave Wash, this blowdown water likely had greater density than native groundwater. Density gradients may therefore have been a factor in moving the higher salinity water downward through the upper, fresher portion of the aquifer during the earlier years of compressor station operations. During this same time, the pumping of fully-penetrating water supply wells located several hundred feet down the wash would have tended to mix the saline water throughout the aquifer thickness. After the earlier years of compressor station operation, density-driven flow would not be expected to be a significant process for groundwater transport given the relatively small range of groundwater density in the Alluvial Aquifer at Topock.

ES.6.3 Additional Groundwater Data to be Collected

The groundwater data presented in this report, collected from July 1997 through October 2007, address the nature and extent of groundwater impacts associated with the historical discharges to Bat Cave Wash and the inactive injection well PGE-8. The primary data needs to support additional groundwater characterization and the site conceptual model development include:

- Further delineation of the groundwater chromium plume in areas along the east shoreline of the Colorado River in Arizona.
- Further characterization of groundwater conditions in the East Ravine area to the east of the compressor station.
- Further characterization of groundwater conditions beneath the compressor station.

To address these data needs, several groundwater investigations are planned for implementation after October 2007. The further plume delineation and installation of additional monitoring wells in Arizona will be reported in an addendum to the RFI/RI

Report, Volume 2. The further characterization and installation of additional monitoring wells in the East Ravine area and within the compressor station will be reported in the RFI/RI Volume 3, data summary reports or monitoring reports, as appropriate, given the nature of the data and the affect on RFI/RI conclusions.

ES.7 Surface Water Quality Characterization Results

Sampling and analyses for surface water characterization have been conducted for shoreline surface water locations, in-channel surface water, and pore water study stations during the RFI/RI. More than 700 surface water samples have been collected through October 2007 for the RFI/RI characterization.

ES.7.1 Shoreline Surface Water Sampling, 1996-2007

Shoreline surface water samples from the Colorado River have been collected at up to 18 shoreline locations during the RFI/RI period at locations both upstream and downstream of the mouth of Bat Cave Wash. Samples have been analyzed for chromium, trace metals, general chemistry parameters, and perchlorate.

Cr(VI) has not been detected in any shoreline surface water samples collected during the July 1997 through October 2007 monitoring period, except for one sampling event. During June 2002 surface water sampling, Cr(VI) was reported at concentrations ranging from 15.9 to 25.7 µg/L in six samples collected from the Colorado River at locations both upstream and downstream of Bat Cave Wash. The June 2002 Cr(VI) results were inconsistent with prior and subsequent Cr(VI) analyses, including laboratory re-testing of the samples. Confirmation sampling at the same locations in August 2002 yielded non-detect results for Cr(VI). According to the data quality review for the June 2002 monitoring, there was indication of false-positive results caused by unidentified interference for these samples. DTSC concurred that no action should be taken or project decisions should be made based on the results. All RFI/RI shoreline surface water samples collected from the Colorado River, other than the June 2002 event, have been non-detect for Cr(VI) at the analytical reporting limit. The false positive samples from the June 2002 event represent 6 samples out of 536 shoreline surface water samples collected under the RFI/RI. All of the Cr(VI) data that are of sufficient quality for decision making purposes are below the chemical-specific ARARs criteria of 11 µg/L.

Dissolved copper has been detected in shoreline surface water samples at six locations downstream of Bat Cave Wash at average concentrations ranging from 4.75 to 13.2 µg/L. Dissolved copper has been detected in two upstream locations at average concentrations ranging from 5.42 to 5.85 µg/L. None of the average copper concentrations exceed the chemical-specific ARARs criteria of 23 µg/L.

Dissolved nickel has been detected in shoreline surface water samples at five locations downstream of Bat Cave Wash at average concentrations ranging from 7.07 to 12.3 µg/L. Dissolved nickel has been detected in an upstream location at an average concentration of 7.82 µg/L. None of the average nickel concentrations exceed the chemical-specific ARARs criteria of 132 µg/L.

Dissolved zinc has been detected in shoreline surface water samples at seven locations downstream of Bat Cave Wash at average concentrations ranging from 3.05 to 96.4 µg/L. Dissolved zinc concentrations have been detected in five upstream locations at average concentrations ranging from 9.25 to 166 µg/L. None of the average zinc concentrations exceed the chemical-specific ARAR criteria of 297 µg/L.

Dissolved lead has not been detected in shoreline surface water samples at locations downstream of Bat Cave Wash. Dissolved lead has been detected in one upstream location at an average concentration of 2.33 µg/L. None of the average lead concentrations exceed the chemical-specific ARAR criteria of 8 µg/L.

None of the average specific conductance values exceed the chemical-specific ARAR criteria of 1,600 µS/cm, with the exception of an area immediately west of the bridge crossing at Bat Cave Wash, which is dry periodically. The RFI/RI shoreline surface water sampling indicates no discernable difference between specific conductance or pH results collected upstream and downstream of Bat Cave Wash. None of the average pH concentrations are outside of the ARAR criteria range of 6.5 to 8.5.

None of the average concentrations from shoreline surface water samples analyzed for other trace metals or perchlorate exceeded the respective ARAR criteria.

ES.7.2 In-channel, Depth-specific Surface Water Sampling (2005-2007)

Depth-specific surface water samples from the Colorado River have been collected at five in-channel stations downstream of the mouth of Bat Cave Wash and four in-channel upstream locations. Analytical suites have varied over time, and have included chromium and general chemistry parameters.

Cr(VI) and dissolved Cr(T) have not been detected in any in-channel surface water samples at analytical reporting limits during the RFI/RI period, except for one occurrence (Table 7-2). During the September 2007 surface water sampling, Cr(VI) was reported at a trace concentration of 0.4 µg/L at one in-channel surface water location (C-R22-D). This reported detection is below the Cr(VI) chemical-specific ARAR criteria of 11 µg/L. Subsequent investigation of the field and laboratory practices for the sample at C-R22 revealed a strong possibility that a low-level contamination of the buffer solution, used for lab and field preservation, was responsible for the low-level Cr(VI) reported result at C-R22-D. None of the Cr(VI) and Cr(T) concentrations from the RFI/RI in-channel samples exceed the chemical-specific ARARs criteria of 11 and 50 µg/L respectively.

None of the average specific conductance values exceed the chemical-specific ARAR criteria of 1,600 µS/cm. The RFI/RI river channel surface water sampling indicates no discernable difference between specific conductance or pH results collected upstream and downstream of Bat Cave Wash. None of the average pH concentrations are outside of the ARAR criteria range of 6.5 to 8.5.

ES.7.3 Pore Water Study Surface Water Sampling (2006)

Additional in-channel surface water samples were collected at 16 locations upstream and downstream of the Topock site during the pore water study in early 2006. The analytical suite included chromium and general chemistry parameters. These locations were co-located and collected at the same time as the corresponding pore water samples.

Cr(VI) and dissolved Cr(T) were not detected in any surface water samples at the analytical reporting limits.

The surface water sampling from the pore water study indicates no discernable difference between specific conductance or pH results collected upstream and downstream of Bat Cave Wash.

ES.8 Pore Water Characterization

A river bottom temperature survey was conducted prior to the collection of samples for the 2006 pore water study to determine the depth of influence from diurnal river level fluctuation and select pore water sampling depths. Shallow river sediment temperatures were measured with small, self-contained, temperature recording devices that were buried in the river bottom to record the temperature in the pore water over a period of approximately a week. The temperature survey indicated that, at a depth of 6 feet below the river bottom, the river influenced fluctuations were effectively damped out to magnitudes below the resolution of the temperature recorders. From these results, it was recommended that the 2006 pore water samples be collected from depths of 6 feet below the river bottom, below the depth of significant diurnal changes in the flow regime.

Pore water samples were collected from six locations in February 2003 and 64 locations in January 2006. Cr(VI) was not detected in any of the 2003 pore samples at the analytical reporting limit. Cr(T) was detected in pore water samples from three locations at trace concentrations around 1 µg/L. Cr(VI) and Cr(T) were not detected in any of the 2006 pore water samples collected from 64 locations both upstream and downstream of the Topock site.

Geochemical indicators for reducing conditions, such as the presence of reduced aquatic species, including iron, manganese, and ammonia, were found in nearly all the samples that were collected for these constituents. Conditions that favor the existence of these species also favor the reduction of Cr(VI). Dissolved organic carbon, which could potentially be metabolized by microorganisms that catalyze reduction reactions, was detected in all of the pore water samples that were collected for this constituent.

The combination of (a) lack of detections of chromium in any of the pore water and associated surface water samples, (b) the consistency of reducing condition indicators in pore water samples along with slant well groundwater samples below the river bottom, and (c) anaerobic core sample laboratory testing results, provide compelling evidence for the presence of a naturally-occurring geochemical zone that would reduce or eliminate Cr(VI) in groundwater that could be migrating toward the river if no IM-3 extraction were occurring. Based on the results of the anaerobic core study and consistent with published literature, reducing material will rapidly reduce Cr(VI) to Cr(III), which is removed from solution by mineral precipitation and adsorption reactions (Kimbrough et al., 1999; Hering and Harmon, 2004). The reducing capacity and the aquifer matrix concentration of the reducing material is variable, so quantification of the amount of Cr(VI) that may be reduced is currently an estimate, based on laboratory testing of a limited number of core samples from localized boreholes.

ES.9 River Sediment Characterization

Sampling and analyses for river sediment characterization has occurred on two occasions during the RFI/RI: in 2003 and in 2005 during the pore water study. In 2005 for the RFI/RI, 17 river sediment samples were collected upstream, downstream, and at the mouth of Bat Cave Wash on the banks of the Colorado River. In the upstream, downstream, and mouth of Bat Cave Wash sediment samples, none of the detected concentrations of Cr(T) were above the sediment quality guideline of 43.4 milligrams per kilogram for Cr(III). Since Cr(III) is one of the forms of Cr(T), if concentrations of Cr(T) do not exceed the guidelines, then Cr(III) concentrations would not exceed the guidelines. Cr(VI) was not detected in any of the sediment samples. None of the other analyzed metal sediment samples were detected above sediment quality guidelines.

The objective of river bottom sediment sampling during the pore water study was to assess the geochemical conditions in shallow sediments below the Colorado River. The intent was primarily to determine whether aerobic or anaerobic conditions are present in the shallow river sediments. A multiple lines-of-evidence approach, using results of sediment sampling in conjunction with the results from the pore water sampling, was used to evaluate the encountered sediment conditions. The results of the sediment sampling and extended suite pore water sampling provided additional evidence for whether geochemical conditions in shallow sediments below the Colorado River favor chromium reduction. However, due to the limited amount of sediment data, definitive conclusions pertaining to shallow sediment redox conditions cannot be made. The presence of total organic carbon in river sediment is suggestive of a mildly reducing environment.

ES.10 Conclusions and Recommendations

The overall conclusions of the hydrogeologic characterization and groundwater and surface water investigations at the PG&E Topock site are summarized below. Recommendations are provided for the disposition of the SWMUs/AOCs addressed in this report under RCRA Corrective Action and CERCLA based on the site history (presented in RFI/RI Volume 1) and the characterization data presented in this report.

ES.10.1 Conclusions

ES.10.1.1 Completeness of the RFI/RI

This report, combined with the forthcoming risk assessment, satisfies all of the requirements to complete the RFI/RI for the media and SWMUs/AOCs addressed, namely, the former percolation bed in Bat Cave Wash (SWMU 1/AOC 1) and the inactive injection well PGE-8 (SWMU 2). With the exception of the identification of human and/or ecological receptors and the evaluation of the potential impacts to them, to be addressed in the forthcoming risk assessment, all of the elements and requirements discussed in Section 1.3 are included in this RFI/RI Report. In addition, all of the comments from DTSC and DOI on the February

2005 RFI/RI Report and the July 2008 RFI/RI Volume 2 Report, as summarized in Appendix A, have been addressed.

ES.10.1.2 Affected Media

The media addressed in this report are groundwater, surface water, pore water, and sediment. This report does not address soil media for SWMU 1/AOC 1 or soil and/or groundwater for other SWMUs and AOCs, which will be addressed in Volume 3. Based on the data and conclusions presented in this report, the only medium that appears to be affected currently by past discharge of wastewater from the Topock Compressor Station to SWMU 1/AOC 1 and SWMU 2 is groundwater. The RFI/RI data show no effects from past wastewater discharge to SWMU 1/AOC 1 and SWMU 2 on surface water, pore water, or river sediment in the vicinity of the site. The collected data are sufficient to make this conclusion. Consistent with the RFI/RI requirements, the typical RCRA/CERCLA process, and the specific agency requirements for this site, a risk assessment is being completed, as appropriate, to finalize the media to be carried forward to the CMS/FS.

ES.10.1.3 Identification of COPCs in Affected Media

While RFI/RI Volume 1 identified the COPCs in groundwater based on site history, this Volume 2 further refines the list of COPCs in groundwater based on characterization data. The characterization data presented in this report include not only those COPCs identified in RFI/RI Volume 1 based upon site history but also numerous additional constituents to ensure completeness and to account for any uncertainties associated with the site history. Based on the characterization data presented in this report, the COPCs in groundwater related to SWMU 1/AOC 1 are Cr(T) and Cr(VI). Molybdenum is also carried forward as a COPC based on its use at the facility and observed distribution in groundwater. Selenium is considered by DTSC to be a COPC in groundwater.

Other constituents (copper, nickel, lead, zinc, pH, and electrical conductivity, arsenic, vanadium, antimony, and fluoride) were found occasionally above the calculated statistical UTL concentrations for regional background conditions and/or the groundwater ARARs. However, with the possible exception of arsenic at well MW-10 (as postulated by DTSC), the occurrence and distribution of these exceedances do not coincide with the historical discharges to Bat Cave Wash and the inactive injection well PGE-8. TPH (identified as a COPC associated with the historic discharge of wastewater from the facility) was not found in groundwater samples above analytical reporting limit. Consistent with RFI/RI requirements, the typical RCRA/CERCLA process and the specific agency requirements for this site, a risk assessment is being completed, as appropriate, to finalize the list of COCs to be carried forward to the CMS/FS.

ES.10.1.4 Characterization of COPCs

For those COPCs are being carried forward for SWMU 1/AOC 1 groundwater (e.g., Cr(T), Cr(VI), molybdenum, and selenium), the data in this report show that the extent of Cr(T) and Cr(VI) is defined sufficiently well for the purpose of establishing remedial action objectives and for evaluating remedial alternatives. There are groundwater delineation wells with chromium concentrations below reporting limit in all downgradient directions from the established plume, including two slant well clusters screened beneath the river. Additional data are recommended to verify the conclusions made for molybdenum and selenium. In the spring of 2008, a groundwater investigation was performed to (a) install and sample additional delineation monitoring wells on the Arizona side of the river, and (b) continue sampling selected site monitoring wells for Title 22 metals. This supplemental investigation is anticipated to complete the groundwater characterization and the results will be summarized in the Addendum to the RFI/RI Volume 2 Report.

ES.10.2 Recommendations

ES.10.2.1 SWMU 1/AOC 1

Based on site history and characterization data, it is recommended that SWMU 1/AOC 1 (the former percolation bed and area around former percolation bed) be carried forward into the CMS/FS. Discharge of wastewater to the percolation beds in Bat Cave Wash has resulted in a chromium plume of approximately 90 acres, concentrations of which are greater than the chemical-specific ARARs. Molybdenum and selenium are also carried forward as COPCs associated with SWMU 1/AOC 1. Following the completion of the risk assessment for SWMU 1/AOC 1, the CMS/FS will define the remedial action objectives for SWMU 1/AOC 1, identify potential corrective/remedial measure technologies, and evaluate corrective/remedial measure alternatives based on RCRA and CERCLA selection criteria, in accordance with the *Corrective Measures/Feasibility Study Work Plan, Topock Compressor Station* (CH2M HILL, 2008c).

ES.10.2.2 SWMU 2

Based on site history and characterization data, it is recommended that SWMU 2 (the inactive injection well PGE-8) be closed with the RFI/RI and not be carried forward into the CMS/FS. This recommendation is based on:

- Site history indicates that untreated cooling tower blowdown water from the compressor station was never discharged to PGE-8.
- The quantity of data that have been collected to evaluate bedrock conditions in the vicinity of PGE-8 indicate that the characterization data are adequate to make this conclusion.
- Hydraulic test data at PGE-8 indicate that a clear hydraulic connection exists between bedrock groundwater and the Alluvial Aquifer. These findings strongly suggest that discharge of treated wastewater to the injection well would have followed the preferential flow path of discharge to the Alluvial Aquifer.
- Based on the recent data collected, it is assumed that reducing conditions within PGE-8 during times of historical waste discharge would have resulted in any Cr(VI) remaining in the water discharged to PGE-8 after treatment at the compressor station to have been reduced to insoluble Cr(III) and, therefore, would have been removed from groundwater.
- The consistent lack of Cr(VI) above reporting limits in groundwater samples from bedrock wells in the vicinity of the SWMU 2 area indicate that no negative effects to bedrock groundwater have resulted from the PGE-8 past operations.

1.0 Introduction

Pacific Gas and Electric Company (PG&E) is conducting investigative and remedial activities at the Topock Compressor Station (also referred to herein as "the compressor station" or "the facility") located in eastern San Bernardino County, California.

The California Environmental Protection Agency, Department of Toxic Substances Control (DTSC) is the state lead agency charged with directing remedial and investigative activities at the compressor station in accordance with the federal Resource Conservation and Recovery Act (RCRA). In February 1996, PG&E and DTSC entered into a Corrective Action Consent Agreement (CACA) pursuant to Section 25187 of the California Health and Safety Code (DTSC, 1996). Under the terms of the CACA, PG&E agreed to conduct a RCRA facility investigation to identify and evaluate the nature and extent of hazardous waste and constituent releases at the compressor station.

The United States Department of the Interior (DOI) is the lead federal agency on land under its jurisdiction, custody or control and is responsible for oversight of response actions being conducted by PG&E pursuant to the Comprehensive Environmental Response, Compensation and Liability Act of 1980 (CERCLA). Portions of the site affected by operations at the Topock Compressor Station are on land managed by the Department's Bureau of Land Management (BLM), United States Fish and Wildlife Service, and Bureau of Reclamation (BOR) (collectively the "federal agencies"). In July 2005, PG&E and the federal agencies entered into an Administrative Consent Agreement to implement response actions at the site as set forth in the National Oil and Hazardous Substances Pollution Contingency Plan (DOI, 2005a).

This document is Volume 2 of what is currently planned to be a three-volume RCRA facility investigation/remedial investigation (RFI/RI) document. Volume 2 contains the hydrogeologic characterization and results of groundwater and surface water investigations at the PG&E Topock site. The purpose of this document is to complete the characterization requirements of the RFI and CERCLA remedial investigation for past releases to groundwater from two specific historical operations at the Topock Compressor Station.

Three draft versions of the RFI/RI Report have previously been prepared in April 2000 (E&E, 2000a), February 2004 (E&E, 2004), and February 2005 (CH2M HILL, 2005a). The RFI/RI Volume 2 Report was submitted to DTSC and DOI in July 2008 (CH2M HILL 2008d) and was prepared in accordance with DTSC's review of and comments on the February 2005 RFI/RI, as documented in its letter dated September 19, 2007 (DTSC, 2007a). In addition, federal agency comments on the February 2005 RFI/RI (DOI, 2005b) were addressed in the July 2008 RFI/RI Volume 2 Report as they pertained to the nature and extent of hazardous waste and constituent releases in groundwater at the compressor station. In letters dated October 21, 2008 and October 17, 2008, DTSC and DOI provided comments on the July 2008 RFI/RI Report and directed that PG&E prepare responses to the comments (DTSC, 2008a; DOI, 2008). This Revised Final RFI/RI Report incorporates those additional changes to the RFI/RI Volume 2 Report as directed by DTSC on December 26, 2008 (DTSC, 2008b). All comments and responses to the comments are included in Appendix A.

This section contains site location and description information for the Topock Compressor Station, history and regulatory background, and a summary of RFI/RI activities. Additional information on site background and history is included in the *Revised Final RCRA Facility Investigation and Remedial Investigation Report, Volume 1, Site Background and History* (CH2M HILL, 2007a).

1.1 Site Location and Description

The Topock Compressor Station is located in eastern San Bernardino County, California, about 15 miles southeast of Needles, as shown in Figure 1-1. The compressor station is located approximately 1,500 feet from the Colorado River and the California and Arizona state border.

The Topock Compressor Station began operations in December 1951 to compress natural gas supplied from the southwestern United States for transport through pipelines to PG&E's service territory in central and northern California. The compressor station is still active and is anticipated to remain an active facility into the foreseeable future.

1.1.1 Topock Compressor Station Operations

Prior to construction of the compressor station in 1951, the surrounding area was mostly undeveloped land. The Teapot Dome restaurant and gas station occupied a small portion of the property at the very northern edge of the facility. The property on which the compressor station was built was owned by the State of California. From 1951 to 1965, PG&E leased the property from the State. In 1965, PG&E purchased the property from the State.

The main structures at the compressor station currently include the compressor building, Cooling Towers A and B, and the auxiliary building. Various auxiliary structures, including an office, a warehouse, a vehicle garage, maintenance buildings, equipment and chemical storage buildings, and a water-softening building, are adjacent to the main building. The facility also has aboveground tanks used for storage of water, water treatment chemicals, odorant, new and used compressor oil, gasoline and diesel, and wastewater.

When originally constructed, the facility was equipped with six compressors and was capable of processing 400 million standard cubic feet per day (scfd) of natural gas (PG&E, 1952). As demand increased, additional compressors were added, and existing compressors were upgraded (by turbocharging and supercharging) to increase the volume of gas that could be processed. Most of the upgrades were completed in the early to mid-1950s. Following the upgrades, the facility was capable of processing 1.1 billion scfd. Depending on demand, the facility currently processes between 300 million to 1.1 billion scfd of natural gas per day (Riddle, 2004, personal communication). The facility operates and is staffed 24 hours per day, 7 days a week.

Other than changes in waste management activities that have evolved with industry practice, current operations at the compressor station are very similar to the operations that occurred from the start of facility operations in 1951. The operations at the compressor station consist of:

- Water conditioning.
- Compression of natural gas.
- Cooling of the compressed natural gas and compressor lubricating oil.
- Wastewater treatment.
- Facility and equipment maintenance.
- Miscellaneous operations.

1.1.2 Land Ownership

The compressor station occupies approximately 15 acres of a 65-acre parcel of PG&E-owned land. PG&E also owns a 100-acre parcel located about 0.25 mile north of the compressor station, purchased in 2004 to facilitate interim remedial measures.

Land ownership near the compressor station is shown on Figure 1-2. The surrounding area includes land owned and/or managed by a number of government agencies and private entities including the BLM, BOR, United States Fish and Wildlife Service, San Bernardino County, California Department of Transportation, Burlington Northern Santa Fe Railroad, and Metropolitan Water District. The compressor station property is immediately surrounded by the land of the Havasu National Wildlife Refuge (HNWR).

1.1.3 Land Use and Nearby Communities and Development

The compressor station is located in a sparsely-populated, rural area. The surrounding land lies within an area of significant cultural and sacred tribal resources. Portions of the Topock Maze are located nearby. The maze is a geoglyph (ground marking) and is of importance to the local Native American community. The area is within the traditional territory of the Aha Makav or Mojave tribe. While the material remains of the past are important to these tribes, this area of traditional and spiritual use knows no boundaries for the Mojave.

Land uses near the project are predominantly open space, interspersed with industrial facilities, recreational uses, and transportation infrastructure. Open space near the compressor station is characterized primarily by sparse desert vegetation on steep, rocky slopes. The area is bisected by several steep-sided ephemeral streams, including Bat Cave Wash and several unnamed washes that flow north to the confluence of the Colorado River. Open space on the Colorado River floodplain is characterized by shifting sand dunes and associated riparian vegetation, primarily non-native tamarisk (salt cedar).

The nearest communities are mobile home parks at Topock, Arizona and Moabi Regional Park, California, as shown in Figure 1-3. Topock is located on the Arizona (or eastern) side of the Colorado River, about 0.5 mile east-northeast of the compressor station. Moabi Regional Park is located on the California (or western) side of the Colorado River about 1 mile northwest of the compressor station. The community of Golden Shores, the largest nearby community, is located approximately 5 miles north of the compressor station on the east side of the Colorado River.

A major gas utility and transportation corridor is located within the project site. This corridor includes six natural gas transmission pipelines, the Burlington Northern Santa Fe Railway, and the Interstate 40 freeway. Other developed land uses within the project site are shown in Figure 1-3 and include National Trails Highway, former Route 66, and various unnamed access roads. A former gravel quarry is located approximately 1,500 feet southwest of the compressor station. Evaporation ponds associated with the compressor station operations are located approximately 3,000 feet west of the compressor station. In addition, an interim remedial measures groundwater treatment plant and numerous groundwater well clusters related to the ongoing groundwater investigation activities are located at the site.

1.1.4 RFI/RI Study Area

The RFI/RI study area is located in the southern portion of the Mohave Valley, along the California-Arizona border in eastern San Bernardino County, California. Figure 1-3 shows the Area of Potential Effect (APE), which forms the approximate boundaries of the study area for the RFI/RI.

1.2 History of Investigative and Remedial Activities at Topock Compressor Station

Investigative and remedial activities at the Topock Compressor Station date to the 1980s with the identification of solid waste management units through a RCRA facility assessment. Closure activities associated with former hazardous waste management facilities and the former oily water treatment system at the compressor station were performed between 1988 and 1993. The RFI began in 1996 with the signing of the CACA, and numerous phases of data collection and evaluation have been completed under the CACA. Since 2005, investigative and remedial activities have been performed pursuant to both RCRA corrective action and CERCLA.

To date, major portions of the RFI/RI have been completed, Interim Measures (IMs) have been implemented, and work toward the risk assessment and RCRA corrective measures study (CMS) is progressing. The CMS will also meet the requirements of the feasibility study under CERCLA and is hereafter referred to as the CMS/FS. The status of the RFI/RI, IMs, and CMS/FS are summarized briefly below.

1.2.1 RCRA Facility Investigation/Remedial Investigation

PG&E's activities in support of the RFI/RI began in 1996 with the signing of the CACA. Since 1996, there have been multiple phases of investigation at the Topock site to collect data to evaluate the nature and extent of contamination at the Solid Waste Management Units (SWMUs) and Areas of Concern (AOCs). Details on the investigation activities for completion of the RFI/RI are discussed in Section 4.0 in this document.

Three draft versions of the RFI/RI Report have previously been prepared in April 2000 (E&E, 2000a), February 2004 (E&E, 2004), and February 2005 (CH2M HILL, 2005a). As directed by DTSC (DTSC, 2006), the Final RFI/RI is being separated into three volumes. The separation of the Final RFI/RI into three volumes is intended to efficiently manage the large amount of information associated with the RFI/RI, and to accelerate site remediation by allowing earlier remedial planning of those portions of the RFI/RI completed earlier:

- **RFI/RI Volume 1**. The *Revised Final RCRA Facility Investigation and Remedial Investigation Report, Volume 1 – Site Background and History* (CH2M HILL, 2007a) was completed in August 2007 and was approved by DTSC (DTSC, 2007b) and DOI (2007). Volume 1 of the RFI/RI identifies the 20 SWMUs, AOCs, and other undesignated areas at the Topock Compressor Station to be carried forward in the Final RFI/RI. An addendum to the RFI/RI Volume 1 is planned that will include additional site background and history information for additional SWMUs and AOCs that may be identified due to ongoing operations of the Topock Compressor Station and remedial facilities, including the current interim measure treatment plant location, the MW-20 bench location, and buried debris found at MW-24 benches. PG&E will continue to document any new units discovered in the future and promptly notify agencies regarding the discovery.

- **RFI/RI Volume 2.** This document contains the hydrogeologic characterization and results of groundwater and surface water investigations to address past historical releases to groundwater from wastewater discharged at Bat Cave Wash and injection well PGE-8 at the Topock Compressor Station. The purpose of this document is to complete the RFI/RI requirements for groundwater impacts associated with the past discharge of wastewater from Bat Cave Wash (SMWU 1/ AOC 1) and injection well PGE-8 (SWMU 2). An addendum to the RFI/RI Volume 2 is planned for submission in early 2009. This addendum will include select data and information collected between October 2007 and September 2008, after the data cutoff period for RFI/RI Volume 2.
- **RFI/RI Volume 3.** RFI/RI Volume 3 will include final characterization data to complete the RFI/RI requirements for remaining Topock Compressor Station operations, including results of soils investigations.

1.2.2 Interim Measures Activities

PG&E began implementing interim measures at the site in March 2004, pursuant to Section IV.A of the CACA. Initially, groundwater was extracted from a monitoring well cluster located on a bench above and to the west of the river floodplain (commonly referred to as the MW-20 bench). This operation was eventually replaced by the existing extraction well system. Groundwater extraction began at wells TW-2S and TW-2D in May 2004, at well TW-3D in December 2005, and at well PE-1 in January 2006. Prior to the construction and operation of the current groundwater treatment and injection systems, a batch treatment plant was located on the MW-20 bench, and treated groundwater was transported offsite for disposal at a permitted facility.

Currently, PG&E is implementing Interim Measure Number 3 (IM-3) at the Topock site. The Interim Measures Performance Monitoring Program (PMP) is a separate and unique monitoring program to evaluate the performance of the IMs to achieve the performance standard. The results of the Interim Measures PMP are published in routine monitoring reports. The performance standard has been achieved for all monitoring periods since the current standard was established in February 2005. IM-3 consists of groundwater extraction for hydraulic control of the groundwater plume in the Colorado River floodplain and management of extracted groundwater. Operation of the current groundwater treatment and injection system began in July 2005. The purpose of the IM is to maintain hydraulic control of the groundwater plume boundaries until the time that a final corrective action is in place at the site. As defined by DTSC, the performance standard for IM-3 is to "establish and maintain a net landward hydraulic gradient, both horizontally and vertically, that ensures that Cr(VI) [hexavalent chromium] concentrations at or greater than 20 micrograms per liter [µg/L] in the floodplain are contained for removal and treatment." The Interim Measure is not considered the final remedial action for the site.

Currently, the IM facilities include a groundwater extraction system (four extraction wells TW-2D, TW-3D, TW-2S, and PE-1), conveyance piping, a groundwater treatment plant, and an injection well field for the discharge of the treated groundwater. Of the four extraction wells, two are currently in operation (TW-3D and PE-1). The groundwater treatment system is a continuous, multi-step process that involves reduction of Cr(VI) to the less soluble trivalent form, Cr(III); precipitation and removal of precipitate solids by clarification and microfiltration; and lowering the naturally-occurring total dissolved solids (TDS) using reverse osmosis. Treated groundwater is returned to the aquifer through an injection system consisting of two injection wells (IW-2 and IW-3).

1.2.3 Corrective Measures Study/Feasibility Study

Simultaneously with RFI/RI investigations and IM activities, PG&E has continued to collect information on and preliminarily evaluate remedial technologies for the Topock site. PG&E submitted a draft CMS work plan to DTSC in December 2002 (CH2M HILL, 2002); a revised CMS/FS work plan in June 2007 (CH2M HILL, 2007b); and a final CMS/FS work plan in March 2008 (CH2M HILL 2008e).

As outlined in the revised CMS/FS work plan, the CMS/FS will be completed after the RFI/RI. The objective of the CMS/FS at the Topock Compressor Station will be to develop and evaluate corrective measure alternatives and to recommend the most appropriate alternative to manage contaminated groundwater, sediment, and soil, where required. The CMS/FS will define media cleanup levels that will be protective of human health and the environment. The CMS/FS will focus on the evaluation of potential cleanup technologies and the development, evaluation, and selection of a recommended alternative that is both protective of human health and the environment and consistent with remedial objectives.

To further the CMS/FS, PG&E has implemented or is implementing several studies at the Topock site to assist in identifying, screening, and evaluating potential remedial technologies for groundwater. These activities were initiated in 2004 and include:

- Extensive data collection regarding groundwater extraction, *ex-situ* groundwater treatment, and groundwater injection through implementation of interim measures.
- Groundwater, pore water, and surface water monitoring to define the nature and extent of contamination.
- Background groundwater study to evaluate naturally-occurring concentrations of inorganic constituents in the region surrounding the Topock site.
- Groundwater level measurements, hydraulic testing, and groundwater modeling to determine the direction and rate of groundwater movement to support design and operation of interim remedial measures wells.
- Anaerobic core testing of floodplain (fluvial) sediments to evaluate the capacity of anaerobic zone materials to chemically and biochemically reduce Cr(VI) to Cr(III).

- Aerobic core testing to evaluate the degree of sorption or other interactions between Cr(VI) in groundwater and the aquifer material in the aerobic zone.
- A chromium isotope study using an experimental technique developed by the United States Geological Survey (USGS) that may be able to differentiate naturally-occurring from anthropogenic chromium in groundwater.
- Soil borings and seismic surveys to determine presence and depth to a low-permeability bedrock layer.
- Groundwater model calibration updates to estimate cleanup times for various scenarios and to model simulations to predict effects of *in-situ,* pump/inject, and barrier wall technologies. For purposes of the CMS/FS, PG&E plans to use the most recent fully-calibrated model (the "5-layer model") originally documented in the *Groundwater Model Update Report, Topock Compressor Station, Needles California,* prepared by CH2M HILL for PG&E, dated July 2005 (CH2M HILL 2005b). The model had been calibrated against observed data through early 2005. Further refinements have been made to the model to reflect data collected between 2005 and 2008.
- *In-situ* pilot testing to evaluate site-specific effectiveness of *in-situ* treatment, longevity of reactants, ability to distribute reactants in the subsurface, and to assess potential effects of injected reagents on aboveground treatment systems. The effectiveness of *in-situ* reduction is being evaluated through pilot testing in both the fluvial aquifer in the floodplain and the Alluvial Aquifer in the upland portion of the site.

1.3 Objectives of RFI/RI Report

The objectives of the RFI/RI as specified in the CACA (DTSC, 1996) and other DTSC directives (DTSC, 2004a-b), are to:

- Provide information pertinent to the facility including current and historical operations, processes, and waste management practices.
- Identify and characterize sources of contamination.
- Define the nature, degree, and extent of contamination.
- Define the rate of movement and direction of contamination flow.
- Characterize the potential pathways of contaminant migration.
- Identify actual or potential human and/or ecological receptors and evaluate potential impacts to them.
- Gather data needed to make decisions on interim measures/stabilization during the early phases of the RFI.
- Support development of alternatives from which a corrective measure will be selected by DTSC.

The purpose of the CERCLA remedial investigation as specified in the National Contingency Plan, Title 40 Code of Federal Regulations Part 300, is to collect data necessary to adequately characterize the site for the purpose of developing and evaluating effective remedial alternatives. Title 40 Code of Federal Regulations Section 300.430(d) requires that the remedial investigation adequately characterize the nature of and threat posed by the hazardous substances and materials, and assess the extent to which the release poses a threat to human health and the environment. To define potential transport pathways and receptor populations and to support the analysis and design of potential response actions, the remedial investigation must assess:

- Physical characteristics of the site, including surface features, soils, geology, hydrogeology, meteorology, and ecology.
- Characteristics of air, surface water, and groundwater.
- Source identification and characterization, including facility characteristics that identify source locations; quantity of wastes that are contained in, or have been released in, the environment; and the physical and chemical characteristics of wastes present in the sources.
- Exposure pathways and exposure routes.
- Other factors, such as sensitive populations, that pertain to the characterization of the site or support analysis of remedial alternatives.

The three-volume document will include the required elements for completion of the RFI/RI. Also, with the exception of the risk evaluation, this document will include the required elements for completion of the CERCLA remedial investigation. Applicable or relevant and appropriate requirements (ARARs), a requirement of the CERCLA remedial investigation, are provided in this report. DOI has the lead role under CERCLA to identify the ARARs. On April 28, 2006 DOI sent a letter to the Topock Consultative Working Group requesting input in identifying ARARs (DOI, 2006). The June 2008 ARARs are provided in this report. PG&E will submit a risk assessment and CMS/FS separately, based on the results of this RFI/RI. As described in the *Corrective Measures/Feasibility Study Work Plan for the PG&E Topock Compressor Station* (CH2M HILL 2008c), the information in this report, combined with the corresponding risk assessment, will define the conceptual site model to be re-iterated in the CMS/FS. The risk assessment will be performed in accordance with the *Human Health and Ecological Risk Assessment Work Plan, Topock Compressor Station, Needles, California* (ARCADIS, 2008a).

1.4 Report Organization

This document is Volume 2 of the RFI/RI for the Topock Compressor Station and is intended to evaluate the nature and extent of hazardous waste and constituent releases in groundwater associated with the past discharge of wastewater from the compressor station to Bat Cave Wash and injection well PGE-8.

Terms defined under RCRA that are used in this report and that correspond to terms defined under CERCLA are intended to be construed to include the CERCLA terms. In particular, SWMUs and AOCs identified in this report shall be construed to be facilities where a release or threatened release of a hazardous substance has occurred, as defined under CERCLA.

The remainder of RFI/RI Volume 2 is organized in the following manner:

- A summary of wastewater discharge activities related to groundwater contaminants at the SWMUs and AOCs addressed in this report is included in Section 2.0
- A discussion of the physical characteristics and setting for the project area is provided in Section 3.0.
- A summary of the investigation programs included in this report is provided in Section 4.0.
- Hydrogeologic conditions and conceptual site model are presented in Section 5.0.
- Groundwater characterization, surface water characterization, pore water characterization, and river sediments characterization are presented in Sections 6.0, 7.0, 8.0, and 9.0, respectively.
- Conclusions of this RFI/RI Report are presented in Section 10.0.
- Documents referenced in the preparation of this report are provided in Section 11.0.

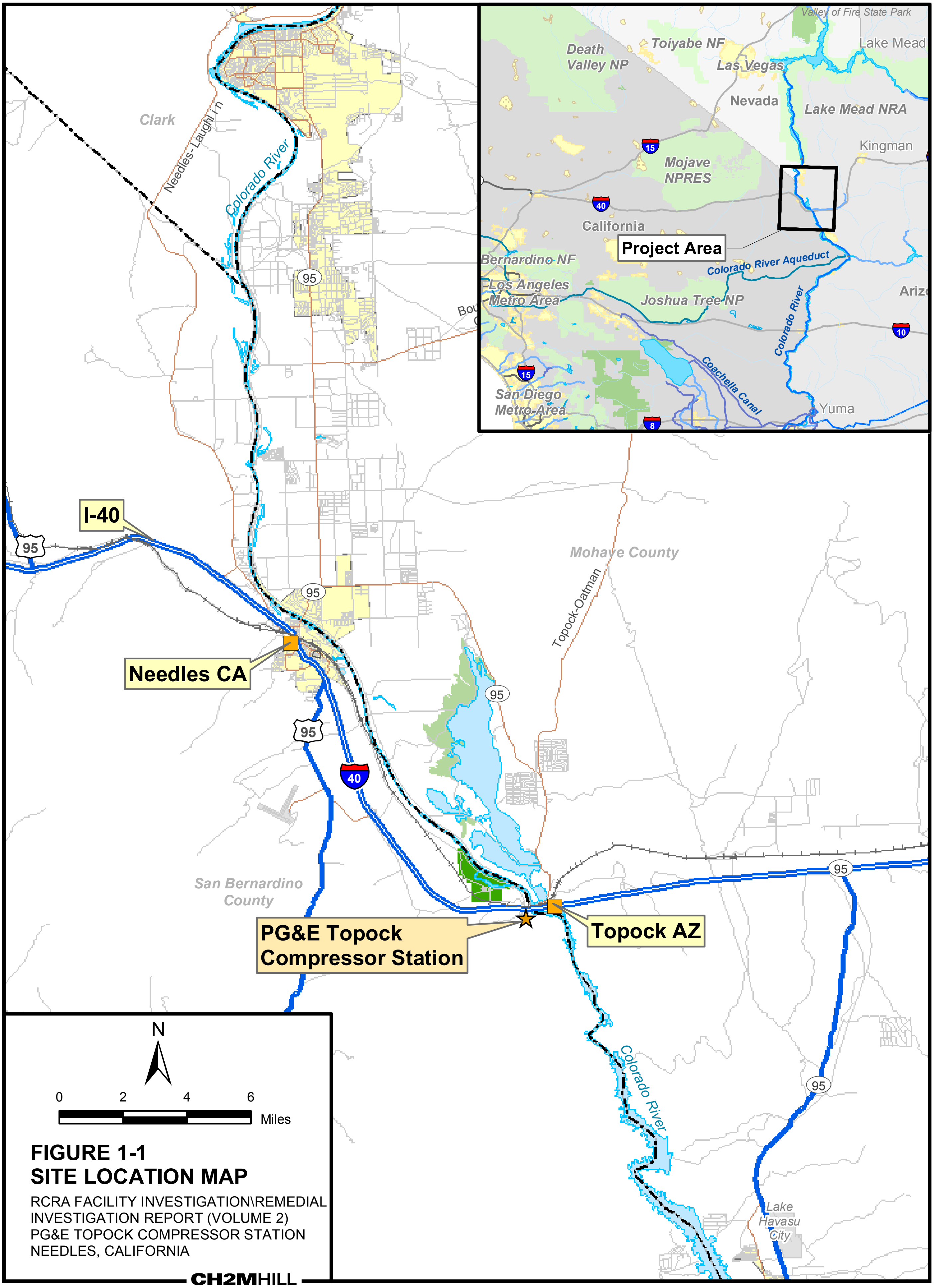
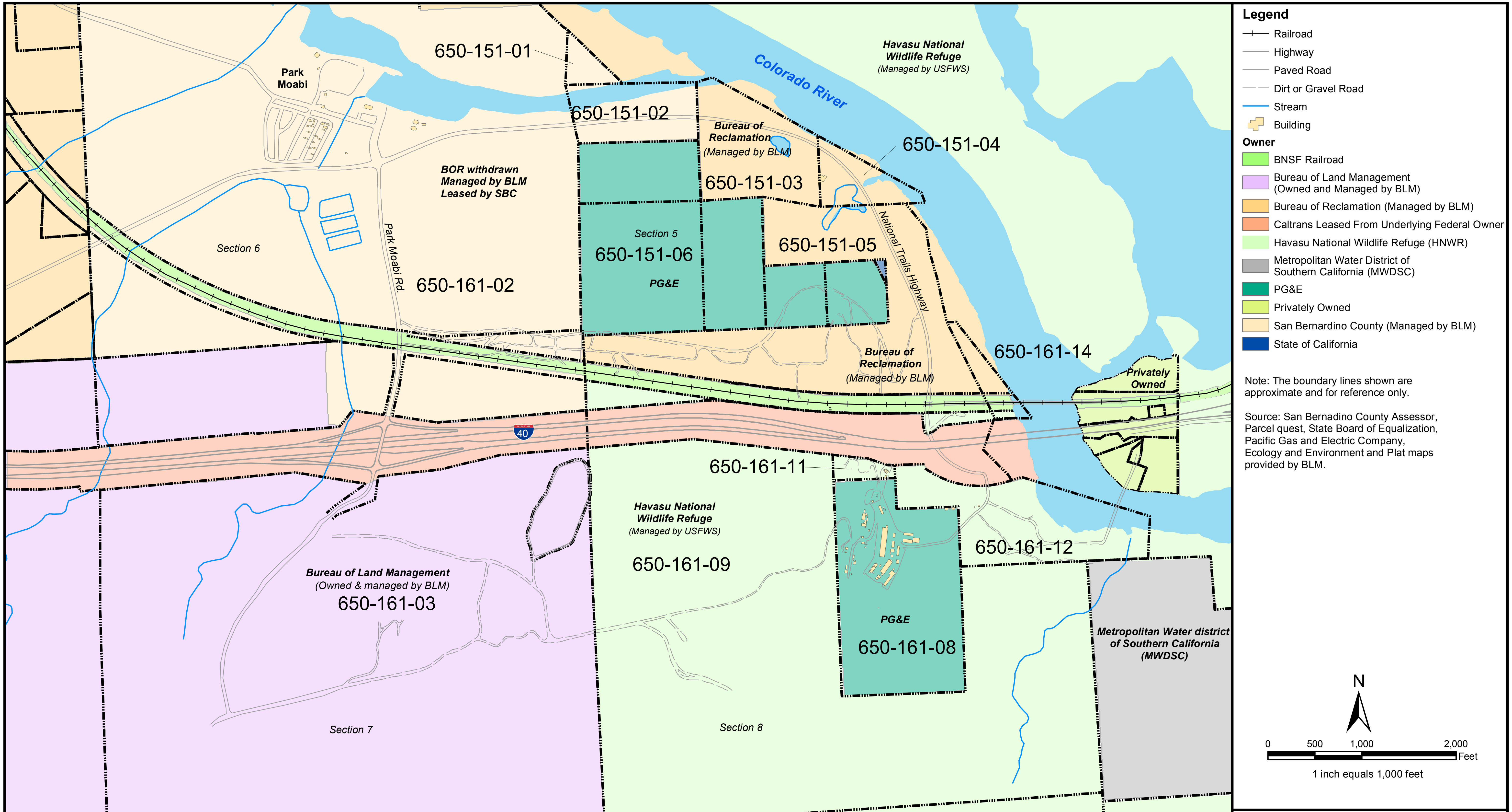


FIGURE 1-1
SITE LOCATION MAP

RCRA FACILITY INVESTIGATION\REMEDIAL
INVESTIGATION REPORT (VOLUME 2)
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

\\ZINFANDEL\PROJ\PACIFICGASELECTRICCO\TOPOCKPROGRAM\GIS\MAPFILES\2006\LOCATION_MAP_PORTRAIT.MXD LOCATION_MAP_PORTRAIT.PDF 2/19/2008 14:57:20



Note: The boundary lines shown are approximate and for reference only.

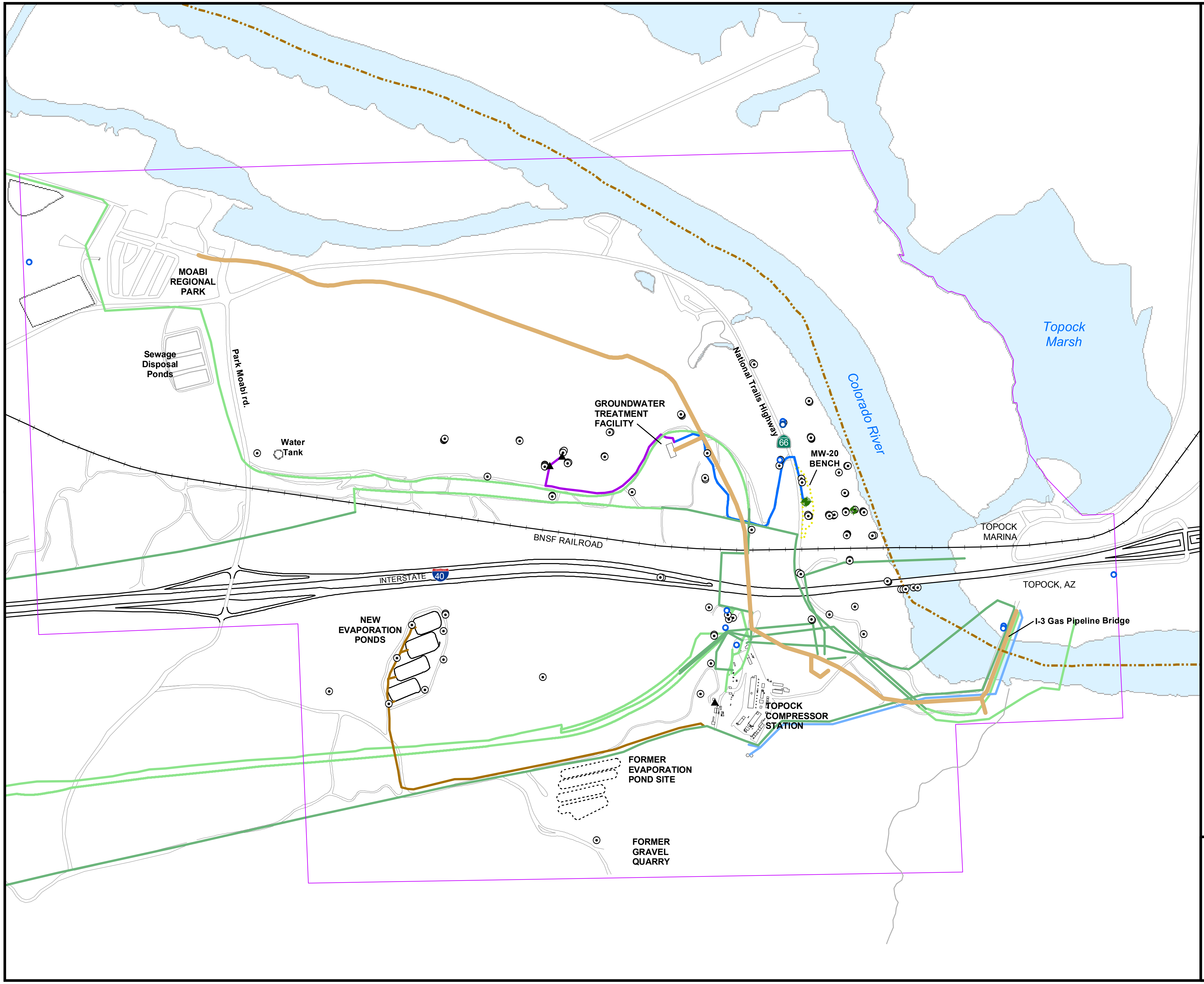
Source: San Bernadino County Assessor, Parcel quest, State Board of Equalization, Pacific Gas and Electric Company, Ecology and Environment and Plat maps provided by BLM.

FIGURE 1-2
SURROUNDING PROPERTIES

RCRA FACILITY INVESTIGATION/REMEDIAL
INVESTIGATION REPORT (VOLUME 2)
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

CH2MHILL

\\ZINFANDEL\PROJ\PACIFICGASELECTRICCO\TOPOCKPROGRAM\GIS\MAPFILES\2007\RFI\FIG1_2RFI_PROPERTY_OWNER_MAPV2.MXD FIG1_2RFIPROPERTY_OWNER_MAPV2.PDF 4/25/2008 14:44:40



NOTE:

The locations of pipelines and existing infrastructure are approximate. This figure is not intended to be a comprehensive depiction of all existing infrastructure in the APE.

FIGURE 1-3
NEARBY COMMUNITIES AND DEVELOPMENT

RCRA FACILITY INVESTIGATION/REMEDIAL
INVESTIGATION REPORT (VOLUME 2)
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

CH2MHILL

BAO \\ZINFANDEL\PROJ\PACIFICGASELECTRICCO\TOPOCKPROGRAM\GIS\MAPFILES\2007\RFI\FIG1-3_NEARBYCOMMUNITIESV2.MXD FIG1-3NEARBYCOMMUNITIESV2 12/12/2008 14:46:20

2.0 Summary of Wastewater Discharge Activities Associated with Groundwater Contaminants

The *Revised Final RCRA Facility Investigation/Remedial Investigation, Volume 1 - Site Background and History* (CH2M HILL, 2007a) for the Topock Compressor Station documented the historical materials and waste management practices at the Topock Compressor Station and presented a comprehensive identification of potential areas for investigation based on the historical information. Information pertaining to past disposal practices at each of the SWMUs, AOCs, and other undesignated areas was reviewed and a determination was made whether to carry a site forward in the RCRA corrective action and CERCLA site investigative programs.

As discussed in Section 1.1.3, the Final RFI/RI for the Topock site is being separated into three volumes to efficiently manage the large amount of information associated with the RFI/RI and to accelerate site remediation by allowing earlier remedial planning for those portions of the RFI/RI completed earlier.

As discussed in Volume I of the RFI/RI, the SWMUs and AOCs to be carried forward and addressed in Volume 2 of the RFI/RI are those associated with the historical discharge of wastewater from the facility, listed below and summarized in this section:

- SWMU 1 – Former Percolation Bed
- SWMU 2 – Inactive Injection Well PGE-8
- AOC 1 – Area Around Former Percolation Bed.

Constituents of potential concern identified in Volume 1 of the RFI/RI are presented in Table 2-1. (Tables are provided at the end of their respective sections.) The soil media at SWMU 1/AOC 1—as well as the remaining SWMUs, AOCs, and other undesignated areas at the Topock Compressor Station—will be addressed in Volume 3 of the RFI/RI.

A groundwater investigation at the East Ravine is planned for early 2009, as described in the *Revised Work Plan for the East Ravine Groundwater Investigation near the Pacific Gas and Electric Company (PG&E) Topock Compressor Station* (CH2M HILL, 2008f). Results of the East Ravine groundwater investigation will be provided in an investigation summary report and/or RFI/RI Volume 3. In addition, assessment of groundwater impacts from potential sources within the Topock Compressor Station is planned. Results of the groundwater investigation within the Topock Compressor Station will be provided in an investigation summary report and/or RFI/RI Volume 3. Additional sources of groundwater contamination that may be identified in the future from other ongoing investigations at the Topock Compressor Station will be investigated and reported in an addendum to RFI/RI Volume 2, RFI/RI Volume 3, data summary reports, or monitoring reports, as appropriate, given the nature of the data and the effect on RFI/RI conclusions. As required by RCRA Corrective Action and

CERCLA, a CMS/FS will be completed as appropriate based on the conclusions of the future investigations.

This section summarizes sections from the RFI/RI Volume 1 (CH2M HILL, 2007a) which describe the background and history of each of the SWMUs/AOCs to be addressed in RFI/RI Volume 2.

2.1 SWMU 1/AOC 1—Former Percolation Bed/Area Around Percolation Bed

SWMU 1, the Former Percolation Bed, was located outside the facility fenceline in Bat Cave Wash, as depicted in Figure 2-1. AOC 1 consists of the area that surrounds SWMU 1, the Former Percolation Bed.

2.1.1 Description and History—SWMU 1

When gas is compressed, it becomes heated. Cooling towers are employed to cool the compressed gas and the lubricating oil for the compressors. Water recirculates through the cooling towers. The evaporation of the recirculated water provides cooling. Periodically, the cooling water must be drained and replaced. This spent cooling water discharged from the cooling towers is called blowdown.

From 1951, when the compressor station first began operation, until 1970, when injection well PGE-8 went into operation, cooling tower blowdown was discharged to Bat Cave Wash.

Based on historical aerial photographs, it appears that during the 1950s, blowdown was released to the wash and flowed downstream. Wastewater was released to the wash through a pipe that ran from the sludge-drying beds area in the lower yard down the slope into Bat Cave Wash. Aerial photographs from that time period show a light-colored flow in the wash that originates at the discharge point and, at times, extends to the railroad tracks about 1,600 feet downstream. Based on aerial photographs, the light-colored flow does not extend beyond the railroad tracks.

Based on aerial photograph and document review, a percolation bed was created in Bat Cave Wash west of the former sludge-drying beds area in about 1964 (PG&E, 1968). This bed was constructed by scraping the wash alluvium from the bottom of the wash into shallow berms. PG&E documentation indicates that the bed had an area of approximately 17,600 square feet (PG&E, 1968). Wastewater was discharged to this area from two pipelines (one 10-inch-diameter pipe and one 4-inch-diameter pipe) that ran from the lower yard down into Bat Cave Wash. The bed was not lined, and discharged blowdown water was allowed to percolate into the ground and/or evaporate in this area. A former employee reported that the percolation bed sometimes crusted over so that the infiltration rate decreased. The berms were periodically moved and the crust was scraped from the bottom of the beds. The configuration of the percolation beds changed periodically, but the beds were located within the general area depicted in Figure 2-1 (Russell, 2006, personal communication).

Ponded water can be seen in this general area of the percolation bed in aerial photographs from 1967 and 1969. In addition, remnants of the 4-inch-diameter discharge pipe are also present on the slope above Bat Cave Wash. For the purposes of this RFI/RI, the entire discharge area within Bat Cave Wash (i.e., the percolation bed area) will be addressed under SWMU 1.

Wastewater discharged to Bat Cave Wash consisted primarily of cooling tower blowdown (about 95 percent) and a minor volume of effluent from an oil/water separator (OWS) and other facility maintenance operations (about 5 percent) (PG&E, 1993). Based on information from PG&E (1968), during the late 1960s, an average of about 48,500 gallons per day (gpd) of cooling tower blowdown were discharged to Bat Cave Wash, with a high of about 64,300 gpd in July and a low of about 25,600 gpd in February.

From 1951 until 1964, cooling tower blowdown was not treated prior to being released to the wash. The cooling tower blowdown contained Cr(VI). From 1964 to 1969, the cooling tower blowdown was treated with a one-step system to reduce Cr(VI) in the wastewater to Cr(III) prior to discharge to the wash. Although the process converted Cr(VI) to Cr(III), the concentration of total chromium [Cr(T)] was apparently not changed. Concentrations of Cr(T) in the wastewater discharged to Bat Cave Wash, as measured from samples collected in the late 1960s, ranged from 13.81 to 14.41 parts per million (ppm) (PG&E, 1968). Wastewater discharged to Bat Cave Wash also contained concentrations of TDS ranging from 4,000 to 11,000 milligrams per liter (mg/L), primarily sodium chloride (Water Board, 1969; PG&E, 1993). Beginning in late 1969, cooling tower blowdown was treated with a two-step system to reduce Cr(VI) to Cr(III) and then to remove Cr(III) from the wastewater prior to discharge to Bat Cave Wash. Following the two-step treatment, Cr(VI) concentrations in the wastewater were generally reduced to below 1 mg/L (Mittelhauser, 1986).

The continuous discharge of wastewater to Bat Cave Wash ceased in May 1970 when injection well PGE-8 was brought online. However, between May 1970 and September 1971 (when Pond 1 of the Old Evaporation Ponds was completed), some treated wastewater may have been temporarily discharged to the percolation bed in Bat Cave Wash when injection well PGE-8 was offline for repairs or maintenance.

2.1.2 Description and History—AOC 1

The aerial extent of AOC 1 has not been formally delineated; however, by definition, it is considered to consist of the floor of Bat Cave Wash in the area surrounding the location of the discharge area (SWMU 1). It also includes the floor of Bat Cave Wash downstream from the area that received the discharge from SWMU 1. Portions of AOC 1 are located on PG&E property, and portions are located on property owned by the HNWR.

2.1.3 Constituents of Potential Concern—SWMU 1/AOC 1

From 1951 to 1970, SWMU 1 received wastewater consisting of cooling tower blowdown and the effluent from the OWS. The wastewater was released to the surface of the wash and allowed to penetrate the soil column and migrate to the water table.

Cooling tower blowdown between 1951 and 1970 contained Cr(VI)-based products that were added to the cooling water to inhibit corrosion, minimize scale, and control biological growth. In addition, due to evaporation loss in the cooling towers, naturally-occurring inorganics (e.g., sodium chloride) in the cooling water were concentrated. In addition, copper, nickel, and zinc are wear metals that could have been released from the tubes in the heat exchangers and therefore may have been contained in the blowdown.

Although the cooling towers were intended to operate at a neutral pH (pH 7), there may have been occasional upsets. The two-step wastewater treatment system also resulted in a neutral or near-neutral effluent pH during normal operating conditions. There is no record of any pH adjustment following chromium reduction in the single-step treatment process. Therefore, it is possible that the treated blowdown from the single-step treatment system, used from approximately 1964 to 1968, was acidic.

The oily water directed to the OWS was derived from a variety of sources, including leaks and drips from plant equipment and drainage from the steam-cleaning area. The effluent from the OWS contained entrained heavy hydrocarbons derived from compressor oil and potentially other sources, such as steam-cleaning operations. Sources of total petroleum hydrocarbons (TPH) in the oily water treated by the OWS are expected to consist of high boiling point straight- and branched-chain hydrocarbons analyzable as TPH. An OWS effluent sample collected in November 1986 showed TPH concentrations at 3 mg/L (Brown and Caldwell, 1986). The OWS effluent may also have contained minor amounts of residual solvents; however, volatile compounds are not expected to have remained in the wastewater once it was released to Bat Cave Wash. Wear metals such as copper, lead, nickel, and zinc could also have been contained in the oily water treated in the OWS.

In 1985 and 1986, samples were collected from facility makeup water, cooling tower blowdown, treated wastewater (including both cooling tower blowdown and oily water), sludge samples from the precipitation tank, and water and solids samples from the evaporation ponds (Brown and Caldwell, 1985a-b, 1986). The samples were analyzed for polychlorinated biphenyls (PCBs), volatile organic compounds (VOCs), and metals, including mercury. Based on these data, metals of concern consist of Cr(T), Cr(VI), copper, lead, nickel, and zinc.

Several storm drains apparently discharge from the station to Bat Cave Wash. The area drained by these storm drains is not known but would most likely include portions of the lower yard. Stormwater runoff from the lower yard historically could have contained TPH and polynuclear aromatic hydrocarbons (PAHs) associated with pipeline liquids and potentially waste oil sprayed on station roads for dust control. Finally, a former employee reported that a mercury spill at the meter building had entered a storm drain that discharges to Bat Cave Wash (Russell, 2006, personal communication). No information is available regarding the amount of mercury that entered the storm drain or whether the material entered Bat Cave Wash.

A plant employee reported that he was personally responsible for welding a cap onto an approximately 12-inch-diameter vertical pipe located in Bat Cave Wash. The pipe apparently looked like a regular well casing. The casing only extended a small amount above the ground, and the area where the pipe was located is now covered by an additional 18 to 24 inches of sediment. The pipe had been covered with a wooden cover and gravel, and there were no materials of any kind visible in the pipe (Russell, 2006 personal communication). This well casing may be one of the exploratory borings installed in 1950 to evaluate the potential water supply for the proposed Topock Compressor Station (PG&E, 1950).

Based on the foregoing, the COPCs for groundwater associated with SWMU 1/AOC 1 identified in Volume 1 of the RFI/RI consist of Cr(T), Cr(VI), copper, lead, nickel, zinc, electrical conductivity, pH, and TPH. Additional COPCs in groundwater have been monitored during the RFI/RI period and are discussed in this report. Constituents that merit designation as SWMU 1/AOC 1 COPCs to be carried forward in the RCRA/CERCLA process are identified at the end of the report. Soil is also a media for SWMU 1/AOC 1 and will be addressed in RFI/RI Volume 3. Electrical conductivity is a routinely measured water quality parameter that is representative of the concentrations of dominant ions (such as sodium and chloride) and total dissolved solids in groundwater.

2.2 SWMU 2—Inactive Injection Well (PGE-8)

Inactive injection well PGE-8 is located within the facility fenceline in the lower yard on the western side of the compressor station (Figure 2-1).

2.2.1 Description and History

Inactive injection well PGE-8 was installed in 1969 for underground injection of treated cooling tower blowdown, pursuant to California Regional Water Quality Control Board, Colorado River Region (Water Board) Order 69-25. The order required PG&E to cease percolation into Bat Cave Wash by January 1, 1970. PG&E requested an extension of 5 months to June 1, 1970 (PG&E, 1984). The original boring for the well extended to approximately 530 feet below ground surface (bgs) (Dames and Moore, 1969).[1] Unconsolidated sediments were encountered in the boring to a depth of about 175 feet bgs, and below 175 feet, the boring penetrated hard, fractured crystalline bedrock (Dames and Moore, 1969). The original well was cased with 6-inch-diameter solid steel casing to a depth of 405 feet bgs, with the remainder of the borehole in the fractured bedrock being left uncased. Yield tests on the well provided short-term flow rates ranging from 20 to 51 gallons per minute (gpm), and a long-term flow rate of about 26 gpm, with a calculated transmissivity of 10,000 gallons per day per foot (Dames and Moore, 1969). This is equivalent to a hydraulic conductivity of 3.8×10^{-3} centimeters per second using the open hole length of 125 feet (E&E, 2004).

Water quality data collected following completion of the well indicated that a distinct stratification was present at about 280 feet bgs (Dames and Moore, 1969). Above 280 feet bgs, brackish water was present with TDS values ranging from 3,500 to 8,900 ppm. Below 280 feet bgs, water was saline, with TDS values ranging from 11,000 to 14,000 ppm.

Following testing, 2-7/8-inch-diameter tubing was placed inside the well casing and was anchored to the bottom of the casing with a packer (Dames and Moore, 1969). The annulus between the casing and the tubing was to be filled with a non-corrosive fluid (diesel fuel was suggested, but it is unknown what, if any, fluid was actually used) (Dames and Moore,

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[1] The Dames and Moore report (1969) lists the total depth of the boring in various places at 530, 540, and 548 feet bgs. The electric log included in the report lists a driller's report of 530 feet but a logged depth of 525 feet bgs.

1969). The design allowed for the injection of wastewater into the lower section of the well through the tubing.

PGE-8 remained unused for approximately one year after it was completed. On or about April 1, 1970, fresh water was injected into the well for testing purposes. Injection of treated wastewater began on May 30, 1970 (Dames and Moore, 1970). Several days after wastewater was initially injected into the well, the pressure rose dramatically. Hydrochloric acid was initially injected into the well (50 gallons of 38 percent hydrochloric acid) in an attempt to unclog the well. Handwritten notes (PG&E, 1984) indicate that the purpose was to acidize the well in an attempt to clean the well and to alleviate high back pressure in the well. It was subsequently determined that the bottom 15 feet of the well had collapsed.

In June, 1970, the well was cleaned out and deepened to 562 feet bgs. A stainless-steel well screen and liner assembly was installed in the well and set at of 405 to 554 feet bgs (Dames and Moore, 1970). A high-pressure pump was also installed to increase injection pressure. In addition, PG&E installed diatomaceous earth filters to remove the small quantities of precipitate noted in the injection water. Well PGE-7 was also deepened at this time and was used as a monitoring well during active injection at well PGE-8.

Injection well PGE-8 was used for the injection of treated wastewater from May 1970 through August 1973. A former employee reported that the well would periodically clog, and he recalled at least one event where sulfuric acid was injected into the well in an effort to unclog it. The employee recalled 2,800 gallons of sulfuric acid being injected into the well (Russell, 2006, personal communication). Between August and December 1973, treated wastewater was discharged alternately on a 3-day cycle between the injection well and the first of four newly-constructed lined evaporation ponds (i.e., SWMU 10, Pond 1). In October 1973, the salinity of the water in the upper portion of the well began to increase notably (PG&E, 1984). In December 1973, all treated wastewater was permanently routed to the evaporation ponds. Since December 1973, PGE-8 has been completely inactive; it has only been used for routine groundwater sample collection.

PG&E estimated that during the injection period (June 1970 through December 1973), approximately 29.4 million gallons of treated wastewater were injected into this well (PG&E, 1987). Handwritten notes by an unknown author ca. 1984 indicated that 42 million gallons of wastewater had been injected into the well (PG&E, 1984). Approximately 95 percent of the wastewater generated at the facility was from cooling tower blowdown, and the remaining 5 percent consisted of effluent from an OWS and other facility maintenance operations (PG&E, 1993). Wastewater sent to PGE-8 for subsurface injection was treated and concentrations levels were generally reduced to below 1 ppm of chromium (Mittelhauser, 1986). Based on the reported treatment process, the chromium in the post-treatment water would have been Cr(III), and given the limited solubility of Cr(III) the concentrations were very likely much less than 1 ppm.

The total volume of blowdown discharged during any given day, month, or year is difficult to estimate because the volume discharged varied daily depending on load (i.e., how much gas was compressed), ambient temperature (hotter temperatures resulted in increased blowdown), and other operational factors. In addition, it appears that overall annual blowdown rates decreased over the years. The first recorded blowdown rate (1968) indicated an average of 48,500 gpd or roughly 17.7 million gallons per year. Currently, the station only produces about 6 million gallons per year (16,400 gpd). Handwritten notes from 1980 (PG&E, 1980) indicate the average blowdown rates ranged from approximately 8,000 gpd to approximately 17,600 gpd between 1975 and 1980.

2.2.2 Constituents of Potential Concern

PGE-8 was used for the subsurface injection of facility wastewater. Treated wastewater was injected directly into groundwater at depths exceeding 405 feet bgs; therefore, groundwater is considered the medium of concern at this SWMU. Soil is not a media of concern at SWMU 2.

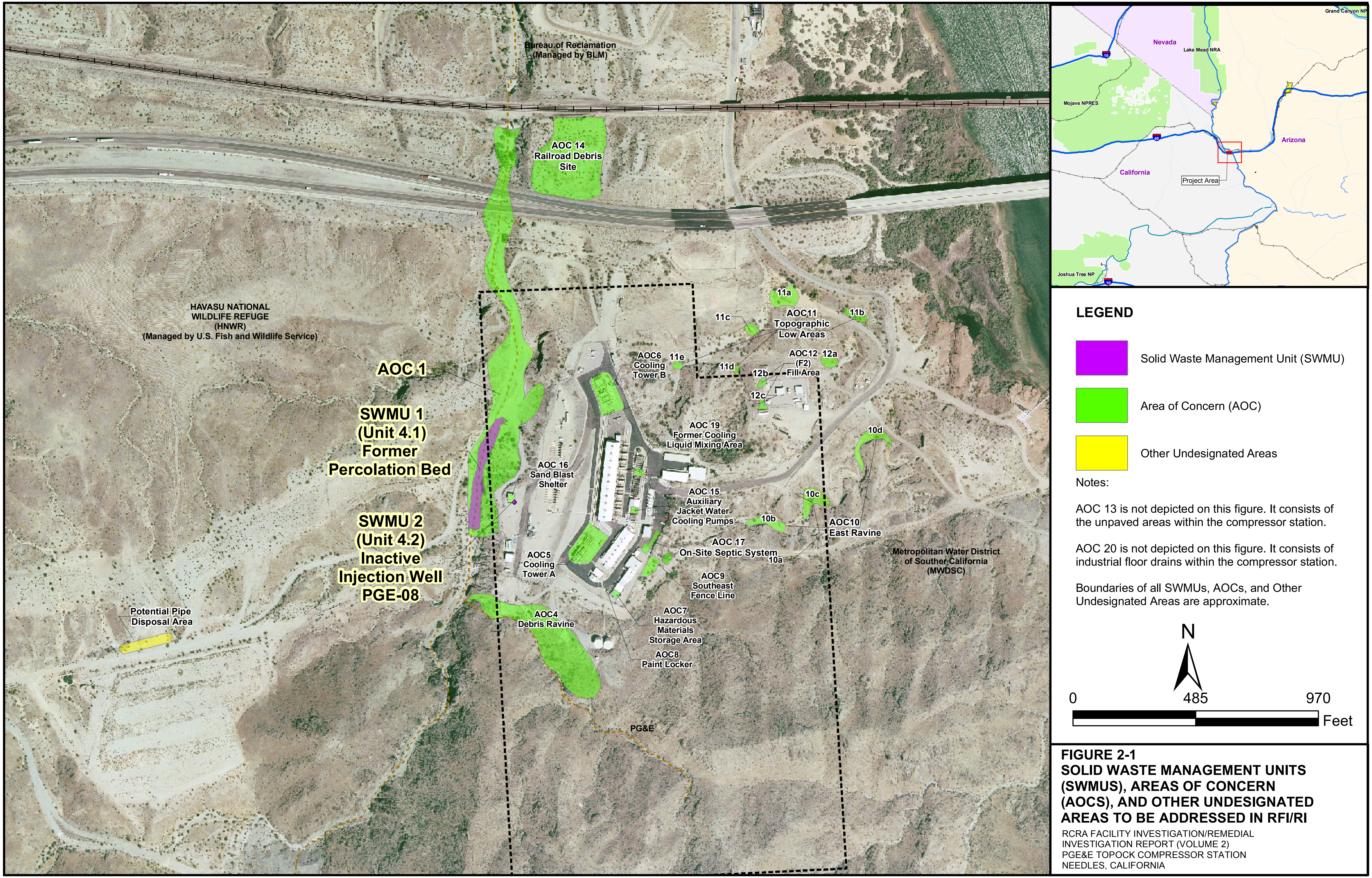
There were no significant modifications in the handling and treatment of the cooling tower blowdown and the OWS effluent during the operation of the injection well from 1970 to 1973. Therefore, based on a review of site history in Volume 1 of the RFI/RI, the COPCs for groundwater associated with SWMU 2 consist of Cr(T), Cr(VI), copper, lead, nickel, zinc, electrical conductivity, pH, and TPH. Additional COPCs in groundwater have been monitored during the RFI/RI period and are discussed in this report.

TABLE 2-1
Summary of Constituents of Potential Concern in SWMUs and AOCs
RCRA Facility Investigation/Remedial Investigation Report (Volume 2), PG&E Topock Compressor Station, Needles, California

SWMU/AOC	Constituents of Potential Concern in Groundwater
SWMU 1 – Former Percolation Bed	Cr(T), Cr(VI), Cu, Ni, Pb, Zn, pH, electrical conductivity, and TPH
SWMU 2 – Inactive Injection Well PGE–08	Cr(T), Cr(VI), Cu, Ni, Pb, Zn, pH, electrical conductivity, and TPH
AOC 1 – Area Around Percolation Bed	Cr(T), Cr(VI), Cu, Ni, Pb, Zn, pH, electrical conductivity, and TPH

Source: CH2M HILL, 2007a.

SWMU	Solid Waste Management Unit
AOC	Area of Concern
Cr(T)	Total Chromium
CR(VI)	Hexavalent Chromium
Cu	Copper
Ni	Nickel
Pb	Lead
TPH	Total Petroleum Hydrocarbons
Zn	Zinc



LEGEND

🟪	Solid Waste Management Unit (SWMU)
🟩	Area of Concern (AOC)
🟨	Other Undesignated Areas

Notes:

AOC 13 is not depicted on this figure. It consists of the unpaved areas within the compressor station.

AOC 20 is not depicted on this figure. It consists of industrial floor drains within the compressor station.

Boundaries of all SWMUs, AOCs, and Other Undesignated Areas are approximate.

FIGURE 2-1
SOLID WASTE MANAGEMENT UNITS (SWMUS), AREAS OF CONCERN (AOCS), AND OTHER UNDESIGNATED AREAS TO BE ADDRESSED IN RFI/RI

RCRA FACILITY INVESTIGATION/REMEDIAL
INVESTIGATION REPORT (VOLUME 2)
PGE&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

\\ZINFANDEL\PROJ\PACIFICGASELECTRICCO\TOPOCKPROGRAM\GIS\MAPFILES\2007\RFI\FIG2_1SOLIDWASTE.MXD FIG2_1SOLID WASTE 2/27/2008 14:35:37

3.0 Physical Characteristics and Hydrogeologic Setting

This section presents the physical characteristics and setting of the study area based on the completed RFI/RI investigations, previous technical reports prepared for the site, and published scientific literature. Surface features, meteorology, site geology and hydrostratigraphy, surface water hydrology, and hydrologic budget are discussed.

3.1 Surface Features and Topography

The study area is located in the southern portion of the Mohave Valley, along the California-Arizona border in eastern San Bernardino County, California. The study area is bounded by the Chemehuevi Mountains to the south and the Colorado River floodplain to the east and north. Figure 3-1 shows the regional features and setting of the Mohave Valley and surrounding region. The RFI/RI study area encompasses approximately 3 square miles of the north-sloping piedmont alluvial terrace and floodplain along the northern margin of the Chemehuevi Mountains. Figure 3-2 is an aerial photograph (dated May 2005) showing the location of the project site and surface features, including the floodplain and surface vegetation in the study area.

Topography in the study area is abrupt, rising from around 450 feet above mean sea level (msl) along the Colorado River to over 1,200 feet msl within 1 mile to the south and southwest. The Chemehuevi Mountains and drainage area to the south exceed 2,000 feet msl in elevation. As shown in Figure 3-3, the surface topography is characterized by moderate to deeply-dissected alluvial terraces, with elevations ranging from 650 to 500 feet msl, extending northward to the Colorado River floodplain. The Colorado River flows along the eastern and northern boundary of the site at an approximate elevation of 455 feet msl.

The land forms in the area are characterized by alluvial terraces and incised drainage channels. One of the largest incised channels is Bat Cave Wash, a north-south dry wash (ephemeral) stream adjacent to the Topock Compressor Station. Bat Cave Wash flows on the surface only briefly following intense rainfall events and drains to the Colorado River (Figure 3-3). The compressor station is located south of Interstate 40 (I-40) on a prominent alluvial terrace at an elevation of 600 to 625 feet msl.

Locally, a floodplain borders both sides of the Colorado River, though the river no longer floods due to upstream dams and flow regulation. Topography on the floodplain is subtle, with elevations typically less than 40 feet above the river elevation. The width of the floodplain adjacent to the site averages 500 feet and narrows to the south of the site as the river enters the Topock Gorge, where the shoreline becomes consolidated Miocene and pre-Tertiary-aged bedrock.

Vegetation is very sparse except in portions of the river floodplain where dense stands of tamarisk and occasional mesquite trees and other native plants occur (see Volume 1, Section 2.8 for site ecology).

3.2 Meteorology

The climate is typical of low desert areas along the Colorado River, with hot summer and mild winter seasons. The nearest weather station is 6.3 miles upriver in the HNWR and is operated by the BLM. The closest National Weather Service station is at the Needles airport, approximately 7.5 miles northwest of the compressor station.

The average daily average maximum temperature ranges from 63.8 degrees Fahrenheit (°F) in January to 108.6°F in July. The average daily maximum temperature exceeds 100°F during June, July, August, and September (NOAA, 2000), and rarely does the temperature drop below freezing.

Based on the 30-year period of 1961 through 1990, average precipitation was 4.67 inches per year in Needles. Between 1950 and 1965, the maximum annual rainfall was 9.5 inches. Rain occurs primarily during summer thunderstorms from July through early September and during the winter rainy season from December through March. May and June are typically the driest months. Figure 3-4 provides a graph of monthly precipitation and average monthly daytime highs and lows for the Needles meteorological station.

As summarized in *Current Conditions Report* (Alisto, 1997a), the predominant wind direction is south-southwest, with an average speed of 8.8 miles per hour, based on data from the Needles airport. The second most predominant wind direction is north-northwest, with an average speed of 10.7 miles per hour. Wind direction and speed are more variable at the compressor station site due to the extreme topography and proximity to the river channel.

3.3 Geologic and Hydrologic Setting

The regional geologic and hydrologic setting of the study area is presented in this section. The geology and geologic structure in the study area are summarized first, followed by a discussion of the regional groundwater basin and hydrologic setting. Site hydrogeology, hydrostratigraphy, and aquifer description are discussed in Section 3.4.

3.3.1 Regional Geology

The Topock site and study area are in the Basin and Range geomorphic province, characterized by roughly parallel north/south fault-block mountains, separated by alluvial valleys. A significant geologic feature in the vicinity of the site is the Chemehuevi Mountains, one of several metamorphic and plutonic basement core complexes exposed in southeastern California and western Arizona (Miller et al., 1983; Miller and John, 1999). The compressor station and the study area lie upon the north-sloping piedmont terrace along the northern margin of the Chemehuevi Mountains.

Figure 3-5 presents a generalized geologic map of the Topock site and surrounding areas. The geologic features shown in Figure 3-5 include the principal geologic units, geologic contacts, and geologic faults mapped in the study area, compiled from the following sources: Metzger and Loeltz (1973), John (1987a-b), Howard et al. (1997). The oldest rocks in the Topock area are exposed in the Chemehuevi Mountains and include Precambrian and Mesozoic-age metamorphic and igneous rocks, primarily metadiorite, gneiss, and granite (pTbr unit on Figure 3-5). Miocene-age sedimentary and volcanic rocks associated with the tectonic uplift and faulting in the region were deposited on the metamorphic and plutonic bedrock complex (John, 1987a-b; Miller and John, 1999). Distinctive, reddish-brown, cemented conglomerate of Miocene age (Tmc unit on Figure 3-5) is exposed in the study area.

Across most of the site, the bedrock basement formations (metamorphic/igneous rocks and consolidated Miocene Conglomerate) are overlain by younger sedimentary deposits. As shown on Figure 3-5, the near-surface geologic units in the study area include Tertiary and Quaternary to Recent-age alluvial fan deposits (Toa and Qa units), Pliocene lacustrine deposits (Tb unit), and Tertiary and Quaternary to Recent-age fluvial deposits of the Colorado River (QTrg and Qrf units). Howard and Malmon (2007) describe the stratigraphy and depositional features of the younger sedimentary and Colorado River deposits that are exposed in the southern Mohave Valley, including specific outcrops within the study area.

3.3.2 Geologic Structure

The most prominent geologic structural feature in the study area is a Miocene-age, low-angle normal fault (referred to as a detachment fault) that forms the northern boundary of the Chemehuevi Mountains (Figure 3-5). The Chemehuevi detachment fault is part of a series of low-angle detachment faults exposed within and surrounding the Chemehuevi Mountains that separate lower-plate Precambrian and Mesozoic-age metamorphic and plutonic rocks from overlying upper-plate pre-Tertiary metamorphic/plutonic, and Miocene volcanic and sedimentary rocks (John, 1987a-b; Howard et al., 1997). The detachment faulting is related to the formation of a series of northeast-trending antiformal bedrock arches bounded by synformal troughs that resulted from crustal extension that occurred in Miocene time, approximately 23 to 15 million years ago (Howard et al., 1997). Based on the published geologic mapping, the Chemehuevi detachment fault in the site area is inferred to be a low-angle (15 to 20 degree) northeast-dipping normal fault that has displaced pre-Tertiary metamorphic bedrock and Miocene sedimentary rocks (upper plate) across underlying, lower-plate crystalline bedrock in a northeast direction (John 1987a-b).

The surface expression of the Chemehuevi detachment fault is evident as the pronounced northeast-southwest lineament that can be traced along the northern boundary of the Chemehuevi Mountains, terminating at the abrupt bend in the Colorado River east of the compressor station (Figure 3-5). The surface trace of the Chemehuevi detachment fault is mapped in western Mohave County, Arizona (John, 1987b; Howard et al., 1997), approximately 2 miles southeast of the Topock site, indicating this regional fault extends eastward across the Colorado River. The surface trace of the detachment fault is partially concealed by younger alluvial deposits in the southwestern portion of the study area.

A major unconformity separates the bedrock formations from the overlying unconsolidated alluvial/fluvial deposits (Metzger and Loeltz, 1973). As noted above, faulting and deformation is confined to the metamorphic and plutonic bedrock complex and the consolidated Miocene conglomerate. In the area east of the compressor station, the thick-bedded Miocene Conglomerate (a geologic unit designation informally defined for this report) has structural dip up to 40° to the northeast beneath the unconformity. Overlying alluvial deposits comprising the piedmont terraces are undeformed and have gentle structural dip of approximately 5° to 10° to the north.

The structure of the bedrock in the study area has been further modified by past period(s) of channel-cutting and erosion by the ancestral Colorado River. Based on the results of a 2004 seismic survey conducted on the Colorado River at the Topock site, a pronounced paleochannel cut into the Miocene bedrock formations exists under the present channel of the Colorado River in the area northeast and east of the PG&E Topock Compressor Station (USGS, 2005). The survey data indicate a local bedrock rise, or saddle, in the area beneath the railroad and I-40 bridges. Farther south of the site, where the pre-Tertiary bedrock outcrops, the Colorado River is confined to a relatively narrow channel cut into bedrock at Topock Gorge. The structure of the bedrock surface is further discussed in Section 5.1.3.

Reconnaissance geologic and geotechnical studies were conducted by PG&E at the Topock site in 1986 for siting the new Class II evaporation ponds for the compressor station (Alisto, 1997a; Alpha Geotechnical, 1986a). These investigations included surface geologic and photolineament mapping (Alpha Geotechnical, 1986b), and a seismic refraction survey in the area of the former evaporation ponds and Bat Cave Wash (Louke, 1986). The geologic data and results of these investigations are summarized in PG&E (1995) and Alisto (1997a). Appendix B5 of this report includes the regional fault and photolineament map from the pond siting report (Alpha Geotechnical, 1986a). This study concluded that the most prominent regional structural lineament is the surface trace of the Chemehuevi detachment fault exposed immediately south of the compressor station (Figure 3-5). Several minor north-trending lineaments are evident in the upland alluvial terraces as defined primarily by drainage and erosional gullies (Appendix B5). None of the surface lineaments mapped by Alpha Geotechnical was found by field inspection to be attributable to Quaternary or Recent faulting. This study concluded that Bat Cave Wash and the minor surface drainage lineaments most likely reflect the older underlying structural features (e.g., local jointing and shear zones) within the bedrock (Alisto, 1997a; Alpha Geotechnical, 1986a).

In the regional area, several Quaternary-aged fault features exist and have been described in USGS 2005 and other published reports. These include the Needles graben (a normal-fault feature), located approximately 8 miles northeast of the Topock site (Figure 3-5), and the Chemeheuvi graben, located approximately 12 to 15 miles south of the Topock site (see Appendix B5). USGS (Howard et al., 1997) has described and mapped a Quaternary-age normal fault near the El Paso Natural gas metering station (Figure 3-5).

3.3.3 Regional Groundwater Basin and Hydrologic Setting

Figure 3-6 shows the groundwater basins and regional groundwater flow directions in the study area. Following the nomenclature of Anderson and Freethy (1992), the study area is within the Mohave groundwater basin, which is bisected by the Colorado River. The Sacramento Valley groundwater basin lies to the east, in Arizona. Sacramento Wash is the principal surface drainage in the Sacramento Valley basin and enters the Colorado River at Topock, Arizona. As described by Metzger and Loeltz (1973) and other groundwater resource reports (Anderson et al., 1992; Anderson and Freethy, 1992), groundwater in the Mohave Basin occurs in the Tertiary and younger alluvial basin deposits, which include the productive Pleistocene to recent fluvial deposits associated with the Colorado River. Based on hydrogeologic investigations and published reports, bedrock water-bearing zones locally occur where bedrock formations are weathered or fractured. No areas or locations have been identified in the Mohave groundwater basin where saturated bedrock formations are capable of significant storage, or sustained production or yield (Wilson and Owen-Joyce, 1994).

The groundwater system in the study area has been described using the concept of the "river aquifer" (Wilson and Owen-Joyce, 1994; Guay et al., 2006). The river aquifer consists of permeable and partly-saturated sediments and sedimentary rocks that are hydraulically connected to the Colorado River so that water can move between the river and the aquifer in response to withdrawal of water from the aquifer or differences in water-level elevations between the river and the aquifer (Wilson and Owen-Joyce, 1994). The subsurface boundaries of the river aquifer are the nearly impermeable bedrock that forms the bottom and sides of the basins that underlie the Colorado River valley. Discussion of the groundwater features of the site study area, including recharge and discharge components, is presented in Section 3.6.

A review of the available RFI/RI and pre-RFI/RI site data and published geologic literature on bedrock formations in the southern Mohave groundwater basin area was presented in *Information Review of Groundwater Conditions in Bedrock Formations at PG&E's Topock Compressor Station* (CH2M HILL, 2006a). This data report concluded that, on the regional and site scales, upward hydraulic gradients exist between the bedrock and alluvial basin fill. Groundwater flowing southward down the basin would be forced upward as the bedrock becomes shallower, which is the hydrologic condition at the Topock site (Chemeheuvi Mountains and Topock Gorge, shown in Figure 3-6).

3.4 Site Hydrogeology and Hydrostratigraphy

Groundwater occurs under unconfined to semi-confined conditions within the alluvial fan and fluvial sediments beneath most of the Topock site. The saturated portion of the alluvial fan and fluvial sediments are collectively referred as the Alluvial Aquifer. In the floodplain area adjacent to the Colorado River, the fluvial deposits interfinger with, and are hydraulically connected to, the alluvial fan deposits. The unconsolidated alluvial and fluvial deposits are underlain by the Miocene Conglomerate and pre-Tertiary metamorphic and igneous bedrock with very low permeability; therefore, groundwater movement occurs primarily in the overlying unconsolidated deposits.

The Alluvial Aquifer is heterogeneous in terms of sediment types and hydraulic properties, as is typical of alluvial aquifer systems in arid regions. The stratigraphic units that are saturated in study area are termed hydrostratigraphic units (HSUs) and are highlighted in Table 3-1 and include both alluvial fan and fluvial deposits. It should be noted, however, that the definition and subdivision of the HSUs do not correspond to any aquitards dividing the aquifer. The Alluvial Aquifer at the Topock site is considered to be a hydraulically undivided single aquifer.

3.4.1 Site Hydrostratigraphy

The geology and stratigraphic units encountered in the study area are shown in map view in Figure 3-5. Table 3-1 summarizes the individual HSUs (both alluvial fan and fluvial deposits) that comprise the Alluvial Aquifer. The alluvial fan HSUs consist primarily of clayey/silty sand and clayey gravel deposits (typically 20 to 40 percent clay and silt content) interbedded with more porous and permeable sand and gravel deposits. Low-permeability clay layers that could serve as an aquitard within the Alluvial Aquifer have been identified in a few of the wells completed in the study area, but the clay layers appear to be localized and not laterally extensive.

The fluvial HSUs (Table 3-1) in the floodplain area similarly consist of interbedded sand, sandy gravel, and silt/clay sediment. However, as described above, several of the shallow, younger fluvial units include unconsolidated, permeable, poorly-graded floodplain sand and dredged sediment. Well-graded, permeable river gravel deposits are also locally present in the floodplain area. As noted in Table 3-1, three of the site stratigraphic units—Younger Alluvium, Older River Gravels, and Bouse Formation—occur above the water table in the study area and, hence, are not part of the saturated Alluvial Aquifer.

The interpretation of the stratigraphy for the study area is based on the published geologic maps and reports (primarily Metzger and Loeltz, 1973; Howard et al., 1997; John, 1987a-b; Wilson and Owen-Joyce, 1994) and the hydrogeologic investigations conducted at the Topock site (E&E, 2004; PG&E, 1993, 1995; CH2M HILL 2005a; 2006a-b). For the RFI/RI hydrogeologic investigations, the stratigraphic terminology used in published reports has been modified to reflect the stratigraphic units observed in the drilling investigations. The terminology is considered informal stratigraphic unit naming, intended solely for this RFI/RI.

Figure 3-7 presents a schematic stratigraphic section illustrating the geologic sequence of the bedrock formations and alluvial and fluvial deposits in the study area. The primary geologic formations and hydrostratigraphic units defined at the Topock site and study area are described below and are summarized in Table 3-1. Figures 3-8a and 3-8b provide photographs of the surface features and geologic units exposed in the vicinity of the compressor station.

3.4.1.1 Bedrock Units

The consolidated bedrock that underlies the Alluvial Aquifer consists of pre-Tertiary metamorphic and igneous rock (primarily grayish metadiorite, gneiss, and granitic rocks) and the Miocene Conglomerate. The Miocene Conglomerate (informal geologic name for this study area) is typically a massively-bedded, brick-red to brown, cemented conglomerate and gravelly sandstone, characterized by poorly-sorted angular rock fragments derived from the local metamorphic and igneous bedrock exposed in the Chemehuevi Mountains. In the regional area, the Miocene Conglomerate formation includes megabreccia deposits (John, 1987b; Howard et al., 1997; Miller and John, 1999).

3.4.1.2 Tertiary Alluvium Units

Tertiary Alluvium refers to the oldest, undeformed alluvial deposits that overlie the Miocene Conglomerate and older bedrock formations in the study area. These alluvial fan deposits, termed “Tertiary Fanglomerate” by Metzger and Loeltz (1973), are composed primarily of moderately-consolidated sandy gravel and silty/clayey gravel. In surface outcrops west of the compressor station, the Tertiary Alluvium is exposed as deeply-dissected alluvial terraces with steep canyon walls (Figure 3-8b). Based on hydrogeologic characteristics observed in the drilling investigations, the Tertiary Alluvium sequence is subdivided into three stratigraphic units: a Basal Alluvium depositional unit (previously referred to as either "Basal Saline unit" or "reworked Miocene Conglomerate"), and overlying lower and upper Tertiary Alluvium units (Table 3-1). A lower (Toa1) and upper (Toa2) unit have been identified through the interpretation of spinner velocity logs and geophysical logs. The Toa1 and Toa2 subdivision is based on hydraulic permeability contrasts observed in well testing and variations in geophysical log responses.

The Basal Alluvium depositional unit (Toa) has been defined in the site drilling locations based on sediment characteristics (grain sorting and angularity), color, and weathering. Geophysical induction logs generally indicate much higher salinity in the Basal Alluvium unit, and boring logs note the presence of more reddish material that is often (though not always) finer-grained than most of the overlying Tertiary Alluvium deposits.

The stratification and depositional features of the alluvial fan deposits of the Tertiary Alluvium HSU are evident in the alluvial terrace/wash slopes at the site (Figure 3-8b). Based on surface geologic mapping (Alpha Geotechnical, 1986a) and published reports (Metzger and Loeltz, 1973), the Tertiary Alluvium was derived from the Chemehuevi Mountains and deposited as a series of coalescing alluvial fans in a north-northeast direction across the study area. Given this depositional setting, the axes of the fan channels in the alluvial sequence are inferred to be generally oriented in a north-northeast direction.

3.4.1.3 Bouse Formation

The Bouse Formation, which consists of interbedded clay, claystone, and sandstone, is exposed in dissected alluvial terraces and local outcrops in the western portion of the study area (Figure 3-5). Where present, the Bouse unit separates the Tertiary Alluvium from younger (Quaternary age) alluvial deposits (Figure 3-7). The Bouse represents a lacustrine (lakebed) deposit left by a large Pliocene lake that covered a large portion of Mohave Valley (Metzger and Loeltz, 1973; Howard et al., 1997; Howard and Malmon, 2007). Most of the Bouse was eroded away by the Colorado River during Pleistocene and Holocene time. The Bouse Formation is preserved in outcrops on the western and eastern flanks of the historical river floodplain. The Bouse formation is present in outcrop and in the subsurface drilling locations in the western portion of the study area but has not been encountered in any of the site borings in the central and eastern portions of the study area.

3.4.1.4 Quaternary Alluvium Units

Older Quaternary (Pleistocene-age) Alluvium, consisting of unconsolidated, sandy gravel and silty/clayey gravel, is exposed in the moderately-dissected alluvial terraces in the study area. The Older Quaternary Alluvium overlies either the Bouse Formation (where preserved in the western area) or the Tertiary Alluvium (where the Bouse was removed by erosion). In outcrop, Quaternary Alluvium is distinguished from older Tertiary Alluvium by alluvial terrace/wash slopes with moderate angle (i.e., 45-degree slopes).

Younger Alluvium includes unconsolidated, sandy gravel, and silty/clayey gravel alluvial deposits of Holocene and Recent age. This stratigraphic unit includes the youngest alluvial deposits (alluvium in streams and washes, recent alluvial/talus deposits, and windblown sand).

3.4.1.5 Fluvial (River) Deposits

Fluvial deposits of the Colorado River are present in surface outcrop and in the subsurface underlying the present Colorado River floodplain and channel. Based on geologic mapping and published reports (Metzger and Loeltz, 1973; Howard et al., 1997; Howard and Malmon, 2007), the Colorado River fluvial deposits within the study area are grouped into an older sequence (assumed Pleistocene-age) and a younger sequence (Holocene to Recent age). The relative age and informal stratigraphic unit descriptions of the fluvial deposits defined for this RFI/RI are shown in Figure 3-7 and Table 3-1.

Older fluvial sediments and river gravel, designated as units Qrs and Qrg in Table 3-1, are exposed only in surface outcrops (above the water table) at the Topock site. The Older River Gravels include sandy, pebble-cobble gravel containing well-rounded clasts of rock types from distant and local sources and reflects fluvial deposits of the early (Pleistocene-age) Colorado River (Figure 3-8b). Fine-grained sand and silt/clay fluvial deposits (Qrs unit) also occur in surface outcrop remnants on alluvial terraces within the study area (above the water table).

The younger Colorado River fluvial deposits occur within the saturated zone underlying the floodplain and the present Colorado River channel and Topock Marsh area. For the RFI/RI hydrogeologic characterization, the younger fluvial deposits have been subdivided into four depositional units (Qr0, Qr1, Qr2, and Qr3, as depicted on Figure 3-7). The available drilling information indicates that the sediments in the younger fluvial sequence include sandy gravel, gravelly sand, well-sorted fine sand, and silt/clay deposits, which vary in thickness and distribution in the floodplain area. Colorado River deposits dominate the subsurface from the floodplain near the MW-20 bench eastward to the far edge the Topock Marsh. Thickness ranges from near zero to approximately 250 feet. The maximum thickness has been observed in the river seismic survey conducted by the USGS (USGS, 2005). The many borings and geophysical logs in the Topock floodplain have provided a detailed picture of the variable thickness and grain size of the deposits. Four fluvial HSUs were assigned: Qr0, Qr1, Qr2, and Qr3 from oldest to youngest (see Table 3-1). The Qr0 represents the channel-fill fluvial sediments that occur below the approximate elevation of 360 feet msl.

Older fluvial sediments, designated as Qrg and Qrs in Table 3-1, are exposed in surface outcrops at the Topock site. These deposits (assumed Pleistocene-age) occur solely above the water table. Similarly, the dredged sand on the floodplain and surficial alluvial deposits (grouped as Younger Alluvium in Table 3-1 and Figure 3-7), occur above the average water table at the site.

3.4.2 Hydrogeologic Setting of the Alluvial Aquifer

Figure 3-9 presents a schematic cross-section to illustrate the regional hydrogeologic setting at the site. In the floodplain area, the fluvial deposits interfinger with, and are hydraulically connected to, the alluvial fan deposits. The unconsolidated alluvial and fluvial deposits are underlain by the Miocene conglomerate and pre-Tertiary metamorphic and igneous bedrock. Because the Miocene Conglomerate and crystalline bedrock have very low permeability, groundwater movement occurs primarily in the overlying unconsolidated deposits.

As shown on Figure 3-9, the water table in the Alluvial Aquifer is very flat throughout the study area and typically equilibrates to an elevation within 2 to 3 feet of the river level. Due to the variable topography at the site, the depth to groundwater ranges from as shallow as 5 feet bgs in floodplain wells next to the river to approximately 170 feet bgs at the upland alluvial terrace areas. The saturated thickness of the Alluvial Aquifer is about 100 feet in the floodplain and thins to the south, pinching out along the Miocene Conglomerate and bedrock outcrops (Figure 3-9). In the western portions of the study area, where the depth to bedrock increases, the saturated Alluvial Aquifer is over 200 feet thick.

Presentation of the site hydrogeology data, including hydrogeologic cross-sections and maps of bedrock structure and detailed hydrostratigraphy, are presented in Section 5.1. Discussion of the hydraulic properties of the site hydrostratigraphic units is included in Section 5.1.

3.5 Surface Water Hydrology

The primary surface water feature at the site is the Colorado River and its adjacent wetlands and marshes. Figure 3-6 shows the hydrologic setting of the Colorado River and major drainages and surface water features in the regional study area. More detailed illustration of the surface water features at the project site are shown in Figure 3-2 and Figure 3-3. The primary surface water features include the Park Moabi inlet/slough, ephemeral dry wash drainages, and the river floodplain and sand dune shoreline features in the study area. The two largest dry wash drainages in the study area are Bat Cave Wash and an unnamed surface drainage extending southwest of Park Moabi (Figure 3-2).

The general features and the river level and flow characteristics of the Colorado River in the site area are summarized below. The surface water quality characteristics of the Colorado River in the site area are discussed in Section 5.3.

3.5.1 Colorado River Features

The primary surface water feature at the Topock site is the Colorado River and its adjacent wetlands and marshes. The river system upstream of Topock, Arizona is characterized by the wide Mohave Valley floodplain, marsh, and alluvial valley (Figure 3-6). Downstream of Topock, the river enters the Topock Gorge, traversing the exposed bedrock of the Chemehuevi Mountains of California and the northern portion of the Mohave Mountains in Arizona. The river channel narrows in the area of the Topock Gorge (Figure 3-6). Sacramento Wash is the principal dry wash surface drainage to the Colorado River from the Sacramento basin in Mohave County, Arizona (Gillespie and Bentley, 1971; Rascona, 1991). Lake Havasu, formed in 1938 with the construction of Parker Dam, extends approximately 24 miles upstream from the city of Parker, Arizona. Parker Dam is approximately 42 river miles below the Topock site.

The Colorado River, Topock Marsh, floodplain and other surface features at the Topock site are shown on a 2005 aerial photograph (Figure 3-2). Two transportation bridges, one for Interstate Highway I-40 and the other for Burlington Northern and Santa Fe Railroads, cross the river at Topock, Arizona. The Colorado River channel ranges from approximately 600 to 700 feet wide in the area upstream of the bridge crossing at Topock. The river channel was typically less than 9 feet deep, with a maximum depth of 21 feet. The last major dredging in the Topock area occurred in the 1960s (Metzger and Loeltz, 1973). Refer to the historical aerial photographs of the study area presented in the RFI/RI Report, Volume 1, for the physical setting and historical features of the Colorado River at Topock.

The flow of the Colorado River is very dynamic, fluctuating seasonally and daily, largely due to upstream flow regulation. The flow of the Colorado River at the Topock site is primarily controlled by water releases at Davis Dam on Lake Mohave, approximately 41 miles upstream. River levels at the site typically fluctuate by 2 to 3 feet per day, and flows vary anywhere from 4,000 to 25,000 cubic feet per second (cfs) according to the dam releases, producing a sinusoidal hydrograph each day.

The Colorado River flows along the eastern and northern boundary of the site at an approximate average elevation of 455 feet msl. Locally, a floodplain borders both sides of the Colorado River, though the river no longer floods due to upstream dams and flow regulation. Topography on the floodplain is subtle, with elevations typically less than 40 feet above the river elevation. The width of the floodplain on the California shore adjacent to the site averages 500 feet and narrows to the south of the site as the river enters the Topock Gorge, where the shoreline becomes consolidated Miocene and pre-Tertiary-aged bedrock.

3.5.1.1 Historical Conditions and Man-made Effects on River Morphology

Significant changes to the Colorado River hydraulic regime occurred after construction of Hoover Dam, located 108 miles upstream of Topock, and Parker Dam, located 42 miles downstream of Topock. With the closure of Hoover Dam in 1936, annual spring floods and associated scouring events ended. With the closure of Parker Dam in 1938 and subsequent filling of Lake Havasu, the Colorado River channel in the vicinity of Topock to Needles rapidly aggraded (Metzger and Loeltz, 1973). By 1944, the aggradation of the river channel caused elevated groundwater levels and flooding in low-lying areas. In response to this condition, the BOR conducted dredging of the river channel to maintain channel geometry. According to Metzger and Loeltz (1973), the significant dredging and channel improvement work in Mohave Valley was completed by July 1960. As part of the channel improvements conducted by BOR, rip-rap embankments have been added to stabilize the shoreline on the Arizona side, immediately east and northeast of the Topock site. Davis Dam was completed in 1950, shortly before the first evidence of BOR dredging operations is visible in aerial photos of the Topock site.

Records on the dredging operations were not available regarding the specific locations and dates of the Colorado River dredging that occurred at the site. However, the historical aerial photographs for the study area (included in Section 3.3 of the 2007 Final RFI/RI Report, Volume 1, CH2M HILL, 2007a) provide information on the general timeframes and locations of dredging, as evidenced by the extensive sand dune areas present in the historical photographs on both the western and eastern shorelines of the Colorado River. Summarized below are selected historical aerial photographs that confirm the general time frames that dredging operations occurred at the site:

- September 1947—river and floodplain are natural; no evidence of dredge spoils (sand dunes) accumulated on shorelines.
- May 1953—sand dunes present on both sides of river channel, suggesting dredging has occurred.
- July 1962—the large, sand-dune-covered peninsula on the Arizona shoreline north of Topock is evident, and a dredge can be seen operating at the mouth of the side channel to Park Moabi. The western, California shoreline is well-defined, suggesting that channel improvements were complete at this time.
- October 1975—vegetation is established on sand dunes on both sides of the river, no "new" sand dunes areas are evident, and the general area of sand dunes is consistent with present site condition (see Figure 3-2).
- November 1997—the vegetation on the sand dunes on both sides of the river is well-established, and the channel morphology is very similar to 1975 conditions, indicating no additional dredging has occurred.

3.5.1.2 River Channel Morphology

The Colorado River channel is approximately 600 feet wide in the site area upstream of the I-40 bridge crossing at Topock (Figure 3-2). At the I-3 gas pipeline bridge, the river channel narrows and trends eastward. According to BOR, when profiled near the site in 1994, the river channel was typically less than 9 feet deep, with a maximum depth of 21 feet. In July 2005, a reconnaissance depth-sounding survey of the river channel was conducted to aid in siting sampling locations for PG&E's pore water and seepage study (discussed in Section 8.0). The river depths ranged from 3 to 12 feet on the two cross-river transects measured at and north of the I-40 bridge (CH2M HILL, 2005c). On the river transect measured at the I-3 bridge, the channel depths ranged from 5 feet near the Arizona shoreline to a maximum of 22 feet near the California shoreline.

3.5.1.3 Current River Levels and Flow

The flow and stage of the Colorado River are both very dynamic, fluctuating seasonally and daily, largely due to upstream flow regulation. The flow of the Colorado River at the Topock site is primarily controlled by water releases at Davis Dam on Lake Mohave, approximately 41 river miles upstream. River levels at the site typically fluctuate by 2 to 3 feet per day. Seasonal fluctuations are on the order of 5 feet, with higher water levels occurring in summer. Daily average flows typically range from 4,000 to 25,000 cfs, according to the dam releases, producing a sinusoidal hydrograph each day. The daily fluctuations in river level at Topock are primarily related to the daily changes in flow from Davis Dam in response to demand for electrical power. At normal river stage, the river stage changes at the Topock site are lagged approximately 11 hours behind changes in flow at Davis Dam.

Records on the historical and current Colorado River hydrology and flow are available from the USGS and the BOR. Metzger and Loeltz (1973) provide descriptions and data on historical stream flow and variations in river stage in the Topock and Needles area due to construction of dams on the lower Colorado River. Figure 3-10 presents graphs of historical river flow and river level data from the USGS gauging station in Topock Gorge, approximately 2 miles downstream from the site. The graphs illustrate the long-term (1930 through 1983) trend and annual/seasonal fluctuations in river stage and flow.

The seasonal fluctuations in river level at Topock are related to both the Davis Dam discharge and the level in Lake Havasu. The river level at the Topock site is affected by backwater from Lake Havasu. This is most apparent when the lake is at extreme high levels. PG&E has developed the following empirical equation that is used to predict future monthly average water levels at Topock:

$$\text{Monthly Average I-3 Level in ft msl} = 327.9531688 + (0.000349497 \times D) + (0.273863491 \times H)$$

Where:

D = Monthly Average Davis Dam Discharge in cfs.
H = Monthly Average Lake Havasu Level in ft msl.

If the BOR projections of future Davis Dam discharge and Lake Havasu level are accurate, this equation predicts future I-3 river level to within 0.5 feet or less. The equation is strictly empirical and was developed by fitting the Davis Dam release and Lake Havasu level data to the measured water level in the river at the I-3 gauging station maintained by PG&E. It is updated monthly as new discharge and lake level data are received from BOR.

Following the completion of Hoover Dam in 1936, the large spring floods were controlled. The completion of Parker Dam downstream from the site in 1938 marked the beginning of a period of rising river levels as Lake Havasu filled and the lower Mohave Valley aggraded. Average river levels at Topock rose by about 15 feet between 1938 and 1944 (Metzger and Loeltz, 1973). In 1944, the BOR began dredging the river channel to improve drainage and navigation. This resulted in a 5-foot drop in river stage between 1947 and 1952. Following this drop, river levels at Topock continued to rise slowly.

To illustrate the recent temporal variation in river level and flow, Figure 3-11 presents graphs of average monthly and average hourly river level measured the I-3 bridge gauge station and Davis Dam discharge flows for the Colorado River (2002 to 2004 monthly data and April 2004 hourly data). Dam releases are greatest in the late spring and early summer, producing higher river levels during this time (April through July). The portion of the aquifer adjacent to the river receives river water recharge during this time of year. Beginning in June, releases decrease, producing lower river levels and groundwater gradients trend towards the river, except at the site where IM-3 pumping maintains the landward gradient. The lowest river levels are typically from October through January. During 2006, the daily Davis Dam releases ranged from 18,300 cfs (April 2006) to 8,222 cfs (November 2006). The lag between the peak release at Davis Dam and the arrival of the pulse at the I-3 gauge near the Topock site is approximately 6 hours (Figure 3-11).

3.6 Hydrologic Budget

The main source of recharge to the Mohave Valley groundwater basin is from the Colorado River, which acts primarily as a losing stream throughout the northern and central areas of the valley (Anderson and Freethy, 1992). In the southern end of the Mohave Valley where the Topock site is located, the river is a gaining stream and, as such, represents a location of groundwater discharge in the basin. This is consistent with published hydrogeologic work in the region (Metzger and Loeltz, 1973), which utilized stable isotope data to show that waters in northern and central Mohave Valley had their source from the river, whereas southern groundwater was derived from local precipitation and runoff. Water levels in Topock Marsh are maintained slightly higher than the river at Topock by diverting river water at an upstream location near Needles and by controlling release from a downstream dike surrounding the marsh. The marsh is therefore an additional source of recharge to groundwater in the study area. Smaller sources of recharge in Mohave Valley include mountain-front recharge associated with precipitation in mountains bordering the basin, return flows from irrigated fields, and groundwater underflow from adjacent basins such as Sacramento Valley (Arizona). Groundwater discharge in Mohave Valley is primarily into the river in the southern portion of the valley. Evapotranspiration along the river floodplain and pumping for municipal, industrial, and agricultural use are other important components of groundwater discharge. The Topock numeric groundwater model incorporates water budget components of the southern end of Mohave Valley that are directly relevant to the Topock site area (CH2M HILL, 2005b). The model, described in more detail in Section 4.2.7, was designed primarily as a tool for development and evaluation of groundwater corrective measures at the site, and the cited version will be used in the CMS/FS. Quantitative estimates of recharge and discharge have been revised since the last model calibration on the basis of newly-acquired data (CH2M HILL, 2006c). The model domain and budget components are presented in Figure 3-12, and estimated groundwater flux for recharge and discharge components are listed in Table 3-2. A revised model has been constructed but not yet calibrated, and has been documented in previous reports (CH2M HILL, 2006b-d). This new model will be further developed and calibrated for the design phase of the CMS/FS if deemed necessary by the TWG and agencies.

3.6.1 Natural Recharge Sources

The two main sources of groundwater recharge in the southern end of Mohave Valley are recharge from Topock Marsh and groundwater flow from the north.

Topock Marsh was a natural wetland prior to construction of the Colorado River dams. It is presently maintained by diversion of a portion of river water near Needles into the marsh area. The HNWR maintains an average water elevation in the marsh of about 458.6 feet msl, and this produces an estimated recharge to groundwater of 6,960 acre-feet per year (afy) (Guay, 2001). Approximately one-half of Topock Marsh lies within the model domain (Figure 3-12), so it is anticipated that about 3,500 afy will be assigned as recharge. This is considered a very rough estimate of groundwater recharge, as it was calculated from several marsh water budget components, each with significant uncertainty (Guay, 2001). However, it is apparent that Topock Marsh is a major source of groundwater recharge in southern Mohave Valley. The recharge value will be refined during final model calibration. The majority of this recharge eventually discharges to the river.

The Mohave Valley aquifer is mainly filled by Colorado River water in the northern portion of the valley, where the river is a losing stream. This groundwater enters southern Mohave Valley flowing roughly parallel to the river. The amount of flux entering the model boundary will be calculated by assigning a constant head boundary at the model edge, and using calibrated hydraulic conductivity, aquifer thickness, and gradient.

A third source of recharge is underflow beneath Sacramento Wash from the east. This wash drains a substantial portion of southeastern Mohave Valley. There are no published estimates of groundwater flow beneath the wash, and the wash itself is not gauged. The current groundwater recharge estimate of 100 afy (USGS, 2005) is assigned into the model domain on Figure 3-12 from beneath Sacramento Wash.

Some precipitation recharge originates in the Chemehuevi Mountains and Sacramento Mountains to the south and southwest of the Topock site, respectively. Precipitation in the highest parts of these mountains is likely no more than 10 inches per year (Metzger and Loeltz, 1973). The metamorphic bedrock that makes up these mountains is assumed to possess very low fracture permeability. As a result, only a small fraction of rainfall provides recharge to the Alluvial Aquifer. Some of this recharge would be in the form of rainwater flowing downward into the mountain bedrock, traveling northward, and eventually flowing upwards into the overlying alluvium. Vertically-upward gradients between bedrock and alluvium in the MW-24 cluster suggest there may be some upwelling of water from bedrock into the Alluvial Aquifer. Also, some amount of mountain-front recharge is expected where surface runoff from the mountains recharges into alluvium along the upper margin of the pediment (Metzger and Loeltz, 1973). The amount of precipitation and mountain-front recharge will be estimated during model calibration. Stable isotope data in the region confirm that groundwater in the southern part of Mohave Valley originates from local recharge sources, rather than the Colorado River (Metzger and Loeltz, 1973).

A small amount of groundwater underflow (10 afy) is shown along the central-western and northeastern model boundaries in Figure 3-12 to account for underflow associated with several small drainages entering the model domain in this area. The assigned flux is based on regional model estimates by the USGS (2005).

3.6.2 Natural Discharge Sources

In the southern portion of Mohave Valley, the Alluvial Aquifer gradually decreases in thickness, forcing groundwater to discharge to the Colorado River during certain times of the year. Because the river levels are artificially maintained by operations of Davis and Havasu Dams, river levels fluctuate daily and seasonally. As a result, there is a net recharge to groundwater from the river during periods of rising river levels in the spring to summer. During the rest of the year, there may be portions of the day where river levels exceed nearby groundwater levels, but during the majority of the time, the groundwater levels are higher than the river. The amount of net groundwater discharge to the river within the model domain was calculated by difference between total recharge and the remaining discharge components. The vast majority of discharge to the river occurs upstream of the Topock Site, based on the last calibrated version of the model (CH2M HILL 2005b) due to the much thicker alluvial aquifer to the north and the progressive thinning in the southerly direction. Because the Topock Site is located at the downstream end of the Mohave Valley Basin, the alluvium is very thin and therefore cannot physically transmit as much groundwater as in areas to the north. Since IM pumping began in 2004, there is a net recharge to groundwater from the river in the site area, based on measured river levels and groundwater levels in the floodplain. Pre-IM discharge to the river was not assigned in the model, but rather calculated based on assigned boundary conditions and aquifer parameters.

Evapotranspiration losses are limited to the river floodplain areas where vegetation is more prominent and the water table is close to the ground surface. The model estimate of evapotranspiration assumes that evapotranspiration will only occur when the water table is within 10 feet of land surface and that significant rates only occur where aerial photos indicate dense vegetation. The estimate is made by assigning a maximum evapotranspiration rate at the water table surface and assuming the rate decreases linearly to zero at an assigned extinction depth below the water table.

The remaining natural discharge is underflow in fluvial materials directly beneath the river, where it flows into Topock Gorge. This flow leaves the model domain at the southern boundary. Because the aquifer is very narrow at this point, the estimated groundwater discharge is small.

3.6.3 Artificial Recharge/Discharge Components

3.6.3.1 Historical and Current Injection in Wells

Between May 1970 and August 1973, treated cooling tower blowdown water was injected into bedrock well PGE-8. It is estimated that between 29.4 million to 42 million gallons of wastewater were injected into PGE-8 while it was operational (PGE, 1984). Over the period of exclusive PGE-8 operation, this works out to an average continuous injection rate of 17 to 24 gpm. PGE-8 was used in tandem with the Old Evaporation Ponds until the end of 1973, when the well was removed from operation.

Operation of IM-3 involves pumping groundwater from wells on the MW-20 bench, treating the water to remove Cr(VI), and injection of the treated water back into the aquifer through injection wells. Injection at wells IW-2 and IW-3 began in August 2005. The injection rate was gradually increased over the first year of operation until the current rates were achieved and maintained. During 2007, the IM-3 pumping rate averaged about 132 gpm (213 afy). Approximately 125 gpm (or 202 afy) is reinjected to the aquifer through injection wells located east of the IM-3 Treatment Plant (shown in Figure 4-2). The remainder is wastewater from the IM-3 reverse osmosis system, which is trucked offsite to a remote disposal facility. Based on model simulations, most of the injected water travels radially outward from the injection wells, or with a portion migrating back to the IM-3 extraction wells. The net groundwater discharge associated with the IM-3 operations is the approximately 7 gpm (11 afy) of waste water generated by the reverse osmosis system.

3.6.3.2 Historical and Current Groundwater Extraction from Wells

The total of groundwater extraction (not including current IM extraction) in and around the model domain is approximately 640 afy. Available records indicate that groundwater extraction occurs within the model domain in two areas. One is the Topock 2A/Topock 3 well pair located about 1 mile northeast of the compressor station in Arizona. These wells supply the Topock station, and with several other private users in Arizona, with water. In 2004, combined pumping from the wells was about 80 afy. It is assumed that this rate has been maintained since the wells became the supply wells for the facility in 1960. The other pumping location is at Park Moabi to the northwest of the Topock Site. Available records indicate the supply well for this facility extracts approximately 6 afy. Extraction rates from the Sanders and Smith wells, privately owned wells across the river from the facility, were not available. The combined average pumping rate from these two wells is assumed to be about 2 afy, typical for domestic well use (Montana Department of Natural Resources and Conservation, 2008).

IM extraction over the past year has been approximately 132 gpm or 213 afy. This rate is expected to be maintained throughout the IM period until a final remedy is approved and put in place. In comparison with IM injection, presented above as 202 afy, there is a net IM removal of about 11 afy from the basin. This quantity is in the form of loss during treatment and reverse osmosis brine removal.

Other pumping centers are not within the model domain but are close enough to the boundaries to be included in the model. The largest of these is the Golden Shores, Arizona community in the northeast corner of the model. Golden Shores consists of two sections (2 square miles) joined at a common corner. Groundwater pumping occurs from various private wells in the community but mostly from four wells owned by the Golden Shores Water Company. The combined total pumping from these wells was about 450 afy in 2003. Although less than one-quarter of the Golden Shores area is contained within the model domain (Figure 3-12), this pumping rate was assigned to the northeast corner of the model domain.

Another pumping well, the Serrano Well, has been reported as pumping at 220 gpm (Kilgore, 2005, personal communication). The well is located off the eastern edge of the model boundary about halfway between the railroad right-of-way and Golden Shores. The well's average annual pumping is estimated to be 70 afy.

Two wells operated by El Paso Natural Gas Corporation at their Mohave Transfer Station, MTS-1 and MTS-2, are located off the eastern model boundary between I-40 and the railroad. These wells together pump about 30 afy.

3.6.4 Summary

The following general statements summarize PG&E's understanding on groundwater balance based on the most recently calibrated version of the model and the most up-to-date hydraulic data:

- The vast majority of recharge in the southern end of Mohave Valley is recharge from Topock Marsh (estimated at 2,700 afy), along with underflow of groundwater from the north (400 afy).
- Minor amounts of recharge come from groundwater underflow from Sacramento Wash (100 afy) and from smaller, unnamed washes on the east and west sides of the valley (combined 20 afy). Local precipitation in nearby mountains produces a modest amount of mountain front recharge (about 200 afy).
- Artificial recharge is associated with the IM-3 injection wells (202 afy).
- The majority of groundwater discharge in the Mohave Valley is directed to the Colorado River, with most discharge occurring upstream of the Topock Site.
- Minor discharge occurs as evapotranspiration in the floodplain, and also as underflow beneath the Colorado River in Topock Gorge.

- Artificial discharge takes the form of extraction from wells in the area (853 afy). These wells include the IM extraction wells and local water supply wells, from which the largest extractions are from the Golden Shores wells, Topock-2A and -3 wells, the Serrano well, and two wells operated by El Paso Natural Gas Company.

An updated version of the model will be further developed and calibrated for the design phase of the CMS/FS if deemed necessary by the Technical Work Group (TWG) and regulatory agencies.

TABLE 3-1
Site Hydrostratigraphic Units, June 2006 Update
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Stratigraphic Age	Site Hydrostratigraphic Units					
	Alluvial Deposits		**Characteristics**	**Fluvial Deposits**		**Characteristics**
Holocene	**Younger Alluvium**	**Qya**	unconsolidated sandy gravel & silty/clayey gravel (youngest alluvial deposits and surficial deposits, undifferentiated)	**Upper Fluvial Sand & Silt** (Floodplain Area)	**Qr3**	unconsolidated sand & silty sand (no gravel), massive-bedded, very well-sorted; contains fine-gr. organic matter
				Middle Fluvial Deposits (Floodplain Area)	**Qr2**	unconsolidated sand, clay & minor gravelly sand, interbedded; clay/silt lenses exhibit both brown and gray (reduced) appearance
				Lower Fluvial Deposits (Floodplain Area)	**Qr1**	unconsolidated sandy gravel & gravelly sand, minor silty gravel (gravel content >15%); subrounded to very well-rounded pebbles & cobbles from distant sources & fluvial transport
				Colorado River Channel Fill fluvial deposits in paleo-channel	**Qr0**	fluvial channel-fill sediments that occur below elevation 360' MSL (deepest river deposits encountered in floodplain borings). Per Caltrans I-40 bridge borings includes moderately consolidated to dense, fine to coarse sand & sandy gravel
Pleistocene	**Older Quaternary Alluvium**	**Qoa**	unconsolidated sandy gravel & silty/clayey gravel (alluvial fan deposits). Comprises moderately-dissected alluvial terraces; terrace/wash slopes are moderate-angle (i.e., 45 degrees)	**Older Fluvial Sediments** (surface outcrop)	**Qrs**	pinkish to tan, weakly to moderately consolidated fine sand, silt/clay, with minor pebble gravel; contains root casts (paleosol); outcrops occur as remnants on alluvial terraces as high as elevation 670' MSL (Old Ponds site)
				Older River Gravels (surface outcrop)	**Qrg**	moderately consolidated to cemented, sandy pebble to boulder gravel; subrounded to very well-rounded clasts from distant sources & fluvial transport (unit outcrops west of MW-20 bench)
Pliocene	**Bouse Formation**	**(Tb)**	pre-Colorado River lacustrine & deltaic deposits: well-bedded, moderately indurated, green clay, siliceous claystone, sandstone & basal marl			
Pliocene to Late Miocene	**Tertiary Alluvium - Upper**	**Toa2**	Moderately consolidated sandy gravel, gravelly sand & silty/clayey gravel (oldest alluvial fan deposits). Comprises deeply-dissected alluvial terraces; terrace canyon walls are vertical/steep	= Tertiary Fanglomerate of Metzger & Loeltz, 1973	Note: Toa1 and Toa2 are subdivisions based on contrasts in hydraulic permeability observed in the Tertiary Alluvium sequence in TW-1, TW-2D, and IW-2 well-flow spinner logs.	
	Tertiary Alluvium - Lower	**Toa1**				
Late Miocene	**Basal Alluvium**	**Toa0**	Moderately consolidated silty sand, clayey/silty gravel & minor gravelly sand. Consists of 100% reddish detritus of Miocene conglomerate unit (reworked Tmc deposits) in floodplain area. In other site areas, Toa0 is well-consolidated alluvium, lacks reddish color, and exhibits high-induction geophyiscal log response			
angular unconformity (post-extension erosion)						
Middle Miocene	**Miocene Conglomerate**	**Tmc**	consolidated conglomerate & sandstone containing rock fragments & megabreccia derived from Chemehuevi Mtns. bedrock			
unconformity & detachment faulting						
Pre-Tertiary	**Metamorphic / Igneous Bedrock**	**pTbr**	metadiorite, gneiss & granitic bedrock exposed in Chemehuevi Mountains & underlies the groundwater basin			

Notes:
1. Hydrostratigraphic units that comprise the Alluvial Aquifer in RFI/RI area are shaded yellow
2. Bedrock formations, grey shaded, are essentially impermeable but locally yield water where fractured
3. Within RFI/RI area, Younger Alluvium and Older Fluvial and River Deposits occur above the water table
4. Stratigraphic age assignments from published geologic reports and are generalized for units in study area

TABLE 3-2

Groundwater Budget Components for Model Domain

RCRA Facility Investigation/Remedial Investigation Report (Volume 2)

PG&E Topock Compressor Station

Recharge Components	**Approximate Flux (acre-ft/year)**	**Totals**
Topock Marsh Influx	2,700	
Underflow from North	400	
Underflow from Sacramento Wash	100	
Underflow from Washes to West	10	
Underflow from Washes to East (north of Sacramento Wash)	10	
Precipitation Recharge in South	200	**Total Recharge = 3,420**
Discharge Components		
Extraction from Wells	640	
Evapotranspiration	140	
Underflow to South	10	
Discharge to River	2,630	**Total Discharge = 3,420**

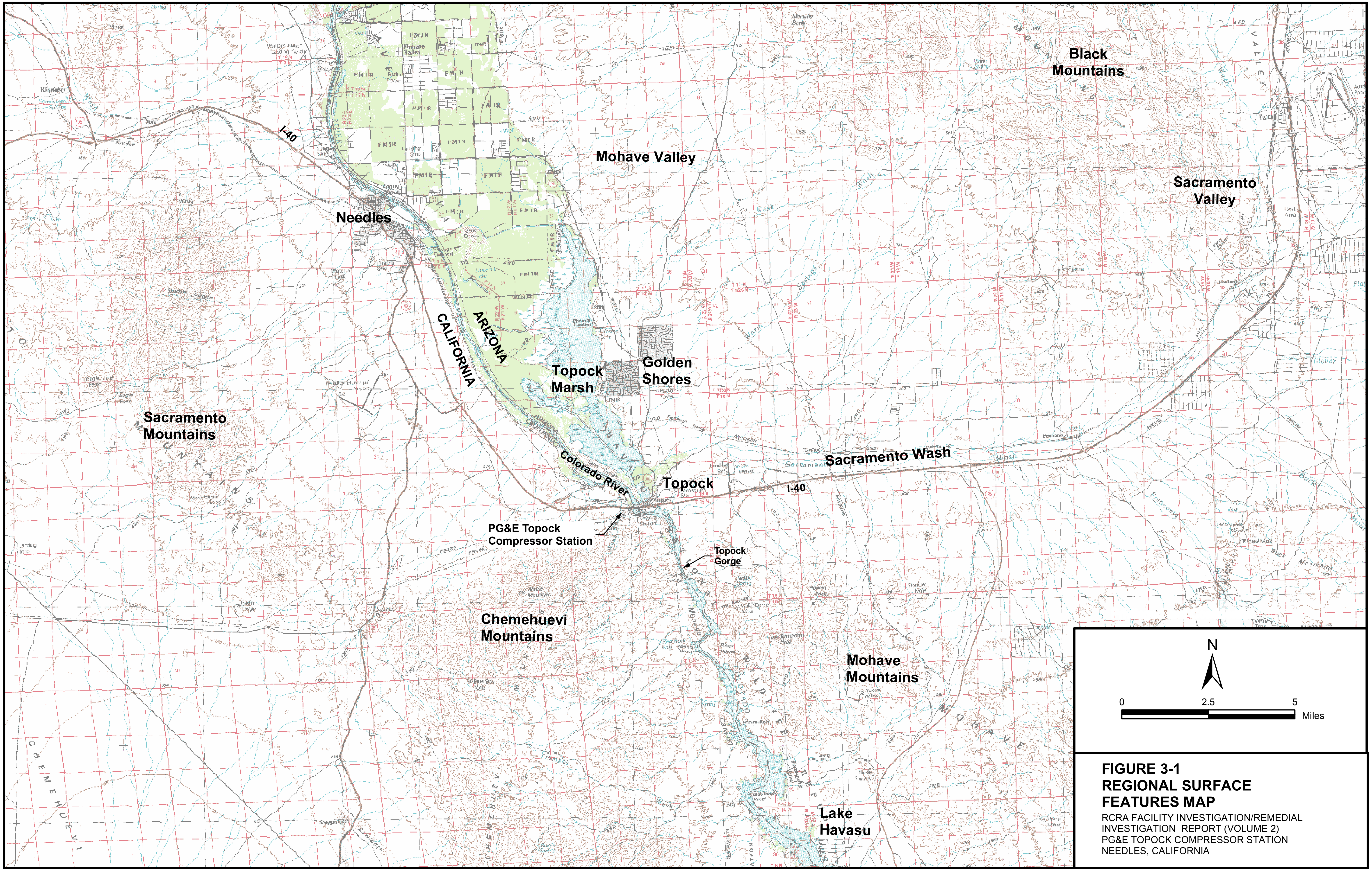


FIGURE 3-1
REGIONAL SURFACE FEATURES MAP

RCRA FACILITY INVESTIGATION/REMEDIAL INVESTIGATION REPORT (VOLUME 2)
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

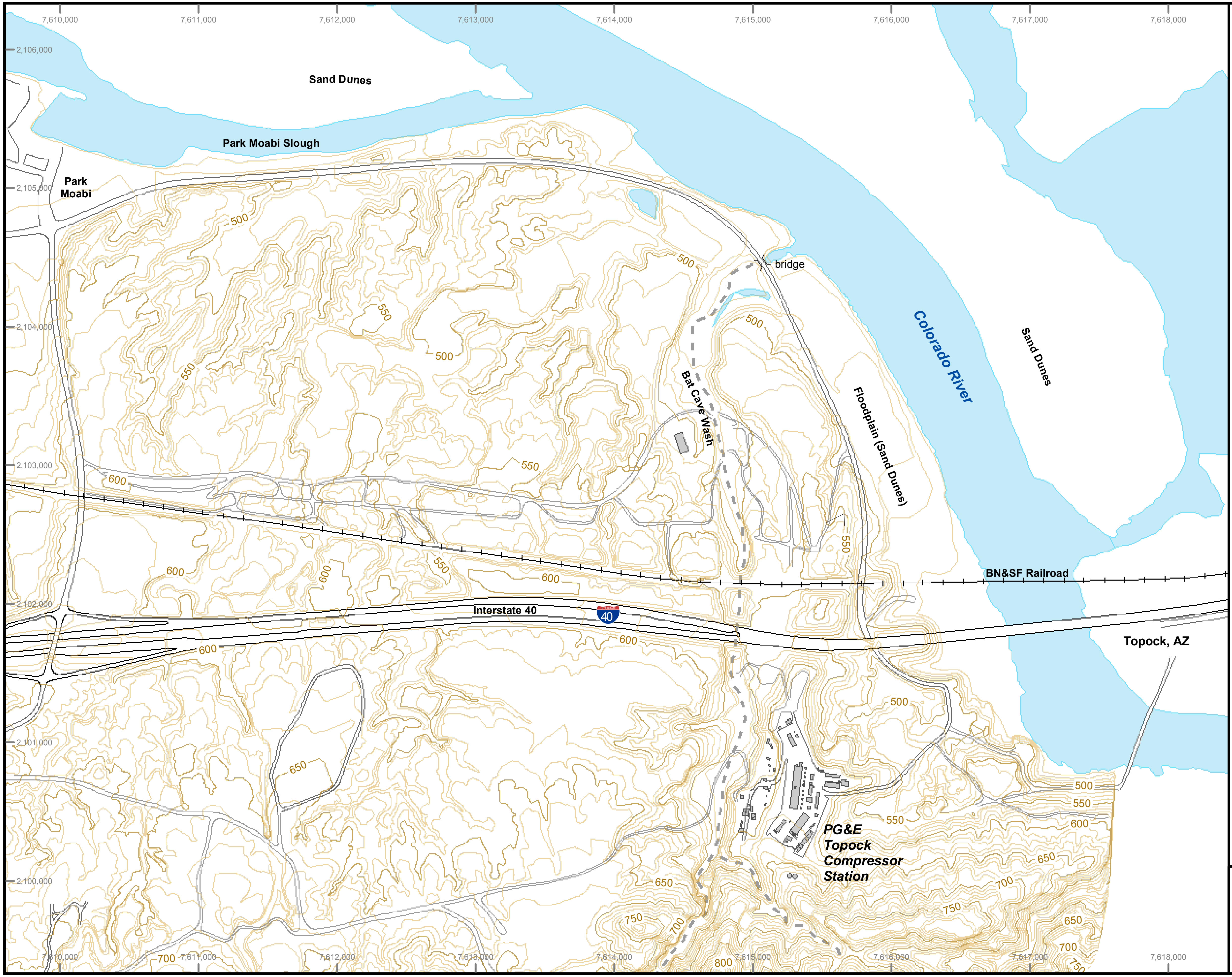
\\ZINFANDEL\PROJ\PACIFICGASELECTRICCO\TOPOCKPROGRAM\GIS\MAPFILES\2007\RFI\FIGURE3-1.MXD FIG3-1_REGIONAL_MAP.PDF 2/19/2008 12:18:47

FIGURE 3-2
AERIAL PHOTOGRAPH OF STUDY AREA, MAY 2005

RCRA FACILITY INVESTIGATION/REMEDIAL
INVESTIGATION REPORT (VOLUME 2)
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

CH2MHILL

BAO \\ZINFANDEL\PROJ\PACIFICGASELECTRICCO\TOPOCKPROGRAM\GIS\MAPFILES\2007\RFI\FIG3-2_AERIAL.MXD FIG3-2_AREIAL 12/29/2008 13:56:44



Source: Topographic data from E & E, Inc., 1997, with additional aerial topographic mapping flown April, 2004 (CH2M HILL)

California State Plane, NAD 83, Zone 5, US Feet
Contour interval is 10 feet, with indices at 50 feet.

FIGURE 3-3
SITE TOPOGRAPHY

RCRA FACILITY INVESTIGATION/REMEDIAL
INVESTIGATION REPORT (VOLUME 2)
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

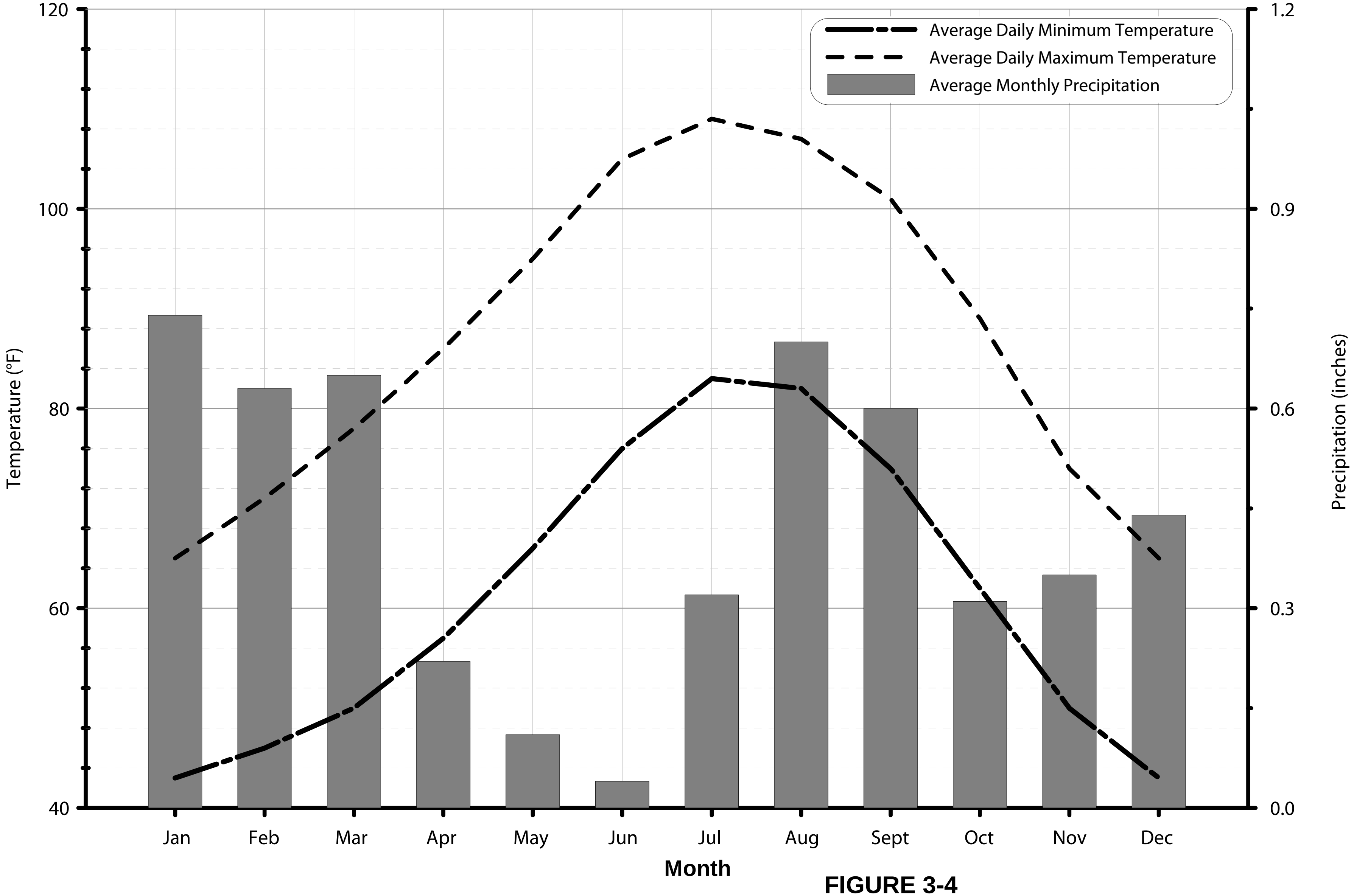


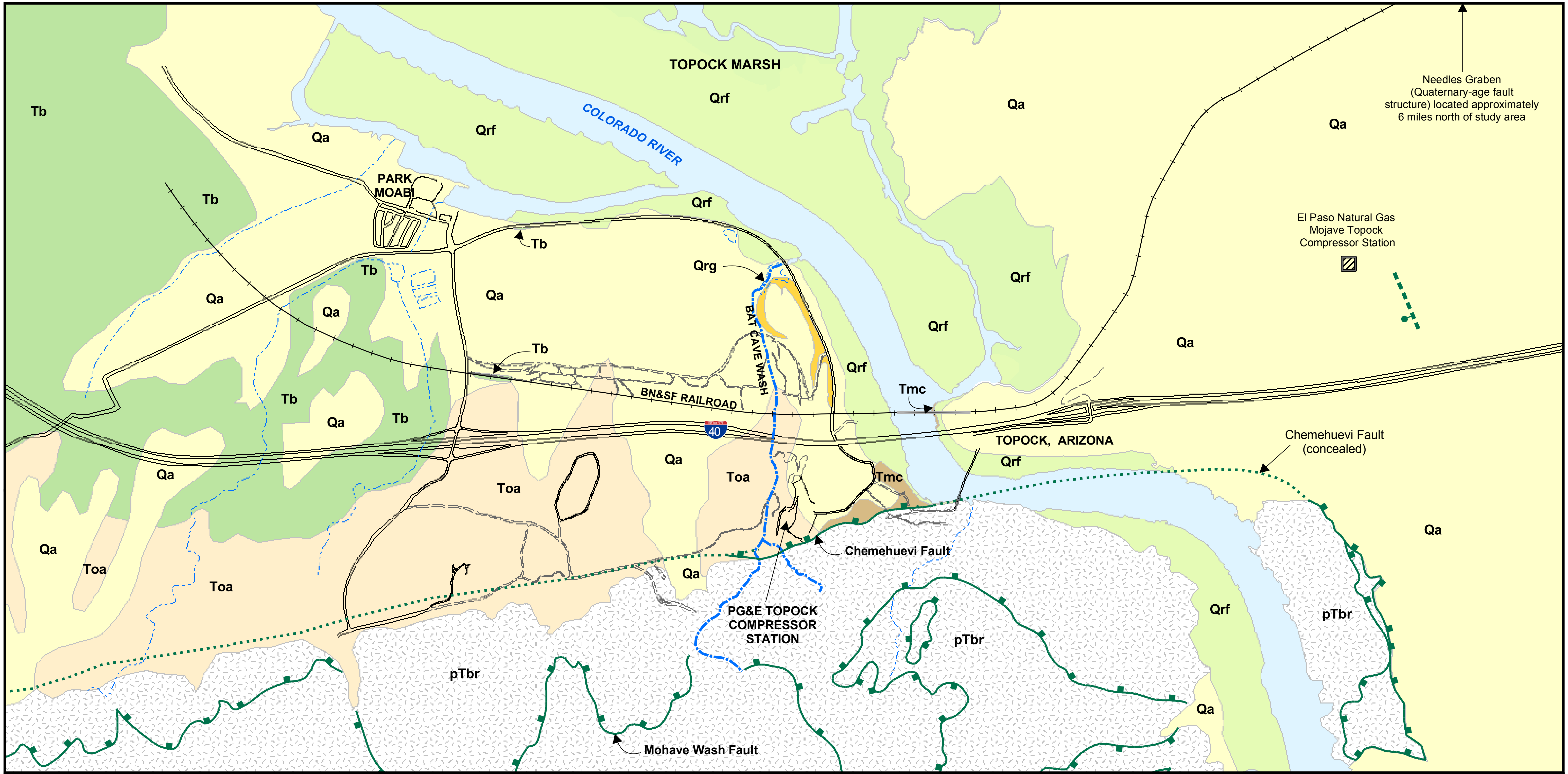
FIGURE 3-4
AVERAGE TEMPERATURE AND PRECIPITATION NEEDLES, CALIFORNIA

RCRA FACILITY INVESTIGATION/REMEDIAL
INVESTIGATION REPORT (VOLUME 2)
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

Notes:
Meteorological data 1961-1990 from Needles, CA Airport.
Data available from http://www.weather.com/activities/other/other/weather/climo-monthly.html?locid=USCA0753.

CH2MHILL

\\zinfandel\proj\PacificGasElectricCo\TopockProgram\Project_GMP\Transducers\Data_Evaluation\RFI_DataEval_Figs\Fig_2-3_PrecipTemperature.grf
ES102007005BAO_RFI_AverageTempPrecip.ai_012408_lho



LEGEND

🟩 Qrf = Quaternary Colorado River and recent Floodplain Deposits

🟨 Qrg = Quaternary River Gravels

🟨 Qa = Quaternary Alluvium and surficial deposits, undifferentiated

🟩 Tb = Bouse Formation

🟧 Toa = Tertiary Alluvium (Fanglomerate of Metzer and Loeltz)

🟫 Tmc = Miocene Conglomerate (Bedrock)

▨ pTbr = Pre-Tertiary Bedrock (Metadiorite, Gneiss, Granitic Rocks)

Normal Fault
ball on downthrown side

Detachment Fault
barbs on downthrown side

Detachment Fault concealed

NOTE:
Generalized surface geologic map compiled from Metzger and Loeltz (1973), John (1987), Howard and others (1997) and PG&E technical reports.

N

0 1,500 3,000
Feet

1 inch equals 1,500 feet

FIGURE 3-5
GEOLOGIC MAP OF STUDY AREA

RCRA FACILITY INVESTIGATION/REMEDIAL
INVESTIGATION REPORT (VOLUME 2)
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

CH2MHILL

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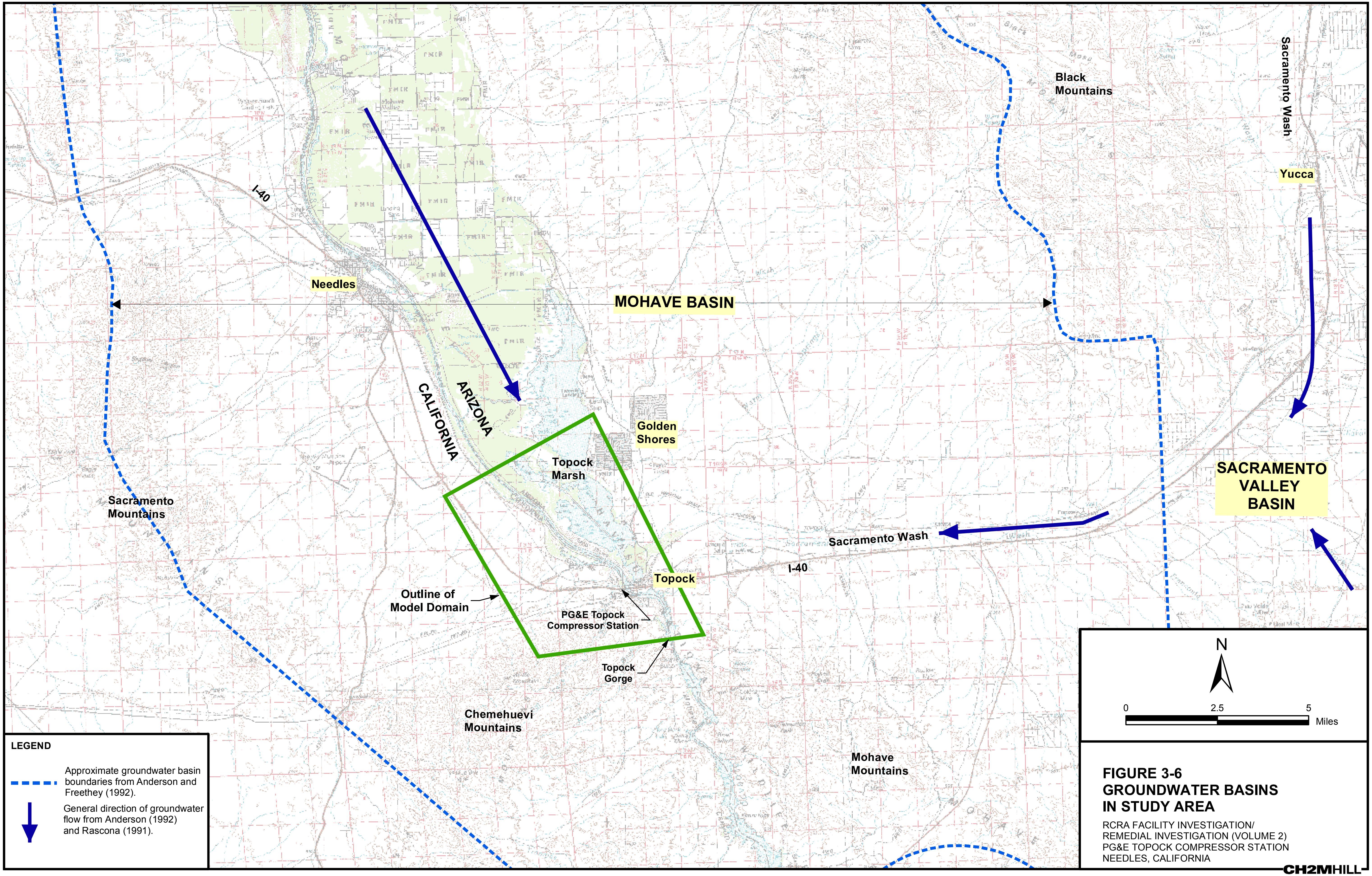
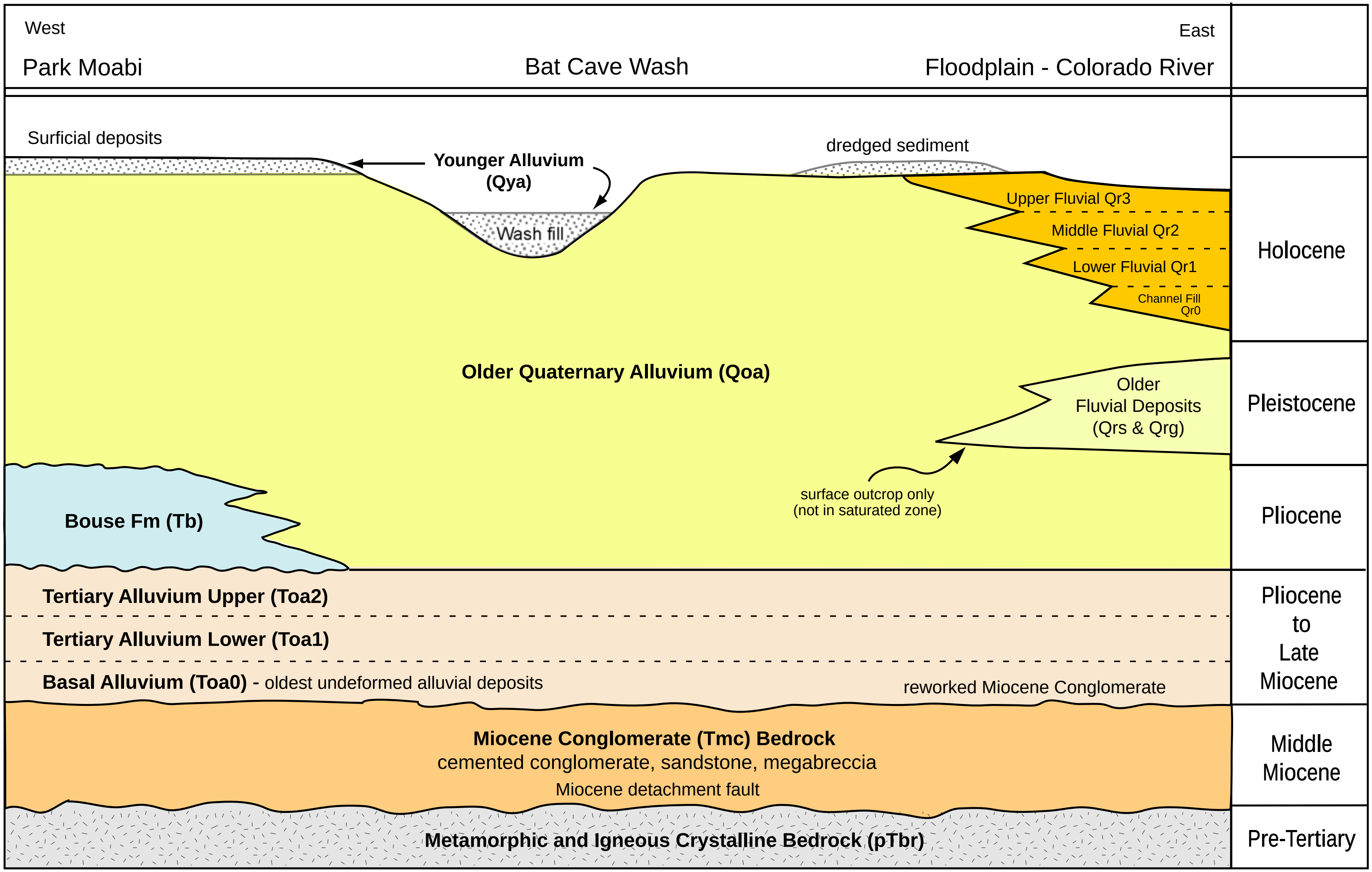


FIGURE 3-6
GROUNDWATER BASINS
IN STUDY AREA

RCRA FACILITY INVESTIGATION/
REMEDIAL INVESTIGATION (VOLUME 2)
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

CH2MHILL



Schematic section illustrating distribution and age of stratigraphic units.
No scale implied.
Refer to Table 3-1 for stratigraphic unit descriptions.

FIGURE 3-7
SCHEMATIC STRATIGRAPHIC SECTION

RCRA FACILITY INVESTIGATION/REMEDIAL
INVESTIGATION REPORT (VOLUME 2)
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

Photograph 1: View of geologic outcrops and Chemehuevi Mountains, south and east of compressor station (right side of photo). Miocene conglomerate bedrock exposed at gas transmission river crossing and pre-Tertiary metamorphic/igneous bedrock (exposures left of gas lines).

Photograph 2: Geologic contact of Oldest Alluvium (Toa unit) and underlying Miocene conglomerate bedrock (Tmc unit), unnamed dry wash southwest of Park Moabi. The depositional contact is an angular unconformity with undeformed alluvial fan deposits (Pliocene or late Miocene?) overlying 40º dipping Miocene conglomerate sequence.

FIGURE 3-8a
PHOTOGRAPHS OF GEOLOGIC UNITS
RCRA FACILITY INVESTIGATION/REMEDIAL
INVESTIGATION REPORT (VOLUME 2)
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

CH2MHILL

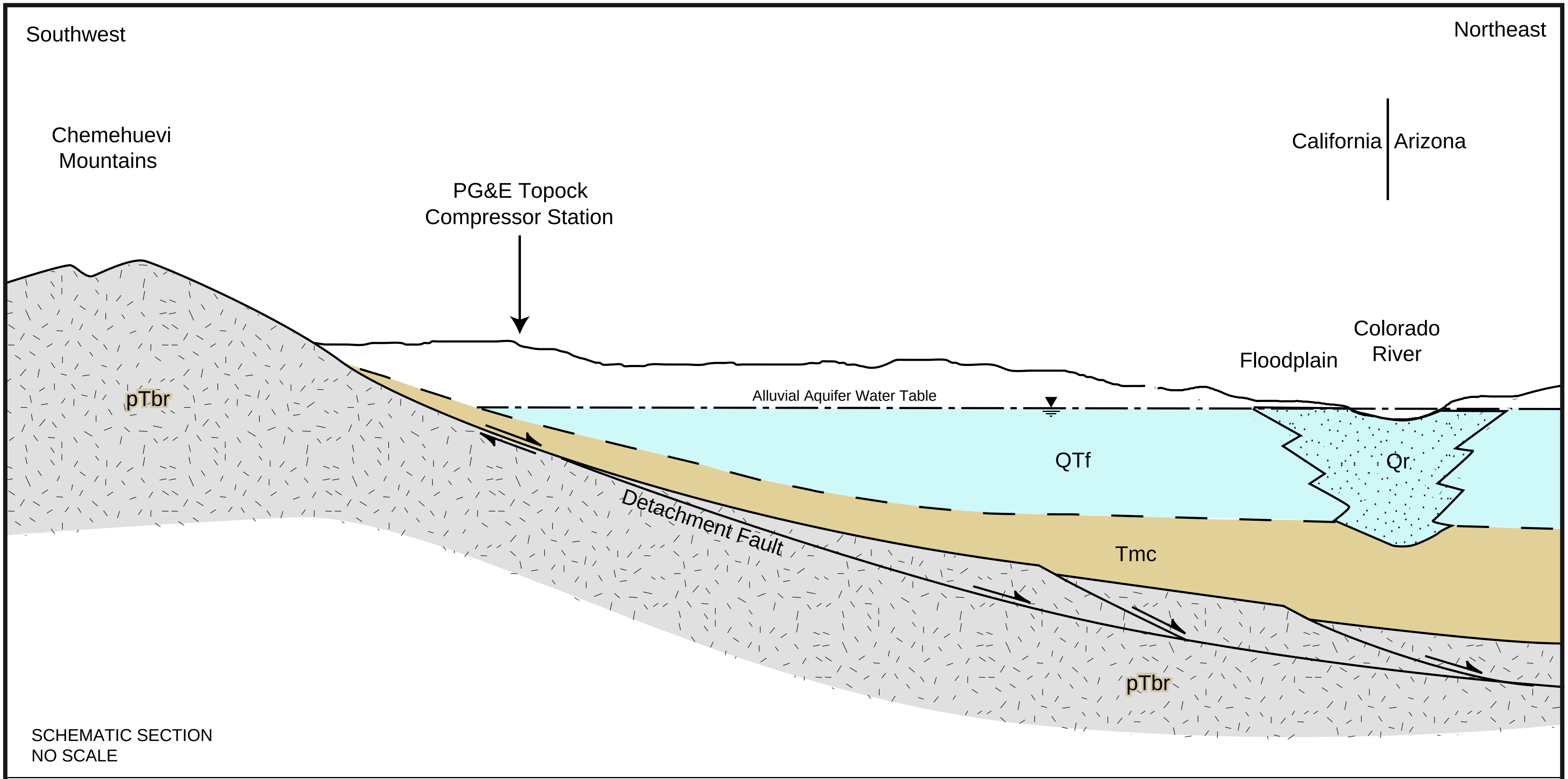
Photograph 3: View of Oldest Alluvium (Toa unit) exposed in Bat Cave Wash, northwest of compressor station. The stratification of sand, gravel, clay layers and 5º depositional dip to the north (right side of photo) are typical of alluvial fan deposits in study area.

Photograph 4: View of Oldest River Gravels (QTrg) exposed in lower Bat Cave Wash. This fluvial unit contains well-rounded clasts (up to 30 inches) of rock types from distant and local geologic sources, characteristic of river gravels of the ancestral Colorado River.

FIGURE 3-8b
PHOTOGRAPHS OF GEOLOGIC UNITS

RCRA FACILITY INVESTIGATION/REMEDIAL
INVESTIGATION REPORT (VOLUME 2)
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

CH2MHILL



PRIMARY GEOLOGIC UNITS

Unit	Description	
QTf	Alluvial Fan Deposits (Qoa, Toa units)	**Alluvial Aquifer**
Qr	Colorado River Fluvial Deposits (Qr0, Qrl, Qr2, Qr3 units)	
Tmc	Miocene Conglomerate	**Bedrock**
pTbr	Metamorphic and Igneous Rocks	

FIGURE 3-9
REGIONAL HYDROGEOLOGIC CROSS SECTION

RCRA FACILITY INVESTIGATION/REMEDIAL
INVESTIGATION REPORT (VOLUME 2)
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

ES102007005BAO_RFI_Vol2-Reg HG Crossection.ai_012408_lho

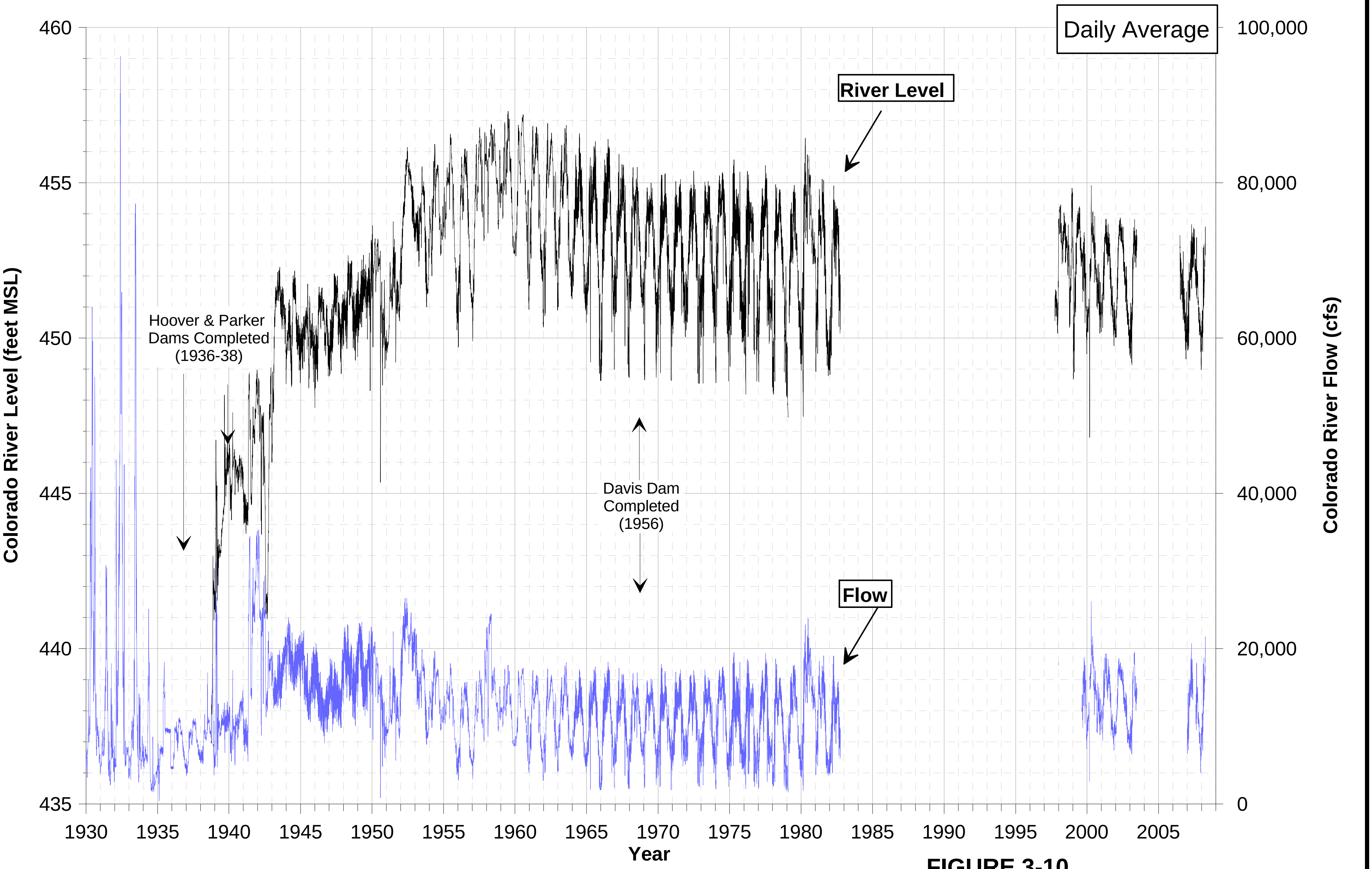


FIGURE 3-10
HISTORIC STAGE AND FLOW OF THE COLORADO RIVER NEAR TOPOCK

RCRA FACILITY INVESTIGATION (RFI)
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

Notes
Colorado River stage and flow data are for USGS Station 9424000, Colorado River Near Topock, Az.
Data obtained from http://water.usgs.gov/data.html.
Dates of dam completions from Metzger and Loeltz (1973).

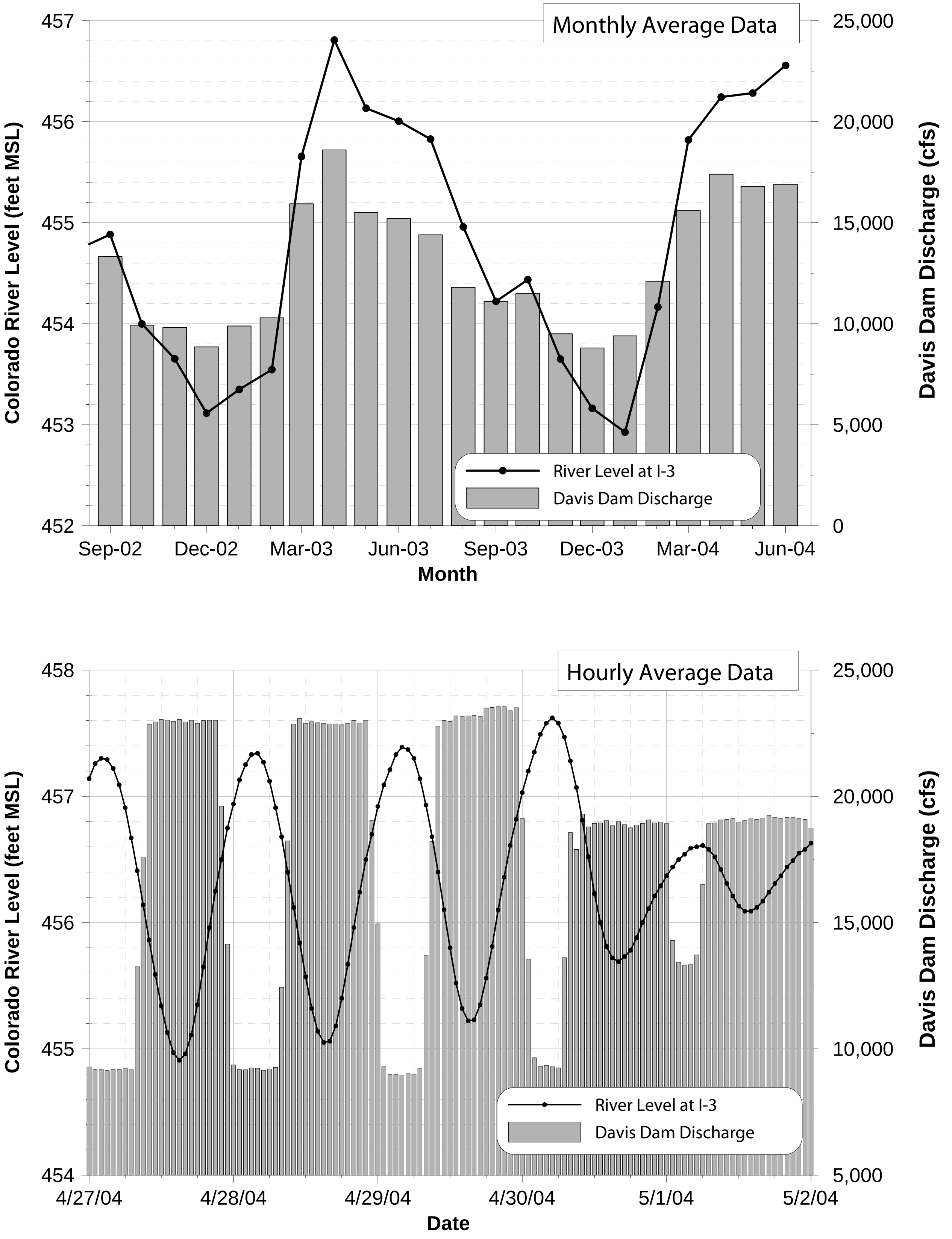
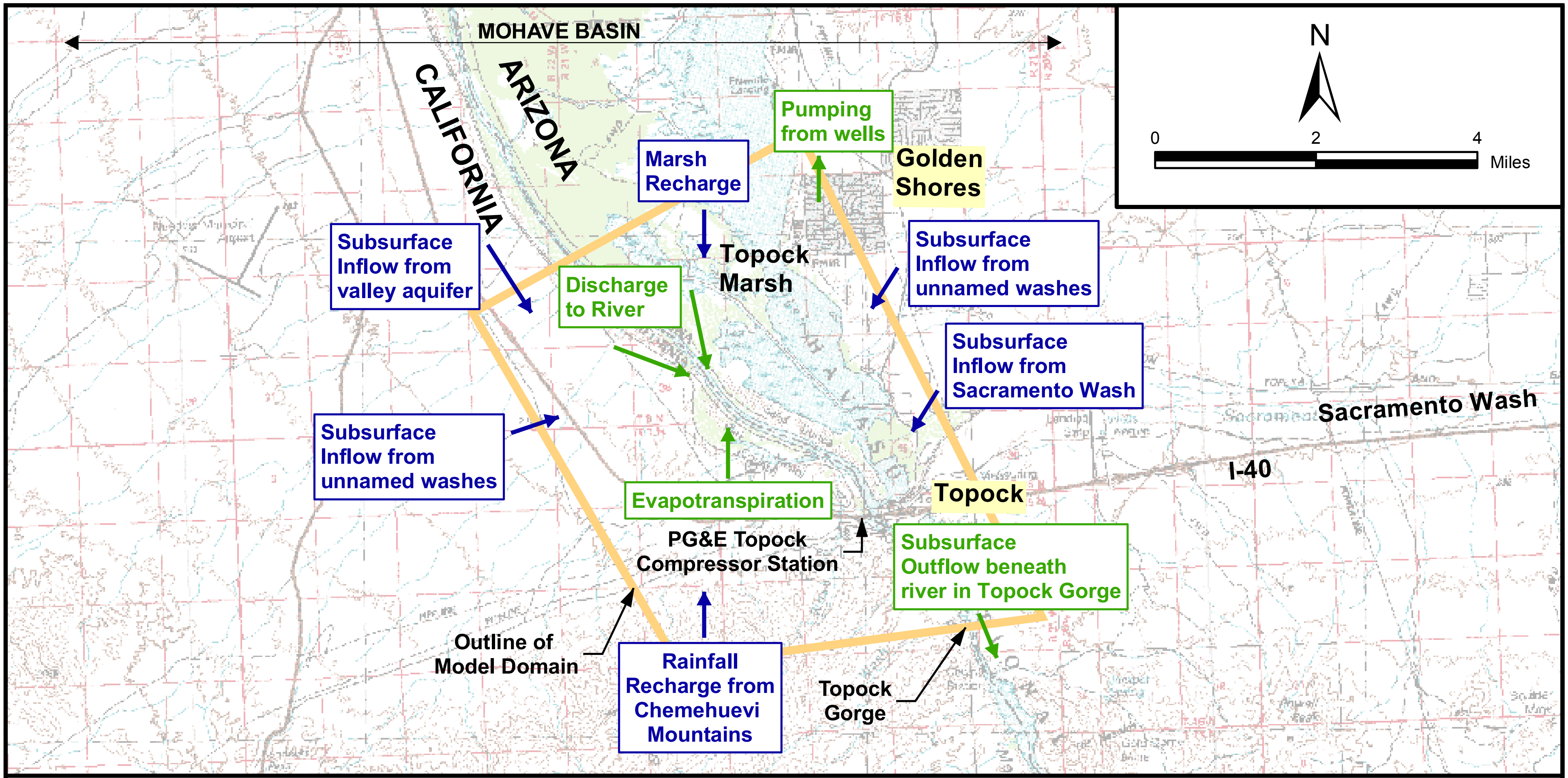


FIGURE 3-11
COLORADO RIVER FLOW AND LEVEL

RCRA FACILITY INVESTIGATION/REMEDIAL
INVESTIGATION REPORT (VOLUME 2)
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

Data source for Davis Dam Discharge:
http://www.usbr.gov/lc/region/g4000/hourly/levels.html.
http://www.usbr.gov/lc/region/g4000/archives.html.

CH2MHILL



Notes

Quantities of Components will be determined from calibrated model.

BLUE= GROUNDWATER RECHARGE

GREEN= GROUNDWATER DISCHARGE

FIGURE 3-12
GROUNDWATER BUDGET COMPONENTS

RCRA FACILITY INVESTIGATION/
REMEDIAL INVESTIGATION (VOLUME 2)
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

\\ZINFANDEL\PROJ\PACIFICGASELECTRICCO\TOPOCKPROGRAM\GIS\MAPFILES\2007\RFI\FIG3-11GW_BUDGET_COMPONENTS.MXD FIG3-12GW_BUDGET_COMPONENTS.MXD 4/25/2008 09:29:49

4.0 Summary of RFI/RI Hydrogeologic Investigations

As discussed in Section 1.2, PG&E's activities in support of the RFI/RI began in 1996 with the signing of the CACA. Since 1996, there have been multiple phases of investigation at the Topock site to collect data to fulfill the objectives of the RFI/RI as outlined in Section 1.3.

This section discusses the data collected for inclusion in this RFI/RI report. Information on the data collection programs, such as work plans and monitoring plans, field methods, data quality programs, and agency approvals for collection of data are summarized in this section. In addition, this section provides a summary of related studies not specifically for the RFI/RI but for which data have been collected and included in this report. The presentation and evaluation of the data collected via the investigations discussed in this section is included in Sections 5.0 through 8.0 for the various media addressed in this report.

4.1 Overview of RFI/RI Data Collection Programs

4.1.1 Phasing of RFI/RI Field Work

RFI/RI field activities began in June 1997, and six phases of work were completed through October 2007. The scope of work for each phase was determined by using the findings from previous investigation phases. Phases 1 through 3 occurred during the period from June 1997 through February 2000, Phase 4 occurred during the period from March 2000 through June 2003, Phase 5 occurred during the period from October 2003 through June 2004, and Phase 6 occurred during the period from June 2004 through October 2007. On behalf of PG&E, Alisto Engineering completed Phases 1 through 3, Ecology and Environment (E&E) completed Phase 4, and CH2M HILL completed Phases 5 and 6. Routine groundwater and surface water monitoring has also been performed as part of ongoing RFI/RI activities. On behalf of PG&E, Alisto performed groundwater and surface water monitoring from June 1997 through November 2001 (primarily quarterly events). Since March 2002, CH2M HILL has performed groundwater and surface water monitoring. A summary of the field activities for each the six phases of the groundwater and surface water RFI/RI is provided in Figure 4-1. Figure 4-2 shows the locations of the RFI/RI wells and drilling locations and additional PG&E monitoring and supply wells that provided data for the RFI/RI. Work performed during each of the six phases is described below.

4.1.1.1 Phase 1

During Phase 1, seven groundwater monitoring wells were installed and sampled. In addition, 11 pre-existing wells and four river locations were sampled. The analytical results indicated that Cr(VI) was present in groundwater and that additional wells were needed to define the extent of Cr(VI) in groundwater. Cr(VI) was not detected in samples collected from the Colorado River.

Initiation of the groundwater and surface water monitoring program began during Phase 1, which included routine collection of groundwater samples from existing wells and surface water samples from the Colorado River.

4.1.1.2 Phase 2

During Phase 2, 11 additional groundwater monitoring wells were installed and sampled to investigate the lateral and vertical extent of Cr(VI) in groundwater and to further define groundwater gradients. Routine groundwater and surface water monitoring continued during this phase, with expansion of the number of wells and surface water locations in the program. Overall, groundwater results indicated that additional wells were needed to define the horizontal and vertical extent of Cr(VI).

4.1.1.3 Phase 3

Nine additional groundwater monitoring wells were installed during Phase 3. The new wells included four in the floodplain, two adjacent to existing well MW-20-70 to create a three-well vertical cluster, and one near the Railroad Debris site. Routine groundwater and surface water monitoring continued during this phase with expansion of the number of wells and surface water locations in the program.

At the request of DTSC, the first draft RFI report (E&E, 2000a) was prepared and submitted to DTSC at the completion of Phase 3 in April 2000. Following review of the first draft RFI report, the DTSC required additional work to better define the groundwater plume boundaries and mechanisms.

4.1.1.4 Phase 4

Seven new groundwater monitoring wells were installed along the western shore of the Colorado River during Phase 4. Routine groundwater and surface water monitoring continued during this phase. In addition, hydraulic testing was conducted on selected wells in the study area. The hydraulic tests were conducted in January and February 2002, and the report was submitted to DTSC in April 2002 (E&E, 2002).

The second draft RFI report (E&E, 2004) was prepared and submitted to DTSC at the completion of Phase 4 in February 2004.

4.1.1.5 Phase 5

As discussed in Section 1.2, PG&E began implementation of an IM at the site in March 2004, and Phase 5 of the RFI/RI included data collection to further characterize COPCs in groundwater and to evaluate the effectiveness of IM activities. During Phase 5, groundwater extraction wells were installed and were tested at two locations, and 22 groundwater monitoring wells were installed at eight locations.

The initial effort for Phase 5, in November 2003, involved installation, development, and aquifer testing of test well TW-1 located on the northern side of the compressor station. Additional field activities in support of the IM included the installation, development, and aquifer testing of test well TW-2 between March and May 2004. TW-2S (shallow) and TW-2D (deep) are paired extraction/test wells screened at different depth intervals.

Phase 5 also included the installation of 22 new monitoring wells at eight locations, conducted between March 2004 and May 2004. Three of these monitoring well locations were on the floodplain between the MW-20 bench and the western shore of the Colorado River. The MW-36 and MW-39 monitoring well clusters—each constructed with six screen depths—were installed in an east-west-trending transect with existing well MW-30 on the floodplain east of the MW-20 bench. The monitoring wells added better vertical definition of the hydrostratigraphy and chromium distribution in the floodplain area. Four new monitoring well clusters (locations MW-35, MW-37, MW-38, and MW-40) were also installed at locations to the north, west, and south of the MW-20 bench for the purpose of plume delineation and a better understanding of the relation of alluvial fan and floodplain hydrostratigraphy.

Routine groundwater and surface water monitoring continued during Phase 5, with expansion of the wells and surface water locations in the program. Prior to Phase 5, routine groundwater and surface water monitoring was generally on a quarterly sampling frequency. Beginning in Phase 5, key floodplain wells were placed on accelerated (weekly, biweekly, monthly) sampling schedules.

In addition, with the initiation of IM activities in March 2004, PG&E began implementation of a separate monitoring program, referred to as the Interim Measures PMP, with a separate data collection program from the routine groundwater and surface water monitoring program. The PMP collects and presents data to assess the performance of the IM to maintain a net landward hydraulic gradient through the collection of water level measurements in wells and the river.

4.1.1.6 Phase 6

During Phase 6, additional data were collected to further characterize site hydrogeologic conditions, to more completely define the nature and extent of contamination, and to address comments on the 2005 RFI/RI Report. In addition, during Phase 6, additional IM wells were installed and data were collected to support evaluation of ongoing IM activities.

During Phase 6, two additional extraction wells, TW-3D and PE-1, were installed on the MW-20 bench and in the floodplain, respectively, for IM extraction activities. In addition, two groundwater injection wells (IW-2 and IW-3) were installed in an area west of the groundwater plume referred to as the East Mesa, as well as 17 compliance/observation wells for monitoring of groundwater injection activities associated with the IM.

Data collected during Phase 6 of the RFI/RI included a pore water study and the installation and sampling of 32 additional monitoring wells (including two wells with multiple screened depths installed at an angle beneath the Colorado River). Phase 6 also included hydraulic testing of bedrock wells, as well as hydraulic testing of alluvial floodplain wells.

Routine groundwater and surface water monitoring continued during this phase with expansion of the number of wells in the program. During this phase, the routine surface water monitoring program was expanded to include nine additional in-channel locations with samples collected at multiple depths in the river. The PMP monitoring program continued during Phase 6 and included routine water level and analytical sampling data from wells in the extraction area (floodplain). Additionally, beginning in July 2006 with the initiation of groundwater injection associated with the IM, PG&E began implementation of a separate and unique monitoring program, referred to as the Interim Measures Compliance Monitoring Program (CMP), which includes routine water level and analytical sampling data from wells in the injection area (East Mesa).

PG&E implemented several related studies during this phase, a portion of the data from which are included in this report. These studies include a groundwater background study, a chromium isotope study, a floodplain *in-situ* pilot study (MWH, 2005), an upland *in-situ* pilot study (ARCADIS, 2006a), and aerobic/anaerobic core testing (CH2M HILL, 2005d). These studies are discussed in more detail in Section 4.3.

4.1.2 Plans and Procedures for Site Investigation and Monitoring

This section provides a summary and inventory of the plans and procedures used during the RFI/RI data collection activities to characterize the hydrogeologic conditions, groundwater and surface water features, and the nature and extent of site COPCs. Since 1997, an extensive set of work plans, sampling/analysis/monitoring plans, quality assurance and data management plans, and methods and procedures have been developed for RFI/RI data collection and analysis.

The purpose of this section is to provide a reference compilation of the plans and procedure documents developed and approved for the field investigations and sampling, analysis, and monitoring activities. Table 4-1 presents a listing of the plans and procedure documents used for this RFI/RI. The work plans outlined below were implemented after approval by DTSC and (since 2004) by DOI agencies. Other state and local agency approvals were obtained prior to work plan implementation, as required by corresponding regulations. Data collected from implementation of the individual work plans has been submitted in previous versions of the RFI/RI and/or data summary reports or monitoring reports. The health and safety plans for RFI/RI site investigation and field activities are maintained in the project file but are not included in this compilation.

Sample collection and management under the RFI/RI program was performed in general accordance with the documents in Sections 4.2 and 4.3 for RFI investigations (1997-2002), RFI/RI/IM investigations (2002–2007), and monitoring programs (2003–2007) (Table 4-1).

4.2 Summary of Data Included in this RFI/RI Report

Data included in this RFI/RI Report have been collected through multiple investigation phases over many years, as outlined in the previous section. The following discusses the spatial, temporal and quality criteria for data included in this RFI/RI Report.

Spatially, the RFI/RI study area for the groundwater characterization is defined as the APE. Location maps and discussion of the defined study area for groundwater and surface water characterization are discussed below.

The data reported in this RFI/RI report were collected between the start of the RFI/RI field sampling activities in July 1997 through October 2007.[2] There are several groundwater investigations planned for implementation after October 2007. Additional groundwater and

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[2] One groundwater sample from bedrock well PGE-7BR collected in December 2007 is also included in this report.

surface data to be collected after October 2007 will be reported in an addendum to RFI/RI Volume 2, RFI/RI Volume 3, and data summary reports or monitoring reports, as appropriate, given the nature of the data and the affect on RFI/RI conclusions. Table 4-6 shows the anticipated reporting of additional groundwater data at the Topock Compressor Station following the cutoff date (October 2007) for the RFI/RI Volume 2.

The data included in this RFI/RI report are generally limited to data collected by PG&E and its consultants, in accordance with agency-approved plans and procedures and in conformance with data quality control programs. Studies conducted within the study area by others are referenced in this report; however, the data collected by others are not presented in this report as part of the RFI/RI data set.

Appendix H1 discusses the PG&E Topock analytical program, designed to ensure that field investigation data are of the appropriate quality to support decision-making in the RFI/RI. Data that are found to lack the appropriate quality are rejected (R-flagged) during the data evaluation process and are excluded from evaluation in this report. Attachment 1 included in Appendix H1 discusses the quality assurance/quality control (QA/QC) of the data during the time period from 1997 to 2004 (date of a prior version of the RFI/RI Report). The body of Appendix H1 discusses the quality of the data during the time period of 2002-2007. In addition to the laboratory requirements included in the documents in Table 4-1, there were statements of work (SOW) were prepared detailing the minimum QA/QC requirements for laboratory analyses. The *Quality Assurance Project Plan* (QAPP) and the *Quality Assurance Project Plan Addendum* (QAPP Addendum) (CH2M HILL, 2004a-b) document the QA/QC activities that have been used in generating analytical data for the groundwater monitoring program and further define the analytical requirements for the Topock analytical program. As discussed in Appendix H1, the quality of the data is evaluated by criteria which include: precision, accuracy, representativeness, completeness, and comparability. In addition to these QA/QC protocols, performance and system audits, data validation, data management, and management of historic data were performed to ensure the quality of the RFI/RI dataset.

The following subsections discuss the data included in this RFI/RI report, organized by type of data. Data collected for inclusion in this RFI/RI are provided in appendices to this report.

4.2.1 Drilling and Hydrogeologic Investigations

4.2.1.1 Drilling Locations and Wells for RFI/RI Characterization

As summarized in Section 4.1, six phases of drilling and hydrogeologic investigations have been conducted (June 1997 through October 2007) to characterize site hydrogeology, groundwater conditions, and the nature and extent of COPCs in groundwater. These investigations included the installation and sampling of 112 groundwater monitoring wells at 53 locations (this includes 27 individual well clusters) to support the RFI/RI groundwater characterization. As part of IM implementation during November 2003 through April 2006, seven groundwater test and extraction wells and two injection wells were installed. Figure 4-2 shows the locations of the RFI/RI wells and drilling locations and additional PG&E monitoring and supply wells that provided data for the RFI/RI. Drilling, well construction, and hydrogeologic characterization information for the wells and borings are summarized in Table 4-2. Appendix B includes the drilling logs and well construction and well survey records for all wells and borings completed for the RFI/RI, IM, and ISPT projects. The geophysical logs collected in selected wells/borings for additional hydrogeologic characterization are included in Appendix C.

From January 2006 to June 2007, drilling investigations were also completed for the *in-situ* pilot test (ISPT) studies, which included installation and sampling of 27 monitoring wells (nine vertical well clusters),three injection wells, and two recirculation wells. Figure 4-3 shows the locations of the wells installed for the ISPT projects, and Table 4-2 summarizes the well drilling and installation data.

PG&E's drilling and well installation activities performed during the RFI/RI were implemented in accordance with RFI/RI, IM, or ISPT work plans approved by DTSC and, where applicable, by DOI and the Water Board. Refer to Table 4-1 for the specific approved work plans.

4.2.1.2 Monitoring Zone Designations

Table 4-2 also notes the monitoring zone assignments for RFI/RI wells. For the purposes of this hydrogeologic characterization, the RFI/RI wells are assigned to one of five primary "monitoring zone" designations, which are based on relative depth and position within Alluvial Aquifer and bedrock lithology, and are **not** directly equivalent with the depositional formation HSUs defined in Table 3-1.

The monitoring zone designations assigned to the RFI/RI wells on Table 4-2 and applied to the hydrogeologic displays in Sections 5.0 and 6.0 are defined as:

- **Shallow zone of the Alluvial Aquifer**, which includes wells completed in saturated alluvial fan and fluvial deposits from the water table (average elevation of 455 feet above msl) to approximately 425 feet msl.
- **Mid-Depth zone of the Alluvial Aquifer**, which includes wells completed in saturated alluvial fan and fluvial deposits between elevations 425 feet msl to approximately 330 feet msl.
- **Deep zone of the Alluvial Aquifer**, which includes wells completed in saturated alluvial fan and fluvial deposits below elevations 330 feet msl to the base of the Alluvial Aquifer.
- **Bedrock well (Tmc)**, which is completed in Miocene Conglomerate formation.
- **Bedrock well (pTbr)**, which is completed in pre-Tertiary metamorphic and igneous bedrock formations.

Drilling and well construction records for other wells installed by PG&E prior to the RFI/RI (Peaker, 1964; Dames and Moore, 1969; PG&E, 1986, 1991, 1992a, 1995), and the logs for groundwater wells and borings installed in the study area by other parties (Caltrans, 1962; Crandall and Associates 1986a-b) are also included in Appendix B. Well location maps and drilling information for wells in the study area that have been decommissioned or destroyed, including the original compressor station supply wells PGE-1 and PGE-2, are presented in Appendices B1 and B2.

4.2.2 Hydraulic Testing

From 1987 through 2007, hydraulic tests have been performed at 31 well locations using a variety of methods and techniques, as described in the approved work plans (Table 4-1). Figure 4-4 shows the locations where the aquifer pumping, clean-water injection, and single well (recovery) hydraulic tests were conducted for hydrogeologic characterization. Several hydraulic tests were conducted by PG&E prior to the RFI/RI (Old and New Evaporation Pond sites; PGE, 1993, 1995). On Figure 4-4, the individual hydraulic tests used for the RFI/RI are color-coded by the primary HSUs tested (alluvial fan, fluvial, and bedrock formations).

Table 4-3 summarizes the locations and types of hydraulic tests and references the source documents that describe and report the hydraulic testing activities. The test results and hydraulic properties by HSU are summarized in Section 5.1.4, and hydraulic testing and analysis displays and documentation are included in Appendix D.

4.2.3 Groundwater Sampling

The analytical data used for this RFI/RI report include sampling data collected from 145 groundwater monitoring wells (total 62 well or cluster locations), 12 test and extraction wells, and seven water supply wells collected during the period July 1997 through October 2007.[3] Table 4-4 presents a summary of the wells and sampling record used to characterize natural groundwater chemistry and the nature and extent of site COPCs. The individual groundwater sampling/well locations are shown on Figure 4-5.

The 1997 to 2007 groundwater analytical data for the RFI/RI well locations on Figure 4-5 specifically include data collected by PG&E in compliance with quality assurance requirements in the CACA and under the investigation work plans and monitoring plans approved by DTSC and other regulatory agencies, as applicable. Table 4-1 lists the specific work plans for the RFI/RI/IM phases and the monitoring and sampling procedures plans for the routine groundwater monitoring programs (e.g., Groundwater Monitoring Program [GMP], PMP, and CMP). Additionally, groundwater data from the RFI/RI wells sampled for PG&E's background and chromium isotope studies (data from California Department of Health Services-certified laboratories) (CH2M HILL, 2008b) and the baseline groundwater quality data from the ISPT wells (Table 4-4) were used for characterization (ARCADIS, 2006a-b, 2007).

In addition to the SWMU 1/AOC 1 COPCs analyses identified in Volume 1 of the RFI/RI (Cr(VI), dissolved Cr(T), electrical conductance, pH, copper, nickel, zinc, lead, and TPH), the RFI/RI groundwater data include analytical results for additional COPCs, general chemistry parameters, stable isotopes, and other constituents of interest (VOCs, semivolatile organic compounds [SVOCs], and perchlorate) requested by DTSC. Cr(T) and other metal concentrations are the dissolved concentrations since metal samples are filtered prior to analyses. As part of the routine groundwater sampling activity, field water quality parameters, including specific conductance, pH, temperature, oxidation reduction potential, and dissolved oxygen, are also collected. All groundwater samples (COPCs and supplemental water quality parameters) used for the RFI/RI have been collected and have

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[3] One groundwater sample from bedrock well PGE-7BR collected in December 2007 is also included in this report.

been analyzed in accordance with the approved plans and procedure documents (Table 4-1). Appendix H1 presents a summary of the analytical data review and quality control procedures for the RFI/RI groundwater data.

The RFI/RI groundwater data are presented and discussed in two sections of this report. Discussion and evaluation of the natural groundwater quality characteristics of the site (primarily general chemistry and stable isotope parameters) are discussed in Section 5.3. The results and evaluation of the COPCs in groundwater are presented and discussed in Sections 6.2 through 6.5.

4.2.4 Surface Water Sampling

From July 1997 through October 2007, surface water samples have been collected from up to 43 surface water sampling locations (some samples collected at multiple depths), as presented in Table 4-5 and depicted in Figure 4-6. The current surface water monitoring program as of October 2007, in place since 2005, includes routine surface water sample collection from nine shoreline locations and nine in-channel stations at specific depths in the Colorado River (Figure 4-1). Sample collection for the River Monitoring Program (RMP) was performed in accordance with approved monitoring plans and Standard Operating Procedures outlined in Table 4-1. Since 2005, RMP events have been conducted quarterly during most of the year and monthly during low river stages (typically November through January). Prior to 2005, RMP events typically were performed quarterly. Surface water samples have also been collected during one-time events, such as during the pore water study in January 2006. Samples have been analyzed for chromium, trace metals, general chemistry parameters, and perchlorate. Sample collection methods and sampling results are discussed in Section 7.2. Detailed analytical results and procedures for the evaluation of the surface water data are presented in Appendix H.

4.2.5 Pore Water Sampling

Pore water samples have been collected from up to 70 pore water locations underneath the Colorado River, as depicted in Figure 4-7. These samples were collected from two one-time events in February 2003 and January 2006 at depths of 2 and 6 feet below the bottom of the Colorado River, as part of Phases 4 and 6 of the RFI/RI (Figure 4-1). Sample collection methods were as outlined in the approved work plans (Table 4-1). The analytical suite included chromium and general chemistry parameters. Objectives for the pore water and sediment sampling from the pore water study in Phase 6 included assessing chromium concentrations in pore water and determining whether geochemical conditions in shallow sediments below the Colorado River favored chromium reduction. Sample collection methods and sampling results are discussed in Section 7.2. Detailed analytical results and procedures for the evaluation of the pore water data are presented in Appendix H.

4.2.6 River Sediment Sampling

Colorado River sediment samples were collected from up to 18 locations, as presented in Table 9-2 and 9-3 and as depicted in Figure 4-8. These samples were collected from two one-time events in February 2003 and December 2005, at depths of ranging from the surface to 2 or 3 feet below the bottom of the Colorado River, as part of Phases 4 and 6 of the RFI/RI (Figure 4-1). Sample collection methods were as outlined in the approved work plans

(Table 4-1). The analytical suite included chromium and general chemistry parameters. Along with the pore water samples from the pore water study in Phase 6, the sediment sampling results were used in a multiple lines of evidence approach to determine whether geochemical conditions in shallow sediments below the Colorado River favored chromium reduction. Detailed analytical results and procedures for the evaluation of the river sediment data are presented in Appendix H.

4.2.7 Groundwater Flow Modeling

As described in Section 3.0, the groundwater system at the Topock site is complicated by upward gradients, Colorado River fluctuations, and multiple HSUs. A numeric model was designed primarily as a tool for development and for evaluation of groundwater corrective measures at the site.

The finite-element model MicroFEM (Hemker 1999) was selected as the modeling code. Finite-element models are preferred when there is a need for a high degree of detail in a limited area (the floodplain area of the plume in this case) but not in the majority of the model domain. In addition, MicroFEM is preferred for its computational efficiency and strong "top system" packages for simulating river-groundwater interaction, evapotranspiration, and precipitation recharge. Details of model development and calibration are provided in a previous document (CH2M HILL, 2005b). This version of the model will be used to evaluate remedial alternatives in the Groundwater CMS/FS. A general description of the model is provided in this section.

The model domain covers approximately 26 square miles, extending from the Needles area south into Topock Canyon (Figure 3-6). It was designed so that regional conditions could be simulated and compared to published conceptual models (e.g., Metzger and Loeltz, 1973; Anderson, 1995) and also provide detailed analysis of the Topock site. The model is divided into five layers, the bottom layer represents low permeability bedrock, while unconsolidated HSUs (described in Section 3.4) are simulated in the remaining four layers. The layer thicknesses vary and generally correspond to elevation intervals of well screen intervals and, where possible, to HSU thickness. Model Layers 1 and 2 correspond to the depth intervals of the upper and middle zone wells, and Layers 3 and 4 correspond to the depth intervals of the deep zone wells (Figure 4-9).

The finite-element model grid is made up of 28,762 nodes and 57,337 triangular elements. Model grid spacing is shown on Figure 4-10. Areas far from the Topock site were assigned 500-foot spacing between nodes. Areas closer to the site (from Park Moabi to about 0.75 mile into Arizona) have 200-foot spacing and become finer-spaced in steps of 100-, 60-, and finally to 20-foot spacing in the floodplain area.

Water budget is represented in the model by: (1) constant head along the northern boundary representing regional groundwater flow, (2) constant flux along part of the eastern and western boundaries representing groundwater flow associated with Sacramento Wash and other drainage, (3) precipitation in the Chemehuevi Mountains, (4) groundwater flow to/from the Colorado River, (5) evapotranspiration in the floodplain, (6) groundwater extraction from water supply wells, and (7) constant head in the fluvial aquifer beneath the river at the southern end of the model domain. Values assigned to these parameters were based on site data and published values and are adjusted as necessary during calibration.

Aquifer properties in the model were assigned on the basis of hydraulic testing in various areas of the site. Lithologic, geophysical, and velocity logging data were also used to estimate properties where direct hydraulic data were insufficient. Properties throughout the model domain were adjusted during calibration.

A revised model has been constructed but not yet calibrated, and has been documented in previous reports (CH2M HILL, 2006b-d). This new model will be further developed and calibrated for the design phase of the CMS/FS if deemed necessary by the TWG and agencies. However, the accuracy of the current calibrated model in predicting water levels in wells installed after calibration has been demonstrated by matching groundwater responses to IM-3 pumping shutdown. The performance of the model was concluded to be sufficiently accurate to justify its use in the CMS/FS. A presentation of the model performance will be presented in the CMS/FS Report. Potential limitations of the current model include the lack of inclusion of the Topock Marsh influence, the absence of very fine grid spacing in upland areas of the plume, and in some well clusters groundwater levels from two or more wells must be averaged in a single layer. For the purposes of comparing long-term remedies, these limitations are not considered important.

4.3 Related Site Investigation and Studies

As discussed previously, as part of Phase 6 of the RFI/RI, PG&E implemented several related studies at the PG&E Topock site. These studies include a groundwater background study, a chromium isotope study, a floodplain *in-situ* pilot study, an upland *in-situ* pilot study, and aerobic/anaerobic core testing. The studies were implemented in accordance with work plans approved by DTSC and, where applicable, by DOI and the Water Board (refer to Table 4-1 for the specific approved work plans). Further, as described in Section 2.0, several site investigations are planned for additional characterization of groundwater conditions at the Topock site. Table 4-6 summarizes the status and reporting of the related, supplemental, and planned groundwater investigation and characterization studies for the Topock site groundwater RFI/RI. A brief description of these studies and their inclusion in the RFI/RI data set is below.

A groundwater background study was performed to define an upper threshold limit concentration for Cr(VI), Cr(T), and other metals in groundwater in the region surrounding the Topock site. The upper threshold concentration represents the upper concentration of the constituent in natural groundwater not affected by contamination. The background study involved sample collection at existing wells both within and outside the APE during six sampling events between May 2005 and May 2006. The results of the background study, including calculated upper threshold limits, are reported in the *Revised Groundwater Background Study, Steps 3 and 4: Final Report of* Results (CH2M HILL, 2008b). The calculated upper tolerance limits (UTLs) for metals from the groundwater background study are reported in Section 6.1 of this report and used for evaluation of metals data collected from the site. In addition, for purposes of the RFI/RI data set, those groundwater samples collected from the wells within the APE for the background study sampling events, as presented in Figure 4-5 and Table 4-4, are included in the RFI/RI data set.

A chromium isotope study was performed to assess whether a recently developed experimental technique involving chromium isotopes can be used to distinguish anthropogenic chromium from naturally-occurring chromium in groundwater at the Topock site. If this technique proves useful, chromium isotopes analysis could assist with delineation of the chromium plume, and assessment of the degree of chromium reduction that is occurring in the floodplain area. The chromium isotope study involved sample collection at existing wells both within and outside the APE during two sampling events in 2006 and 2007. Samples collected for the chromium isotope study were analyzed by both a California-certified laboratory, as well as by a USGS laboratory using non-United States Environmental Protection Agency-certified methods. The results of the chromium isotope study were reported in the summary report (CH2M HILL, 2008g). Those groundwater samples collected from wells within the APE for the chromium isotope study events, as presented in Figure 4-5 and Table 4-4, and analyzed by California-certified laboratories in accordance with the Quality Assurance Project Plan, are included in the RFI/RI data set. In addition, chromium isotope data from USGS laboratories are shown on a regional scale in Section 6.0.

In-situ pilot studies have been implemented at site to collect site-specific data on implementation of *in-situ* reduction of Cr(VI) as a possible remedial action at the site. The pilot studies involved installation of wells and facilities for injection of reductants for *in-situ* chromium treatment testing and monitoring (MWH, 2005; ARCADIS, 2006c). From January 2006 to June 2007, drilling investigations completed for the ISPT projects, included installation and sampling of 27 monitoring wells (nine vertical well clusters), three injection wells, and two recirculation wells. Figure 4-3 shows the locations of the wells installed for the ISPT projects, and Table 4-2 summarizes the well drilling and installation data. The drilling and hydrogeologic data collected for these wells, as well as the baseline groundwater sampling events prior to the start of the pilot studies, are included in the RFI/RI characterization. Groundwater monitoring data collected after start of the pilot studies is not included in the RFI/RI data set and is published in separate monitoring and pilot test completion reports.

Several phases of laboratory testing of cores collected from fluvial sediments near and beneath the Colorado river have been performed to evaluate various properties including the ability of the core materials to reduce Cr(VI) to Cr(III). The first phase of anaerobic core testing was performed on samples collected from floodplain wells in 2004 and was reported in the *Summary of Results - Anaerobic Core Hexavalent Chromium Uptake Capacity at the PG&E Topock Compressor Station, Needles, California* (CH2M HILL, 2005d). The second phase of anaerobic core testing was performed on samples collected in February 2007 from slant well clusters drilled on the western edge of the Colorado River and reported in the *Phase II Anaerobic Core Testing Summary Report, PG&E Topock Compressor Station, Needles, California* (CH2M HILL, 2008a). Because of the unique testing program, the laboratory data collected during the core testing program is not repeated in this RFI/RI.

A hydrogeologic investigation was performed near the shore of the Colorado River in Arizona in March and April 2008. The purpose of the investigation was to supplement the site conceptual model, to complete the groundwater characterization of the potential eastern extent of the groundwater plume, and further characterize the hydrogeologic conditions beneath the river channel downstream of the chromium plume observed in the California floodplain. The results of the investigation are documented in the *Installation Report for Wells on the Arizona Shore of the Colorado River at Topock Arizona,* dated August 12, 2008

(CH2M HILL, 2008h). Hydrogeologic and water quality data collected during this investigation will be reported in the RFI/RI Volume 2 Addendum Report.

In early 2009, a groundwater investigation will be conducted to characterize the groundwater conditions of bedrock formations in the East Ravine area. In addition, a groundwater investigation to assess potential sources within the Topock Compressor Station is planned as part of an upcoming onsite investigation, anticipated in 2009.

4.4 Data Not Included in this RFI/RI Report

4.4.1 PG&E Studies

4.4.1.1 Soil Data

As indicated in Figure 4-1 and as presented in the Draft RFI/RI (CH2M HILL, 2005a), soil data have been collected at sites within and surrounding the Topock Compressor Station during Phase 1 through Phase 4 of the RFI/RI. Additional soil sampling is planned to supplement the data collected during Phase 1 through Phase 4; the additional soil data are anticipated to be collected in 2008 and 2009. This report does not address the soil media at the SWMUs and AOCs at the facility; soil data collected for the RFI/RI will be included in Volume 3.

4.4.1.2 Groundwater Data

Prior to the RFI/RI, PG&E installed and sampled groundwater monitoring wells at the Old Evaporation Ponds site (sampling period 1985 to 1992) and the Class II, double-lined, New Evaporation Ponds site (sampling period 1986 to present) to assess groundwater conditions and to comply with Waste Discharge Requirement detection monitoring (PG&E, 1992b, 1993). As part of pond closure activities in 1995, nine of the monitoring wells at the Old Ponds site were decommissioned, and three monitoring wells were kept as inactive status (Figure 4-2). At the New Ponds site, routine groundwater sampling of the seven monitoring wells continues in accordance with the active Waste Discharge Requirement monitoring.

The water quality data and findings of the initial groundwater characterization at the Old and New Ponds sites are presented in PG&E's Technical and Ecological Services reports (PG&E, 1993, 1995) and routine monitoring reports. Because the early characterization data (1985 to 1995) and active New Ponds Waste Discharge Requirement monitoring data were analyzed outside of the RFI/RI analytical and data review program (Appendix H1), these data have not been compiled or included in this RFI/RI characterization.

Additional groundwater analytical data have been collected from the RFI/RI wells as part of the drilling investigations, hydraulic testing, and IM well testing and operations. The IM drilling investigations frequently used the collection of depth-discrete grab groundwater sampling for screening-level evaluation of water quality for supporting well installation decisions. Groundwater samples were also collected during aquifer pumping tests and spinner flow velocity log tests to aid in test characterization. Groundwater analytical samples have also been collected as part of extraction/injection well performance evaluations. The analytical data and evaluation of the drilling, testing, and IM operations groundwater analyses have not been compiled or included in this RFI/RI characterization.

Refer to the specific drilling investigation, hydraulic testing, and IM operations, testing, and performance reports (Sections 5.0 and 6.0) for these data.

4.4.2 Studies by Others

As discussed in Section 4.2, the data included in this RFI/RI report are generally limited to data collected by PG&E and its consultants, in accordance with agency-approved plans and procedures, and in conformance with data quality control programs. Studies and data conducted within the study area by others were reviewed and referenced in this report, and considered during the planning of field activities; however, the data collected by others are not presented in this report as part of the RFI/RI data set. The following provide a brief summary of studies performed by others.

In 2006, the Arizona Department of Environmental Quality (ADEQ) conducted a reconnaissance water quality investigation of active and inactive water supply wells in western Mohave County, Arizona (study area from Golden Shores to locations approximately 10 miles east of Topock, Arizona) (Geotrans, 2006). The study found that low levels of chromium were detected throughout the study area; however, the chromium concentrations did not exceed the Arizona maximum contaminant level (MCL) of 100 µg/L, and chromium concentrations in wells nearest the PG&E Topock site were similar to those more distant from the site. Further evaluation showed that the detected concentrations were consistent with background concentrations in groundwater calculated for the Topock site, as reported in PG&E's *Revised Groundwater Background Study, Steps 3 and 4: Final Report of Results* (CH2M HILL, 2008b), as well as published regional studies (ADEQ, 2001; Robertson, 1991). The ADEQ study recommended that additional monitoring wells be installed to better assess the eastern extent of the chromium plume at the Topock site. Because the focus of the ADEQ study was primarily outside the RFI/RI study area and the study was performed outside the RFI/RI analytical and data review program, these data have not been compiled or included in this RFI/RI characterization.

The DOI performed sediment toxicity testing using 21 sediment samples collected in October 2001 from the Colorado River both upstream and downstream of the Topock site. The results are reported in *A Reconnaissance Study on Potential Chromium Contamination in the Colorado River near the Pacific Gas and Electric Facility, Topock, California* (USGS Columbia Research Center, 2004). Results of the study indicated that chromium, cadmium, copper, nickel, lead and zinc in the sediment samples were not elevated to concentrations that would be toxic to sediment-dwelling organisms. While the sediment samples were collected from within the RFI/RI study area, the data were collected outside the RFI/RI analytical and data review program by non-certified laboratories; therefore, these data have not been compiled or included in this RFI/RI characterization.

The Metropolitan Water District (MWD) collected surface water samples from the Colorado River from three locations on an approximately monthly basis from July 2003 to June 2007. Additionally, MWD collected pore water and water-sediment interface samples at five locations during three events between March and July 2007 (MWD, 2007). Sample results for Cr(T) and Cr(VI) from the MWD sampling were similar to sampling by PG&E, with most results less than analytical detection limits, and a few low level detections (up to 1.2 µg/L Cr(T), up to 0.04 µg/L Cr(VI)) both upstream and downstream of the Topock site. While the samples were collected from within the RFI/RI study area, the data were collected outside the RFI/RI analytical and data review program; therefore, these data have not been included in this RFI/RI characterization. For reference, however, these data and related information are provided in Appendix J.

The DTSC collected groundwater samples from MW-20 monitoring wells (MW-20-70, MW-20-100, MW-20-130) in May 2004 for metals analysis (Advanced Technology Laboratories, 2004). The samples were collected to assess water quality of the extraction area at the start of the interim measure extraction (see Section 1.2.2). Because the data were collected outside the RFI/RI analytical and data review program, these data have not been compiled or included in this RFI/RI characterization.

In June 27, 2007, DTSC collected split samples during a multiple step sampling program to evaluate chromium concentrations in MW-23. Because the split samples were collected outside the RFI/RI analytical and data review program, these data have not been compiled or included in this RFI/RI report.

TABLE 4-1
Plans and Procedures for RFI/RI Investigations and Data Collection
RCRA Facility Investigation/Remedial Investigation Report (Volume 2)
PG&E Topock Compressor Station, Needles, California

Title	Reference
Plans and Procedures for RFI Investigations, 1997 - 2002	
RCRA Facility Investigation Work Plan, Pacific Gas and Electric Company, Topock Compressor Station	Alisto, 1997b
Work Plan Amendment No. 1, RCRA Facility Investigation at Bat Cave Wash Area, PG&E Topock Compressor Station, Needles, California	PG&E, 1997
Work Plan Amendment No. 2, RCRA Facility Investigation at Bat Cave Wash Area, PG&E Topock Compressor Station, Needles, California	PG&E, 1998a
Work Plan Amendment No. 3, RCRA Facility Investigation at Bat Cave Wash Area, PG&E Topock Compressor Station, Needles, California	PG&E, 1998b
Work Plan Amendment No. 4, RCRA Facility Investigation at Bat Cave Wash Area, PG&E Topock Compressor Station, Needles, California	PG&E, 1998c
Work Plan for Additional Soil Sampling, Corrective Action Consent Agreement for Bat Cave Wash Area, Pacific Gas and Electric Company, Topock Compressor Station, Needles, California	E&E, 2000b
Work Plan for Hydrogeological Testing, Corrective Action Consent Agreement for Bat Cave Wash Area, Pacific Gas and Electric Company, Topock Compressor Station, Needles, California	E&E, 2001
Work Plan Amendment No. 5, RCRA Facility Investigation at Bat Cave Wash Area, PG&E Topock Compressor Station, Needles, California	PG&E, 2002a
Work Plan Amendment No. 6, RCRA Facility Investigation at Bat Cave Wash Area, PG&E Topock Compressor Station, Needles, California	PG&E, 2002b
Addendum to Work Plan Amendment No. 5, RCRA Facility Investigation at Bat Cave Wash Area, PG&E Topock Compressor Station, Needles, California	PG&E, 2003
Plans and Procedures for RFI/RI/IM Investigations, 2002 - 2007	
Technical Memorandum (Draft), Groundwater Pilot Study, Topock Compressor Station, Needles, California	CH2M HILL, 2003a
Tech Memo: Summary Workplan Groundwater Exploratory Boring and Test	CH2M HILL, 2003b
Work Plan, Field Activities for Groundwater Extraction Pilot System, Topock Compressor Station, Needles, California	CH2M HILL, 2003c
Interim Measures Work Plan (Draft), Topock Compressor Station	CH2M HILL, 2004a
Draft Interim Measures Workplan (Interim Measure No. 1)	CH2M HILL, 2004b
Addenda to Interim Measures No. 2 Workplan	CH2M HILL, 2004c
Final Interim Measures No. 2 Workplan	CH2M HILL, 2004d
Draft Work Plan: Assessing Background Metals Concentrations in Groundwater	CH2M HILL, 2004e
Draft Conceptual Work Plan for Hydrogeologic Characterization and Well Installation on Parcel Number 650-151-06, Interim Measure No. 3	CH2M HILL, 2004f
Summary and Work Plan to Conduct Geotechnical Investigation on MWD Property, APN 650-151-06, Interim Measure No. 3	CH2M HILL, 2004g

TABLE 4-1
Plans and Procedures for RFI/RI Investigations and Data Collection
RCRA Facility Investigation/Remedial Investigation Report (Volume 2)
PG&E Topock Compressor Station, Needles, California

Title	Reference
Interim Measures No. 3 Workplan Revision 1	CH2M HILL, 2004h
Work Plan for Expanded Groundwater Extraction and Treatment, Construction under Interim Measure No. 3 MWD property, APN 650-151-06 Agreement for entry and Inspection of Property	CH2M HILL, 2004i
Final Workplan for Injection Well Installation, Interim Measures No. 3	CH2M HILL, 2004j
In Situ Hexavalent Chromium Reduction Pilot Test Work Plan, Floodplain Reductive Zone Enhancement	Arcadis, 2005
Final Phase 2 Monitoring Well Installation Work Plan - January 31, 2005	CH2M HILL, 2005e
Final Extraction Well Installation Work Plan - March 15, 2005	CH2M HILL, 2005f
Draft Work Plan for Installation of Supplemental Extraction Well IM Groundwater Extraction System	CH2M HILL, 2005g
In-Situ Hexavalent Chromium Reduction Pilot Test Work Plan--Floodplain Reductive Zone Enhancement	CH2M HILL, 2005h
Work Plan for Installation of Extraction Well TW-3D	CH2M HILL, 2005i
Revised Pore Water and Seepage Study Work Plan	CH2M HILL, 2005c
Draft Well Installation Work Plan for Interim Measures Performance Monitoring Program	CH2M HILL, 2005j
Addendum to Pore Water Seepage Study Work Plan - Revised Contingency Plan	CH2M HILL, 2005k
Addendum to Revised Pore Water and Seepage Study Work Plan	CH2M HILL, 2005l
In Situ Hexavalent Chromium Reduction Pilot Test Work Plan, Upland Plume Treatment	Arcadis, 2006c
Technical Addendum No. 1 Well Installation Work Plan for Interim Measures Performance Monitoring Program	CH2M HILL, 2006e
Technical Addendum No. 2 Well Installation Work Plan for Interim Measures Performance Monitoring Program	CH2M HILL, 2006f
Supplement to Technical Addendum No. 1: Well Installation Work Plan for Interim Measures Performance Monitoring Program	CH2M HILL, 2006g
Revised Chromium Isotope Study Workplan	CH2M HILL, 2006h
Revised In-Situ Hexavalent Chromium Pilot Test Work Plan Upland Plume Treatment	CH2M HILL, 2006i
Work Plan for Additional Groundwater Characterization Beneath the Colorado River by Slant Boring in California. PG&E Topock Compressor Station, Needles, California	CH2M HILL, 2006j
Addendum to Work Plan for California Slant Drilling Activities Beneath the Colorado River, PG&E Topock Compressor Station, Needles, California	CH2M HILL, 2006k
Work Plan for Hydraulic Testing in Bedrock Wells. PG&E Topock Compressor Station, Needles, California	CH2M HILL, 2006l
Technical Addendum: Work Plan for Hydraulic Testing in Bedrock Wells. PG&E Topock Compressor Station, Needles, California	CH2M HILL, 2006m
Phase II Chromium Isotope Study Work Plan PG&E Topock Compressor Station	CH2M HILL, 2007c

TABLE 4-1
Plans and Procedures for RFI/RI Investigations and Data Collection
RCRA Facility Investigation/Remedial Investigation Report (Volume 2)
PG&E Topock Compressor Station, Needles, California

Title	Reference
Revised Work Plan for Well Installation and Groundwater Characterization on Arizona Shore of the Colorado River at Topock, Arizona, PG&E Topock Compressor Station, Needles, California	CH2M HILL, 2007d
Plans and Procedures for Monitoring Programs, 2003 – 2007	
Sampling and Analysis Plan for September 2003 Quarterly Groundwater Monitoring, PG&E Topock Project	CH2M HILL, 2003d
Sampling Plan Addendum for Evaluating Monitoring Well Sampling Methods, February 2004 Groundwater Monitoring Event, PG&E Topock Project	CH2M HILL, 2004k
Sampling and Analysis Plan, Groundwater and Surface Water Monitoring, PG&E Topock Compressor Station, Needles, California	CH2M HILL, 2004l
Sampling Plan Supplement, PG&E Topock Interim Measures Drilling Program	CH2M HILL, 2004m
PG&E Program Quality Assurance Project Plan	CH2M HILL, 2004n
Quality Assurance Project Plan Addendum, Groundwater and Surface Water Monitoring, PG&E Topock Compressor Station, Needles, California	CH2M HILL, 2004o
Work Plan for Seismic Profiling, PG&E Topock Compressor Station, Needles, California	CH2M HILL, 2004p
Sampling, Analysis, and Field Procedures Manual, PG&E Topock Program, Revision 1, PG&E Topock Compressor Station, Needles, California	CH2M HILL, 2005m
Performance Monitoring Plan for Interim Measures in the Floodplain Area. PG&E Topock Compressor Station, Needles, California	CH2M HILL, 2005n
Monitoring Plan for Groundwater and Surface Water Monitoring Program, PG&E Topock Compressor Station, Needles, California	CH2M HILL, 2005o
Revised Sampling Plan and Standard Operating Procedure for Depth-Specific Surface Water Sampling, Topock Compressor Station, Needles, California, Revision 1	CH2M HILL, 2005p
Proposed Revision to Surface Water Sampling Program, Pacific Gas and Electric Company – Topock Project	CH2M HILL, 2005q
Groundwater Compliance Monitoring Plan for Interim Measures No. 3 Injection Area	CH2M HILL, 2005r
Final Work Plan for Chromium Sample Filtration Comparison Test	CH2M HILL, 2005s
Attachment B to Workplan for Chromium Sample Filtration Comparison Test	CH2M HILL, 2005t
Interim Measures Compliance Monitoring Program, Request for Approval to Implement Limited Sampling Frequency for Selected Metals/General Minerals	CH2M HILL, 2006n
PG&E Topock Summer Access Procedures for Floodplain Areas Near Potential Southwestern Willow Flycatcher Habitat	CH2M HILL, 2007e
Updates and Modifications to the PG&E Topock Groundwater and Surface Water Monitoring Program	CH2M HILL, 2007f

TABLE 4-2

Drilling and Well Construction Summary for RFI/RI Characterization

RCRA Facility Investigation/Remedial Investigation Report (Volume 2)

PG&E Topock Compressor Station, Needles, California

Location ID	Investigation Program & Well Type [1]	Status [2]	Date Installed	Ground Elevation (feet MSL)	Screen Interval (feet bgs)	Monitoring Zone [3]	Additional Characterization [4]		
							Geophys	Gr-Size	Hyd Test
Groundwater Monitoring Wells									
MW-1	New Ponds - Monitoring	Active	Aug-86	660	201 - 211	SA - alluvial			
MW-3	New Ponds - Monitoring	Active	Aug-86	649	193 - 203	SA - alluvial			
MW-4	New Ponds - Monitoring	Active	Aug-86	624	165 - 175	SA - alluvial			
MW-5	New Ponds - Monitoring	Active	Jun-89	635	176 - 185	SA - alluvial			
MW-6	New Ponds - Monitoring	Active	Jun-89	642	185 - 194	SA - alluvial			
MW-7	New Ponds - Monitoring	Active	Jun-89	630	173 - 183	SA - alluvial			
MW-8	New Ponds - Monitoring	Active	Jun-89	627	169 - 178	SA - alluvial			
MW-9	RFI - Monitoring	Active	Jul-97	534	77 - 87	SA - alluvial		X	
MW-10	RFI - Monitoring	Active	Jun-97	529	74 - 94	SA - alluvial		X	
MW-11	RFI - Monitoring	Active	Jun-97	521	63 - 83	SA - alluvial		X	
MW-12	RFI - Monitoring	Active	Jul-97	483	28 - 48	SA - alluvial			
MW-13	RFI - Monitoring	Active	Jul-97	487	29 - 49	SA - alluvial			
MW-14	RFI - Monitoring	Active	Jul-97	570	111 - 131	SA - alluvial			
MW-15	RFI - Monitoring	Active	Jul-97	640	181 - 201	SA - alluvial		X	
MW-16	RFI - Monitoring	Active	Apr-98	655	198 - 218	SA - alluvial			
MW-17	RFI - Monitoring	Active	May-98	588	130 - 150	SA - alluvial		X	
MW-18	RFI - Monitoring	Active	Apr-98	544	85 - 105	SA - alluvial			
MW-19	RFI - Monitoring	Active	Mar-98	499	46 - 66	SA - alluvial			
MW-20-70	RFI - Monitoring	Active	Mar-98	499	50 - 70	SA - alluvial			
MW-20-100	RFI - Monitoring	Active	Apr-99	499	90 - 100	MA - alluvial			X
MW-20-130	RFI - Monitoring	Active	Apr-99	499	121 - 131	DA - alluvial	X		X
MW-21	RFI - Monitoring	Active	May-98	506	39 - 59	SA - alluvial			
MW-22	RFI - Monitoring	Active	Apr-98	458	6 - 11	SA - fluvial		X	
MW-23	RFI - Monitoring	Active	Apr-98	505	60 - 80	BR-Tmc	X		
MW-24A	RFI - Monitoring	Active	May-98	565	104 - 124	SA - alluvial	X		
MW-24B	RFI - Monitoring	Active	May-98	563	193 - 213	DA - alluvial	X		
MW-24BR	RFI - Monitoring	Active	Apr-98	563	378 - 437	BR-pTbr	X		X
MW-25	RFI - Monitoring	Active	Apr-99	541	85 - 105	SA - alluvial			
MW-26	RFI - Monitoring	Active	Apr-99	503	52 - 72	SA - alluvial			X
MW-27-20	RFI - Monitoring	Active	Apr-99	459	7 - 17	SA - alluvial			X
MW-27-60	IM - Monitoring	Active	Feb-05	458	47 - 57	MA - alluvial			
MW-27-85	IM - Monitoring	Active	Feb-05	458	78 - 88	DA - alluvial	X		
MW-28-25	RFI - Monitoring	Active	Apr-99	465	13 - 23	SA - fluvial			X
MW-28-90	IM - Monitoring	Active	Apr-04	465	70 - 90	DA - fluvial	X	X	
MW-29	RFI - Monitoring	Active	Apr-99	483	30 - 40	SA - fluvial			
MW-30-30	RFI - Monitoring	Active	Apr-99	466	12 - 32	SA - fluvial			X
MW-30-50	RFI - Monitoring	Active	Mar-03	466	40 - 50	MA - fluvial			
MW-31-60	RFI - Monitoring	Active	Apr-99	495	42 - 62	SA - alluvial			
MW-31-135	IM - Monitoring	Active	Mar-04	495	113 - 133	DA - alluvial	X	X	
MW-32-20	RFI - Monitoring	Active	Mar-03	459	10 - 20	SA - fluvial			
MW-32-35	RFI - Monitoring	Active	Mar-03	459	28 - 35	SA - fluvial			
MW-33-40	RFI - Monitoring	Active	Mar-03	485	29 - 39	SA - fluvial			

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Location ID	Investigation Program & Well Type [1]	Status [2]	Date Installed	Ground Elevation (feet MSL)	Screen Interval (feet bgs)	Monitoring Zone [3]	Additional Characterization [4]		
							Geophys	Gr-Size	Hyd Test
Groundwater Monitoring Wells									
MW-33-90	RFI - Monitoring	Active	Mar-03	485	69 - 89	MA - fluvial			
MW-33-150	IM - Monitoring	Active	Feb-05	485	132 - 152	DA - alluvial			
MW-33-210	IM - Monitoring	Active	Feb-05	485	190 - 210	DA - alluvial	X		
MW-34-55	RFI - Monitoring	Active	Jun-03	459	45 - 55	MA - fluvial			
MW-34-80	RFI - Monitoring	Active	Jun-03	459	73 - 83	DA - fluvial	X	X	
MW-34-100	IM - Monitoring	Active	Jan-05	459	90 - 100	DA - fluvial	X		
MW-35-60	IM - Monitoring	Active	Mar-04	481	41 - 61	SA - alluvial			
MW-35-135	IM - Monitoring	Active	Mar-04	481	116 - 136	DA - alluvial	X	X	
MW-36-20	IM - Monitoring	Active	May-04	467	10 - 20	SA - fluvial			
MW-36-40	IM - Monitoring	Active	May-04	467	30 - 40	SA - fluvial			
MW-36-50	IM - Monitoring	Active	May-04	467	46 - 51	MA - fluvial			
MW-36-70	IM - Monitoring	Active	May-04	467	60 - 70	MA - fluvial			
MW-36-90	IM - Monitoring	Active	May-04	467	80 - 90	DA - fluvial			
MW-36-100	IM - Monitoring	Active	May-04	467	88 - 98	DA - fluvial	X	X	
MW-37S	IM - Monitoring	Active	Apr-04	484	64 - 84	MA - alluvial			
MW-37D	IM - Monitoring	Active	Apr-04	484	180 - 200	DA - alluvial	X	X	
MW-38S	IM - Monitoring	Active	Apr-04	523	75 - 95	SA - alluvial			
MW-38D	IM - Monitoring	Active	Apr-04	523	163 - 183	DA - alluvial	X	X	
MW-39-40	IM - Monitoring	Active	Apr-04	465	30 - 40	SA - fluvial			
MW-39-50	IM - Monitoring	Active	Apr-04	465	47 - 52	MA - fluvial			
MW-39-60	IM - Monitoring	Active	Apr-04	465	49 - 59	MA - fluvial			
MW-39-70	IM - Monitoring	Active	Apr-04	465	60 - 70	MA - alluvial			
MW-39-80	IM - Monitoring	Active	Apr-04	465	70 - 80	DA - alluvial			
MW-39-100	IM - Monitoring	Active	Apr-04	465	80 - 100	DA - alluvial	X	X	
MW-40S	IM - Monitoring	Active	May-04	566	115 - 135	SA - alluvial			
MW-40D	IM - Monitoring	Active	May-04	567	240 - 260	DA - alluvial	X	X	
MW-41S	IM - Monitoring	Active	Nov-04	477	40 - 60	SA - alluvial			
MW-41M	IM - Monitoring	Active	Nov-04	477	170 - 190	DA - alluvial			
MW-41D	IM - Monitoring	Active	Nov-04	477	271 - 291	DA - alluvial	X		X
MW-42-30	IM - Monitoring	Active	Feb-05	461	10 - 30	SA - fluvial			
MW-42-55	IM - Monitoring	Active	Feb-05	461	43 - 53	MA - fluvial			
MW-42-65	IM - Monitoring	Active	Feb-05	461	56 - 66	MA - fluvial	X		
MW-43-25	IM - Monitoring	Active	Feb-05	463	15 - 25	SA - fluvial			
MW-43-75	IM - Monitoring	Active	Feb-05	463	65 - 75	DA - fluvial			
MW-43-90	IM - Monitoring	Active	Feb-05	460	80 - 90	DA - fluvial	X		
MW-44-70	IM - Monitoring	Active	Mar-06	471	61 - 71	MA - fluvial			
MW-44-115	IM - Monitoring	Active	Mar-06	470	103 - 113	DA - alluvial			
MW-44-125	IM - Monitoring	Active	Mar-06	471	116 - 125	DA - alluvial	X		
MW-45-095a	IM - Monitoring	Active	Feb-06	467	83 - 93	DA - fluvial			
MW-46-175	IM - Monitoring	Active	Feb-06	481	165 - 175	DA - alluvial			
MW-46-205	IM - Monitoring	Active	Feb-06	481	197 - 207	DA - alluvial	X		
MW-47-55	IM - Monitoring	Active	Mar-06	483	45 - 55	SA - alluvial			

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Location ID	Investigation Program & Well Type [1]	Status [2]	Date Installed	Ground Elevation (feet MSL)	Screen Interval (feet bgs)	Monitoring Zone [3]	Additional Characterization [4]		
							Geophys	Gr-Size	Hyd Test
Groundwater Monitoring Wells									
MW-47-115	IM - Monitoring	Active	Mar-06	483	105 - 115	DA - alluvial			
MW-48	IM - Monitoring	Active	May-06	484	124 - 134	BR-Tmc			X
MW-49-135	IM - Monitoring	Active	Mar-06	483	125 - 135	DA - alluvial			
MW-49-275	IM - Monitoring	Active	Mar-06	483	255 - 275	DA - alluvial			
MW-49-365	IM - Monitoring	Active	Mar-06	483	345 - 365	DA - alluvial	X		
MW-50-095	IM - Monitoring	Active	Apr-06	495	85 - 95	MA - alluvial			
MW-50-200	IM - Monitoring	Active	Apr-06	495	190 - 200	DA - alluvial	X		
MW-51	IM - Monitoring	Active	Apr-06	502	97 - 112	MA - alluvial			
MW-52S	IM - Monitoring	Active	Mar-07	460	47 - 49	MA - fluvial			
MW-52M	IM - Monitoring	Active	Mar-07	460	66 - 68	DA - fluvial			
MW-52D	IM - Monitoring	Active	Mar-07	460	85 - 87	DA - fluvial			
MW-53S	IM - Monitoring	Inactive	Mar-07	460	29 - 30	SA - fluvial			
MW-53M	IM - Monitoring	Active	Mar-07	460	99 - 100	DA - fluvial			
MW-53D	IM - Monitoring	Inactive	Mar-07	460	124 - 125	DA - fluvial			
MWP-1	Old Ponds - Monitoring	decomm	Jul-85	675	75 - 115	SA - alluvial			
MWP-2	Old Ponds - Monitoring	decomm	Jul-85	675	200 - 260	SA - alluvial			
MWP-2RD	Old Ponds - Monitoring	decomm	Jul-85	674	265 - 275	BR-pTbr			
MWP-3	Old Ponds - Monitoring	decomm	Jul-85	661	108 - 208	SA - alluvial			
MWP-7	Old Ponds - Monitoring	decomm	Oct-85	675	70 - 110	SA - alluvial			
MWP-8	Old Ponds - Monitoring	Standby	Oct-85	677	181 - 211	SA - alluvial			
MWP-9	Old Ponds - Monitoring	decomm	Oct-85	680	179 - 219	SA - alluvial			
MWP-10	Old Ponds - Monitoring	Standby	Jan-86	675	194 - 234	SA - alluvial			
MWP-12	Old Ponds - Monitoring	Standby	Jan-86	662	96 - 136	SA - alluvial			
MWP-14	Old Ponds - Monitoring	decomm	Jun-92	674	206 - 216	SA - alluvial			
MWP-15	Old Ponds - Monitoring	decomm	Jun-92	676	198 - 208	SA - alluvial			
MWP-16	Old Ponds - Monitoring	decomm	Jun-92	690	210 - 220	SA - alluvial			
OW-1S	CMP - Monitoring	Active	Nov-04	548	84 - 114	SA - alluvial			
OW-1M	CMP - Monitoring	Active	Sep-04	548	165 - 185	MA - alluvial			
OW-1D	CMP - Monitoring	Active	Sep-04	548	257 - 277	DA - alluvial		X	
OW-2S	CMP - Monitoring	Active	Dec-04	546	71 - 101	SA - alluvial			
OW-2M	CMP - Monitoring	Active	Dec-04	546	190 - 210	MA - alluvial			
OW-2D	CMP - Monitoring	Active	Dec-04	547	310 - 330	DA - alluvial		X	
OW-3S	IM - Monitoring	Active	Oct-04	556	86 - 116	SA - alluvial			
OW-3M	IM - Monitoring	Active	Oct-04	556	180 - 200	MA - alluvial			
OW-3D	IM - Monitoring	Active	Oct-04	556	242 - 262	DA - alluvial	X	X	X
OW-5S	CMP - Monitoring	Active	Nov-04	549	70 - 110	SA - alluvial			
OW-5M	CMP - Monitoring	Active	Nov-04	549	210 - 250	DA - alluvial			
OW-5D	CMP - Monitoring	Active	Nov-04	550	300 - 320	DA - alluvial		X	
P-1	Old Ponds - Monitoring	decomm	Feb-86	694	171 - 211	SA - alluvial			
P-2	New Ponds - Monitoring	Inactive	Aug-86	536	239 - 249	DA - alluvial			
PGE-7BR	IM - Monitoring	Active	Oct-07	563	249 - 300	BR-pTbr	X		X
CW-1M	CMP - Monitoring	Active	Jan-05	563	140 - 190	MA - alluvial			

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Location ID	Investigation Program & Well Type [1]	Status [2]	Date Installed	Ground Elevation (feet MSL)	Screen Interval (feet bgs)	Monitoring Zone [3]	Additional Characterization [4]		
							Geophys	Gr-Size	Hyd Test
Groundwater Monitoring Wells									
CW-1D	CMP - Monitoring	Active	Jan-05	564	250 - 300	DA - alluvial	X		
CW-2M	CMP - Monitoring	Active	Feb-05	547	152 - 202	MA - alluvial			
CW-2D	CMP - Monitoring	Active	Jan-05	547	285 - 335	DA - alluvial	X		
CW-3M	CMP - Monitoring	Active	Feb-05	532	172 - 222	MA - alluvial			
CW-3D	CMP - Monitoring	Active	Jan-05	532	270 - 320	DA - alluvial	X		
CW-4M	CMP - Monitoring	Active	Jan-05	516	120 - 170	MA - alluvial			
CW-4D	CMP - Monitoring	Active	Jan-05	516	233 - 283	DA - alluvial	X		
Extraction, Test & Injection Wells									
IW-2	IM - Injection	Active	Dec-04	547	170 - 330	MA-DA - alluvial	X		X
IW-3	IM - Injection	Active	Dec-04	551	160 - 320	MA-DA - alluvial	X		X
PE-1	IM - Extraction	Active	Mar-05	458	79 - 89	DA - fluvial			X
PGE-8	TCS - Injection	Inactive	Jun-69	595	405 - 554	BR-pTbr	X		X
PGE-PT-1	New Ponds - Test	Inactive	Nov-86	625	220 - 260	MA-DA - alluvial			
TW-1	IM - Test	Active	Nov-03	621	169 - 269	SA-MA-DA - alluvial	X		X
TW-2S	IM - Extraction	Standby	Apr-04	497	43 - 93	SA-MA - alluvial	X		
TW-2D	IM - Extraction	Standby	Apr-04	497	113 - 148	DA - alluvial	X	X	
TW-3D	IM - Extraction	Active	Oct-05	497	111 - 156	DA - alluvial			X
TW-4	IM - Test	Active	Mar-06	483	210 - 250	DA - alluvial	X		X
TW-5	IM - Test	Active	Apr-06	495	110 - 150	DA - alluvial			X
In-Situ Pilot Test Wells									
PT-1S	ISPT - Monitoring	Active	Jan-06	472	35 - 45	SA - fluvial			
PT-1M	ISPT - Monitoring	Active	Jan-06	472	60 - 70	MA - fluvial			
PT-1D	ISPT - Monitoring	Active	Jan-06	472	95 - 105	DA - fluvial			
PT-2S	ISPT - Monitoring	Active	Feb-06	471	35 - 45	SA - fluvial			
PT-2M	ISPT - Monitoring	Active	Feb-06	471	60 - 70	MA - fluvial			
PT-2D	ISPT - Monitoring	Active	Feb-06	471	95 - 105	DA - fluvial			
PT-3S	ISPT - Monitoring	Active	Feb-06	472	35 - 45	SA - alluvial			
PT-3M	ISPT - Monitoring	Active	Feb-06	472	60 - 70	MA - alluvial			
PT-3D	ISPT - Monitoring	Active	Feb-06	472	95 - 105	DA - alluvial			
PT-4S	ISPT - Monitoring	Active	Feb-06	472	35 - 45	SA - fluvial			
PT-4M	ISPT - Monitoring	Active	Feb-06	472	60 - 70	MA - fluvial			
PT-4D	ISPT - Monitoring	Active	Feb-06	472	95 - 105	DA - fluvial			
PT-5S	ISPT - Monitoring	Active	Feb-06	471	35 - 45	SA - fluvial			
PT-5M	ISPT - Monitoring	Active	Feb-06	471	60 - 70	MA - fluvial			
PT-5D	ISPT - Monitoring	Active	Feb-06	471	95 - 105	DA - fluvial			
PT-6S	ISPT - Monitoring	Active	Jan-06	474	35 - 45	SA - fluvial			
PT-6M	ISPT - Monitoring	Active	Jan-06	474	60 - 70	MA - fluvial			
PT-6D	ISPT - Monitoring	Active	Jan-06	474	95 - 105	DA - fluvial			
PT-7S	ISPT - Monitoring	Active	May-07	561	130 - 155	SA - alluvial			
PT-7M	ISPT - Monitoring	Active	May-07	561	165 - 185	MA - alluvial			
PT-7D	ISPT - Monitoring	Active	May-07	560	177 - 217	DA - alluvial			
PT-8S	ISPT - Monitoring	Active	May-07	562	147 - 152	SA - alluvial			

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Location ID	Investigation Program & Well Type [1]	Status [2]	Date Installed	Ground Elevation (feet MSL)	Screen Interval (feet bgs)	Monitoring Zone [3]	Additional Characterization [4]		
							Geophys	Gr-Size	Hyd Test
In-Situ Pilot Test Wells									
PT-8M	ISPT - Monitoring	Active	May-07	562	162 - 183	MA - alluvial			
PT-8D	ISPT - Monitoring	Active	May-07	562	190 - 210	DA - alluvial			
PT-9S	ISPT - Monitoring	Active	Jun-07	562	128 - 148	SA - alluvial			
PT-9M	ISPT - Monitoring	Active	Jun-07	560	163 - 183	MA - alluvial			
PT-9D	ISPT - Monitoring	Active	Jun-07	560	190 - 210	DA - alluvial			
PTI-1S	ISPT - Injection	Active	Jan-06	473	35 - 45	SA - alluvial			
PTI-1M	ISPT - Injection	Active	Jan-06	473	60 - 70	MA - fluvial			
PTI-1D	ISPT - Injection	Active	Jan-06	473	95 - 105	DA - fluvial			
PTR-1	ISPT - recirculation	Active	May-07	558	125 - 220	MA-DA - alluvial			
PTR-2	ISPT - recirculation	Active	Jun-07	565	118 - 218	MA-DA - alluvial			
Water Supply Wells									
PGE-1	TCS - original supply	decomm	Sep-51	555	99 - 177	MA - alluvial			
PGE-2	TCS - original supply	decomm	Jul-51	552	98 - 152	MA - alluvial			
PGE-6	TCS - replacement supply	decomm	Jun-64	562	110 - 180	SA-MA - alluvial			
PGE-7	TCS - replacement supply	Inactive	Sep-64	563	195 - 330	DA-BR-pTbr	X		
PGE-9N	TCS - replacement supply	Inactive	Apr-97	460	25 - 95	MA-DA - fluvial			
PGE-9S	TCS - replacement supply	Inactive	Apr-97	459	30 - 100	MA-DA - fluvial			
Park Moabi-1	SBC original supply	decomm	Mar-61	470	28 - 180	---			
Park Moabi-3	SBC supply	Active	Aug-86	517	80 - 200	MA - alluvial			
Park Moabi-4	SBC supply	Standby	Oct-06	485	93 - 140	MA - alluvial	X		
Selected Wells in Arizona									
Sanders	private supply	Active	Jun-05	464	48 - 68	SA			
Smith	private supply	decomm	Feb-98	505	48 - 68	SA			
TMW-6	TM - Monitoring	decomm	Jan-91	469	12 - 32	SA - fluvial			
TMW-8	TM - Monitoring	decomm	Jan-91	465	5 - 25	SA - fluvial			
TMW-9	TM - Monitoring	decomm	Jan-91	461	6 - 31	SA - fluvial			
TMW-10	TM - Monitoring	decomm	Jan-91	470	10 - 30	SA - fluvial			
TMW-11	TM - Monitoring	decomm	Jan-91	468	10 - 30	SA - fluvial			
Topock-1	ATSF original supply	decomm	---	505	---	SA - fluvial			
Topock-2	City of Needles supply	Active	Sep-80	509	100 - 140	SA - alluvial			
Topock-3	City of Needles supply	Active	May-74	511	85 - 130	SA - alluvial			
Exploratory & Test Borings									
B-25	RFI - Boring	Closed	Apr-98	672	---	---			
CB-1	Caltrans - Boring I-40	Closed	Mar-62	471	---	---			
CB-2	Caltrans - Boring I-40	Closed	Mar-62	499	---	---			
CB-3	Caltrans - Boring I-40	Closed	Mar-62	504	---	---			
CB-4	Caltrans - Boring I-40	Closed	Mar-62	504	---	---			
CB-5	Caltrans - Boring I-40	Closed	Mar-62	460	---	---			
CB-6	Caltrans - Boring I-40	Closed	Mar-62	460	---	---			
CB-7	Caltrans - Boring I-40	Closed	Mar-62	459	---	---			
CB-8	Caltrans - Boring I-40	Closed	Mar-62	460	---	---			
CB-9	Caltrans - Boring I-40	Closed	Mar-62	461	---	---			

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Location ID	Investigation Program & Well Type [1]	Status [2]	Date Installed	Ground Elevation (feet MSL)	Screen Interval (feet bgs)	Monitoring Zone [3]	Additional Characterization [4]		
							Geophys	Gr-Size	Hyd Test
Exploratory & Test Borings									
CB-10	Caltrans - Boring I-40	Closed	Mar-62	459	---	---			
CB-11	Caltrans - Boring I-40	Closed	Mar-62	459	---	---			
CB-12	Caltrans - Boring I-40	Closed	May-62	458	---	---			
CB-13	Caltrans - Boring I-40	Closed	Mar-62	458	---	---			
CB-14	Caltrans - Boring I-40	Closed	Mar-62	458	---	---			
IW-1	IM - Boring	Closed	Nov-04	545	---	---	X		
PE-1A	IM - Boring	Closed	Feb-05	461	---	---			
PE-1B	IM - Boring	Closed	Feb-05	459	---	---			
PM-B1	SBC Park Maobi - Boring	Closed	Mar-86	475	---	---			
PM-B2	SBC Park Maobi - Boring	Closed	Mar-86	495	---	---			
XMW-9	RFI - Boring	Closed	Jun-97	536	---	---			

Notes:

Boring and well constuction logs included in Appendex B

[1] Investigation Programs:

CMP	Compliance Monitoring Program, for IM No. 3 injection well field
IM	Interim Measures, includes IM No. 3 investigations and well installation
ISPT	In-situ Pilot Test, includes Floodplain and Upland test areas
New Ponds	TCS evaporation ponds, current operated site with active monitoring WDR
Old Ponds	TCS former, closed evaporation pond site
RFI	RCRA Facility Investigation / Remedial Investigation
SBC	San Bernardino County, Park Moabi water supply
TCS	PGE's Topock Compressor Station, operations facilities
TM	Topock Marina underground storage tank (UST) investigation

[2] Location status (as of October 2007):

Active	Well used in current PGE monitoring, testing, or compliance project
Standby	Existing well (servicable condition) not used in current monitoring
Inactive	Existing well (closed condition)
Decomm	Destroyed, permanently abandoned well
Closed	Exploratory or test boring, closed and sealed after logging
Unknown	Well status unknown

[3] Monitoring zone:

SA	Shallow zone of the Alluvial Aquifer completed in alluvial fan deposits (alluvial) or Colorado River deposits (fluvial)
MA	Mid-depth zone of the Alluvial Aquifer completed in alluvial fan deposits (alluvial) or Colorado River deposits (fluvial)
DA	Deep zone of the Alluvial Aquifer completed in alluvial fan deposits (alluvial) or Colorado River deposits (fluvial)
BR-Tmc	Bedrock well; completed in Miocene Conglomerate
BR-pTbr	Bedrock well; completed in pre-Tertiary metamorphic and igneous bedrock.

[4] Additional Characterization:

Geophy	Wireline geophysical log (Appendix C this report)
Gr-Size	Sediment grain-size analysis (Appendix B4 this report)
Hyd Test	Hydraulic test preformed (constant discharge or single-well recovery/slug test; Appendix H)

Additional Abbreviations:

ATSF	Atchison, Topeka and Santa Fe Railway
MSL	Feet above mean sea level; ground elevations rounded to whole foot for presentation.
bgs	Feet below ground surface; well screen depths rounded to whole foot for presentation.
---	data not available or not applicable

TABLE 4-3
Summary of Hydraulic Tests for Hydrogeologic Characterization
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PG&E Topock Compressor Station

Wells Tested	Well Type	HSU / Aquifer Tested	Hydraulic Tests	Test Date	Reference
Pre-RFI Hydraulic Testing					
PT-1	test well (New Ponds)	Toa - alluvial	Constant Rate Test	14-Jan-87	PG&E-TES, 1995
MWP-3	monitoring well (Old Ponds)	Toa - alluvial	Constant Rate Test	2-Aug-92	PG&E-TES, 1995
MWP-8, -9, -10, -12	monitoring well (Old Ponds)	Toa - alluvial	Recovery (Slug) Test	2-Aug-92	PG&E-TES, 1995
MWP-14, -15, -16	monitoring well (Old Ponds)	Toa - alluvial	Recovery (Slug) Test	2-Aug-92	PG&E-TES, 1995
RFI - 2002 Hydraulic Testing					
MW-20-100	monitoring well	Toa - alluvial	Constant Rate Test	29-Jan-02	E&E, 2002
MW-20-130	monitoring well	Toa - alluvial	Constant Rate Test	30-Jan-02	E&E, 2002
MW-24B	monitoring well	Toa - alluvial	Constant Rate Test	31-Jan-02	E&E, 2002
MW-23	monitoring well	Tmc - bedrock	Recovery (Slug-out) Test	31-Jan-02	E&E, 2002
MW-24BR	monitoring well	pTbr - bedrock	Recovery (Slug-out) Test	29-Jan-02	E&E, 2002
MW-27	monitoring well	Qr3 - fluvial	Recovery (Slug-in) Test	30-Jan-02	E&E, 2002
MW-28-25	monitoring well	Qr3 - fluvial	Recovery (Slug-in) Test	1-Feb-02	E&E, 2002
MW-30-30	monitoring well	Qr3 - fluvial	Recovery (Slug-in) Test	1-Feb-02	E&E, 2002
IM Investigation Testing					
TW-1	test well	Toa - alluvial	Step Test	21-Nov-03	CH2M HILL, 2003e
			Spinner Test Velocity Log	15-Dec-03	CH2M HILL, 2003e
TW-2S	extraction well	Toa - alluvial	Constant Rate Test	30-Apr-04	CH2M HILL, 2005a
TW-2D	extraction well	Toa - alluvial	Constant Rate Test	5-May-04	CH2M HILL, 2005a
TW-2S & TW-2D	extraction well	Toa - alluvial	Constant Rate Test	9-May-04	CH2M HILL, 2005a
TW-3D	extraction well	Toa - alluvial	Step Test	17-Nov-05	CH2M HILL, 2005u
			Constant Rate Test	19-Dec-05	CH2M HILL, 2005u
PE-1	extraction well	Qr1 - fluvial	Step Test	5-Mar-05	CH2M HILL, 2005v
TW-4	test well	Toa - alluvial	Constant Rate Test	13-Jun-06	CH2M HILL, 2006o
TW-5	test well	Toa - alluvial	Step Test	6-May-06	CH2M HILL, 2006o
			Constant Rate Test	11-May-06	CH2M HILL, 2006o
MW-26	monitoring well	Toa - alluvial	Constant Rate Extraction Test	12-May-06	CH2M HILL, 2006o
MW-51	monitoring well	Toa - alluvial	Constant Rate Extraction Test	12-May-06	CH2M HILL, 2006o
IM Injection Area Testing					
IW-2	injection well	Toa - alluvial	Constant Rate Extraction Test	6-Jan-05	CH2M HILL, 2005w
			Constant Rate Injection Test #1	8-Jan-05	CH2M HILL, 2005w
			Constant Rate Injection Test #2	9-Jan-05	CH2M HILL, 2005w
			Step Test	22-Dec-05	CH2M HILL, 2005w
			Spinner Test Velocity Log	22-Dec-05	CH2M HILL, 2005w
IW-3	injection well	Toa - alluvial	Constant Rate Extraction Test	14-Jan-05	CH2M HILL, 2005w
			Constant Rate Injection Test	20-Jan-05	CH2M HILL, 2005w
			Step Test	14-Jan-05	CH2M HILL, 2005w
			Spinner Test Velocity Log	12-Jan-05	CH2M HILL, 2005w
Bedrock Hydraulic Testing					
PGE-8	former injection well	pTbr - bedrock	Constant Rate Extraction Test	11-Aug-07	CH2M HILL, 2008i
			Constant Rate Injection Test	19-Aug-07	CH2M HILL, 2008i
PGE-7BR	test well	pTbr - bedrock	Recovery (Slug-out) Test	14-Nov-07	CH2M HILL, 2008i
MW-48	monitoring well	Tmc - bedrock	Recovery (Slug-out) Test	4-Oct-07	CH2M HILL, 2008i

Notes:

1. Aquifer types and site hydrostratigraphic units (HSUs) are defined in Table 3-1
2. Test plots and documentation for the hydraulic tests listed are included in Appendix D

TABLE 4-4

Sampling Record for Groundwater Monitoring Locations, July 1997 through October 2007

RCRA Facility Investigation/Remedial Investigation (Volume 2)

PG&E Topock Compressor Station, Needles, California

Monitoring Events used in RFI/RI Characterization[1]

Well ID	Monitored Zone [2]	1997-2002	2003	2004	2005	2006	2007	Number of Sample Events
Groundwater Monitoring Wells								
MW-1	SA	14	2		2			18
MW-3	SA	14	2		2			18
MW-4	SA	14	2		2			18
MW-5	SA	14	2		2			18
MW-6	SA	14	2		2			18
MW-7	SA	14	2		2			18
MW-8	SA	14	2		2			18
MW-9	SA	19	4	4	5	2	3	37
MW-10	SA	19	4	4	5	4	3	39
MW-11	SA	19	4	4	5	3	3	38
MW-12	SA	19	4	3	6	4	3	39
MW-13	SA	19	4	5	4	4	2	38
MW-14	SA	18	4	5	6	4	2	39
MW-15	SA	17	4	4	3	2	3	33
MW-16	SA	15	4	3	5	4	1	32
MW-17	SA	13	3	3	5	4	1	29
MW-18	SA	16	4	6	7	5	2	40
MW-19	SA	15	4	4	4	5	3	35
MW-20-70	SA	16	4	6	5	5	3	39
MW-20-100	MA	15	4	6	4	4	3	36
MW-20-130	DA	15	4	5	6	4	3	37
MW-21	SA	15	5	10	4	4	3	41
MW-22	SA	17	4	4	4	3	2	34
MW-23	BR-Tmc	16	4	4	4	4	3	35
MW-24A	SA	16	4	4	4	3	3	34
MW-24B	DA	15	4	4	4	4	3	34
MW-24BR	BR-pTbr	16	4	4	2	4	3	33
MW-25	SA	14	4	5	5	3	3	34
MW-26	SA	15	4	6	4	3	2	34
MW-27-20	SA	16	5	36	8	4	1	70
MW-27-60	MA				14	3	1	18
MW-27-85	DA				19	12	10	41
MW-28-25	SA	16	5	36	9	3	1	70
MW-28-90	DA			12	19	11	3	45
MW-29	SA	16	4	13	8	3	1	45
MW-30-30	SA	16	5	35	7	3	1	67
MW-30-50	MA		5	35	7	3		50
MW-31-60	SA	15	4	7	5	3	2	36

TABLE 4-4
Sampling Record for Groundwater Monitoring Locations, July 1997 through October 2007
RCRA Facility Investigation/Remedial Investigation (Volume 2)
PG&E Topock Compressor Station, Needles, California

		Monitoring Events used in RFI/RI Characterization[1]						
Well ID	**Monitored Zone [2]**	**1997-2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**Number of Sample Events**
Groundwater Monitoring Wells								
MW-31-135	DA			4	4	3	3	14
MW-32-20	SA		5	14	8	4	3	34
MW-32-35	SA		5	14	8	4	3	34
MW-33-40	SA		5	13	8	4	3	33
MW-33-90	MA		4	30	15	5	3	57
MW-33-150	DA				9	11	3	23
MW-33-210	DA				9	12	3	24
MW-34-55	MA		4	35	8	3	1	51
MW-34-80	DA		4	41	23	12	10	90
MW-34-100	DA				32	27	20	79
MW-35-60	SA			4	4	4	2	14
MW-35-135	DA			4	4	4	3	15
MW-36-20	SA			6	7	3	1	17
MW-36-40	SA			6	7	3	1	17
MW-36-50	MA			6	7	3	1	17
MW-36-70	MA			6	7	10	3	26
MW-36-90	DA			6	11	12	10	39
MW-36-100	DA			12	17	12	10	51
MW-37S	MA			4	5	4	2	15
MW-37D	DA			4	4	5	3	16
MW-38S	SA			4	3	3	1	11
MW-38D	DA			4	3	2	3	12
MW-39-40	SA			6	8	4	3	21
MW-39-50	MA			6	8	4	1	19
MW-39-60	MA			6	8	4	1	19
MW-39-70	MA			6	8	10	5	29
MW-39-80	DA			6	12	12	10	40
MW-39-100	DA			6	13	12	10	41
MW-40S	SA			4	5	4	1	14
MW-40D	DA			4	4	4	3	15
MW-41S	SA			2	4	3	2	11
MW-41M	DA			2	4	3	2	11
MW-41D	DA			2	4	3	2	11
MW-42-30	SA				4	3	2	9
MW-42-55	MA				4	4	3	11
MW-42-65	MA				4	4	3	11
MW-43-25	SA				5	3	2	10
MW-43-75	DA				9	7	3	19

TABLE 4-4

Sampling Record for Groundwater Monitoring Locations, July 1997 through October 2007

RCRA Facility Investigation/Remedial Investigation (Volume 2)

PG&E Topock Compressor Station, Needles, California

		Monitoring Events used in RFI/RI Characterization[1]						
Well ID	**Monitored Zone[2]**	**1997-2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**Number of Sample Events**
Groundwater Monitoring Wells								
MW-43-90	DA				9	7	3	19
MW-44-70	MA					8	3	11
MW-44-115	DA					21	10	31
MW-44-125	DA					20	10	30
MW-45-095a	DA					2	1	3
MW-45-095b	DA					1		1
MW-46-175	DA					18	10	28
MW-46-205	DA					10	3	13
MW-47-55	SA					4	3	7
MW-47-115	DA					4	3	7
MW-48	BR-Tmc					4	3	7
MW-49-135	DA					4	3	7
MW-49-275	DA					4	3	7
MW-49-365	DA					4	3	7
MW-50-095	MA					4	3	7
MW-50-200	DA					4	3	7
MW-51	MA					4	3	7
MW-52S	MA						7	7
MW-52M	DA						7	7
MW-52D	DA						7	7
MW-53M	DA						7	7
MW-53D	DA						7	7
MWP-12	SA		1					1
CW-1M	MA				4	2	2	8
CW-1D	DA				4	2	2	8
CW-2M	MA				4	2	2	8
CW-2D	DA				4	2	2	8
CW-3M	MA				4	2	3	9
CW-3D	DA				4	2	2	8
CW-4M	MA				4	2	3	9
CW-4D	DA				4	2	2	8
OW-1S	SA			1	7	4	4	16
OW-1M	MA			3	8	4	4	19
OW-1D	DA			3	8	4	4	19
OW-2S	SA			1	7	5	5	18
OW-2M	MA				9	4	5	18
OW-2D	DA				9	4	4	17
OW-3S	SA			3	1	2	3	9

TABLE 4-4

Sampling Record for Groundwater Monitoring Locations, July 1997 through October 2007

RCRA Facility Investigation/Remedial Investigation (Volume 2)

PG&E Topock Compressor Station, Needles, California

		Monitoring Events used in RFI/RI Characterization[1]						
Well ID	**Monitored Zone[2]**	**1997-2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**Number of Sample Events**
Groundwater Monitoring Wells								
OW-3M	MA			3	1	3	3	10
OW-3D	DA			3	1	2	2	8
OW-5S	SA			1	8	4	5	18
OW-5M	DA				9	4	4	17
OW-5D	DA			1	8	4	4	17
PGE-7BR	BR-pTbr						1	1
Extraction, Test & Injection Wells								
P-2	DA				4	2	1	7
PE-1	DA				3	13	8	24
PGE-8	BR-pTbr	15	1		1		1	18
TW-1	SA-MA-DA			2	1		1	4
TW-2S	SA-MA			4	3	3	1	11
TW-2D	DA			4	3	6	1	14
TW-3D	DA					14	8	22
TW-4	DA					3	2	5
TW-5	DA					3	1	4
In-Situ Pilot Test Wells (Baseline Sampling)								
PT-1S	SA					2		2
PT-1M	MA					2		2
PT-1D	DA					2		2
PT-2S	SA					2		2
PT-2M	MA					2		2
PT-2D	DA					2		2
PT-3S	SA					2		2
PT-3M	MA					2		2
PT-3D	DA					2		2
PT-4S	SA					2		2
PT-4M	MA					2		2
PT-4D	DA					2		2
PT-5S	SA					2		2
PT-5M	MA					2		2
PT-5D	DA					2		2
PT-6S	SA					2		2
PT-6M	MA					2		2
PT-6D	DA					2		2
PT-7S	SA						1	1
PT-7M	MA						1	1
PT-7D	DA						1	1

TABLE 4-4

Sampling Record for Groundwater Monitoring Locations, July 1997 through October 2007

RCRA Facility Investigation/Remedial Investigation (Volume 2)

PG&E Topock Compressor Station, Needles, California

		Monitoring Events used in RFI/RI Characterization[1]						
Well ID	**Monitored Zone[2]**	**1997-2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**Number of Sample Events**
In-Situ Pilot Test Wells (Baseline Sampling)								
PT-8S	SA						1	1
PT-8M	MA						1	1
PT-8D	DA						1	1
PT-9S	SA						1	1
PT-9M	MA						1	1
PT-9D	DA						1	1
PTI-1S	SA					2		2
PTI-1M	MA					2		2
PTI-1D	DA					2		2
PTR-1	MA-DA						1	1
PTR-2	MA-DA						1	1
Water Supply Wells								
PGE-6	SA-MA	16	2		1			19
PGE-7	DA-BR-pTbr	14	1		1			16
PGE-9N	MA-DA				2			2
PGE-9S	MA-DA				4	2		6
Park Moabi-3	MA	16	3	5	8	5	2	39
Park Moabi-4	MA						3	3
Sanders	SA			1	4	2		7

Notes:

[1] Monitoring Events:
Table summarizes the number of sampling events, July 1997 through October 2007, that were used for groundwater characterization for the RFI/RI. New bedrock monitoring well PGE-7BR was first sampled in December 2007 and is included in the RFI/RI characterization. Parameters sampled include the site COPCs (all events) and general chemistry and other metals (selected events/wells).

[2] Monitoring Zone:
SA - Shallow zone of the Alluvial Aquifer
MA - Mid-depth zone of the Alluvial Aquifer
DA - Deep zone of the Alluvial Aquifer
BR-Tmc - Bedrock well, completed in Miocene Conglomerate
BR-pTbr - Bedrock well, completed in pre-Tertiary crystalline bedrock

TABLE 4-5
Sampling Record for Surface Water Monitoring Locations, July 1997 through October 2007
RCRA Facility Investigation/Remedial Investigation (Volume 2)
PG&E Topock Compressor Station, Needles, California

Monitoring Events used in RFI/RI Characterization

Station ID	Monitored Zone	1997-2002	2003	2004	2005	2006	2007	Number of Sample Events
Shoreline Surface Water Locations								
A-Dock	River	4	1	1				6
CON	River	22	4	11	15	12	7	71
I-3	River	20	4	11	12	12	7	66
Needles Gauge	River		1	1				2
NR-1	River	1	1	11	12	12	7	44
NR-2	River	1	1	11	12	12	7	44
NR-3	River			11	12	12	7	42
R-19	River	1						1
R-19-B	River	1						1
R-19-C	River	1						1
R-20	River	1						1
R-20-B	River	1						1
R-20-C	River	1						1
R-22	River	15	4	11	15	12	7	64
R-27	River	16	4	12	15	12	7	66
R-28	River	16	4	12	12	12	7	63
RRB	River	16	4	11	9	11	7	58
Seasonal Wetlands	River	8						8
In-Channel Surface Water Locations								
C-CON	River				4	6	8	18
C-I-3	River				4	6	8	18
C-MAR	River				3	6	8	17
C-NR1	River				4	6	8	18
C-NR3	River				4	6	8	18
C-NR4	River				4	6	8	18
C-R22	River				4	6	8	18
C-R27	River				4	6	8	18
C-TAZ	River				4	6	8	18
Pore Water Study Surface Water Locations								
SW-1B	River					1		1
SW-2B	River					1		1
SW-3B	River					1		1
SW-4B	River					1		1
SW-5B	River					1		1
SW-6B	River					1		1
SW-7B	River					1		1
SW-8B	River					1		1
SW-9B	River					1		1

TABLE 4-5

Sampling Record for Surface Water Monitoring Locations, July 1997 through October 2007

RCRA Facility Investigation/Remedial Investigation (Volume 2)

PG&E Topock Compressor Station, Needles, California

Monitoring Events used in RFI/RI Characterization

Station ID	Monitored Zone	1997-2002	2003	2004	2005	2006	2007	Number of Sample Events
Pore Water Study Surface Water Locations								
SW-10B	River					1		1
SW-11B	River					1		1
SW-12B	River					1		1
SW-13B	River					1		1
SW-14B	River					1		1
SW-15B	River					1		1
SW-16B	River					1		1

NOTES:

Table summarizes the number of sampling events, July 1997 through October 2007, that were used for surface water characterization for the RFI/RI.

TABLE 4-6

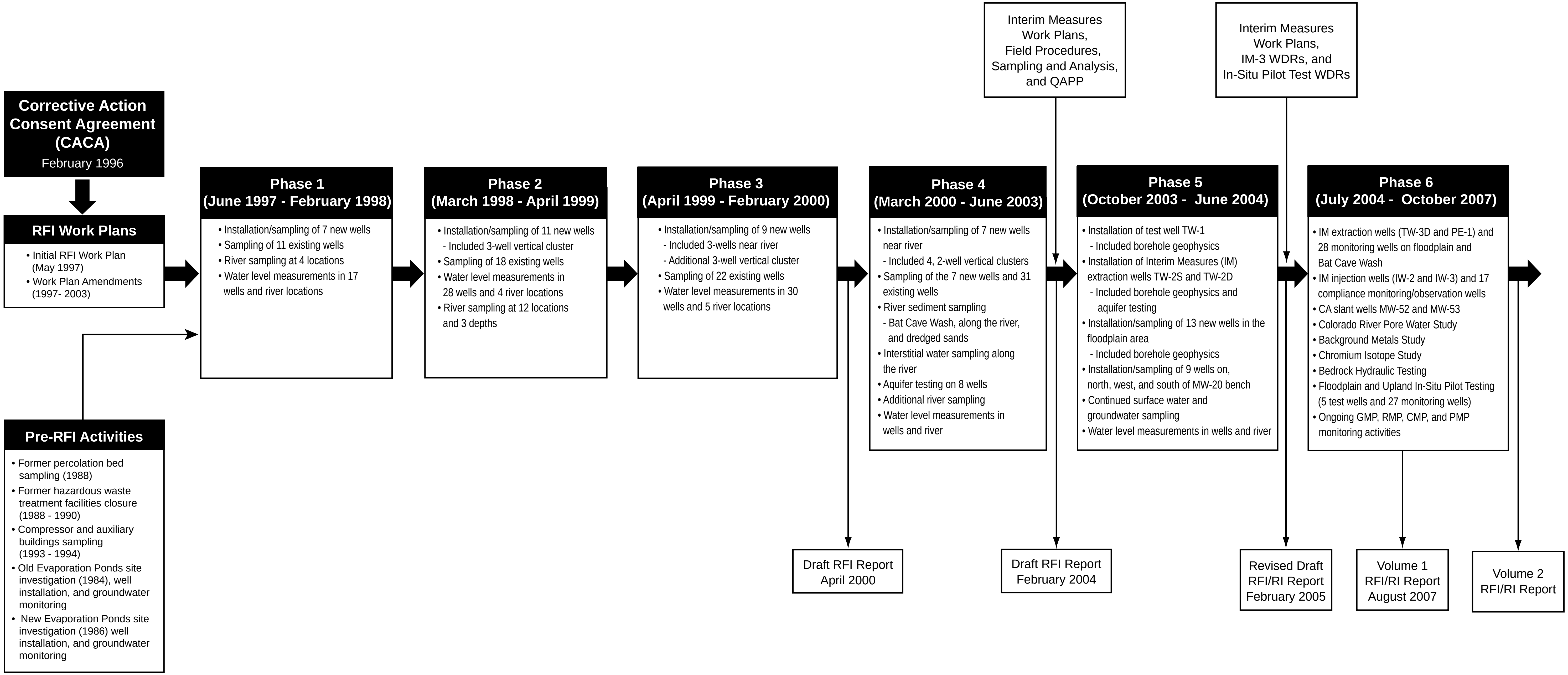
Summary of Related Investigation and Characterization Studies to Supplement the Groundwater RFI/RI

RCRA Facility Investigation/Remedial Investigation Report (Volume 2)

PG&E Topock Compressor Station

Groundwater Characterization Activity / Study	Status (December 2008)	Investigation / Study Report	RCRA/CERCLA Document with Findings Incorporated
Completed or Ongoing Activities			
Groundwater Background Study	Completed January 2008	CH2M HILL, 2008b	RFI/RI Report Vol. 2 and Groundwater Risk Assessment Report
Chromium Isotope Study	Completed May 2008	CH2M HILL, 2008g	RFI/RI Report Vol. 2
Floodplain *In-Situ* Pilot Study	Testing completed November 2007 Monitoring continues through 2009	ARCADIS, 2008b	CMS/FS Report
Upland *In-Situ* Pilot Study	Testing completed December 2008 Monitoring continues through 2009	ARCADIS, 2008c	CMS/FS Report
Aerobic/Anaerobic Core Testing	Completed June 2008	CH2M HILL, 2008a	CMS/FS Report
Arizona Groundwater Investigation	Well installation completed August 2008. Monitoring continues through March 2009	CH2M HILL, 2008h	RFI/RI Report Vol. 2 Addendum
Hydraulic Analysis of May 2008 IM No. 3 Extraction Shut-down	Completed September 2008	NA	RFI/RI Report Vol. 2 Addendum
Soil Investigation outside of Compressor Station	Completed October 2008	future Tech Memo (anticipate Second Quarter 2009)	RFI/RI Report Vol. 3
Planned and Scheduled Activities			
East Ravine Groundwater Investigation	Start field work in January 2009	future Tech Memo (anticipate Second Quarter 2009)	RFI/RI Report Vol. 3
Soil and Groundwater Investigation inside Topock Compressor Station	Proposal submitted in September 2008, currently in agencies review	future Investigation Report	RFI/RI Report Vol. 3

NA denotes not applicable



Corrective Action Consent Agreement (CACA)
February 1996

RFI Work Plans
- Initial RFI Work Plan (May 1997)
- Work Plan Amendments (1997- 2003)

Pre-RFI Activities
- Former percolation bed sampling (1988)
- Former hazardous waste treatment facilities closure (1988 - 1990)
- Compressor and auxiliary buildings sampling (1993 - 1994)
- Old Evaporation Ponds site investigation (1984), well installation, and groundwater monitoring
- New Evaporation Ponds site investigation (1986) well installation, and groundwater monitoring

Phase 1 (June 1997 - February 1998)
- Installation/sampling of 7 new wells
- Sampling of 11 existing wells
- River sampling at 4 locations
- Water level measurements in 17 wells and river locations

Phase 2 (March 1998 - April 1999)
- Installation/sampling of 11 new wells
  - Included 3-well vertical cluster
- Sampling of 18 existing wells
- Water level measurements in 28 wells and 4 river locations
- River sampling at 12 locations and 3 depths

Phase 3 (April 1999 - February 2000)
- Installation/sampling of 9 new wells
  - Included 3-wells near river
  - Additional 3-well vertical cluster
- Sampling of 22 existing wells
- Water level measurements in 30 wells and 5 river locations

Phase 4 (March 2000 - June 2003)
- Installation/sampling of 7 new wells near river
  - Included 4, 2-well vertical clusters
- Sampling of the 7 new wells and 31 existing wells
- River sediment sampling
  - Bat Cave Wash, along the river, and dredged sands
- Interstitial water sampling along the river
- Aquifer testing on 8 wells
- Additional river sampling
- Water level measurements in wells and river

Interim Measures Work Plans, Field Procedures, Sampling and Analysis, and QAPP

Phase 5 (October 2003 - June 2004)
- Installation of test well TW-1
  - Included borehole geophysics
- Installation of Interim Measures (IM) extraction wells TW-2S and TW-2D
  - Included borehole geophysics and aquifer testing
- Installation/sampling of 13 new wells in the floodplain area
  - Included borehole geophysics
- Installation/sampling of 9 wells on, north, west, and south of MW-20 bench
- Continued surface water and groundwater sampling
- Water level measurements in wells and river

Interim Measures Work Plans, IM-3 WDRs, and In-Situ Pilot Test WDRs

Phase 6 (July 2004 - October 2007)
- IM extraction wells (TW-3D and PE-1) and 28 monitoring wells on floodplain and Bat Cave Wash
- IM injection wells (IW-2 and IW-3) and 17 compliance monitoring/observation wells
- CA slant wells MW-52 and MW-53
- Colorado River Pore Water Study
- Background Metals Study
- Chromium Isotope Study
- Bedrock Hydraulic Testing
- Floodplain and Upland In-Situ Pilot Testing (5 test wells and 27 monitoring wells)
- Ongoing GMP, RMP, CMP, and PMP monitoring activities

Draft RFI Report
April 2000

Draft RFI Report
February 2004

Revised Draft RFI/RI Report
February 2005

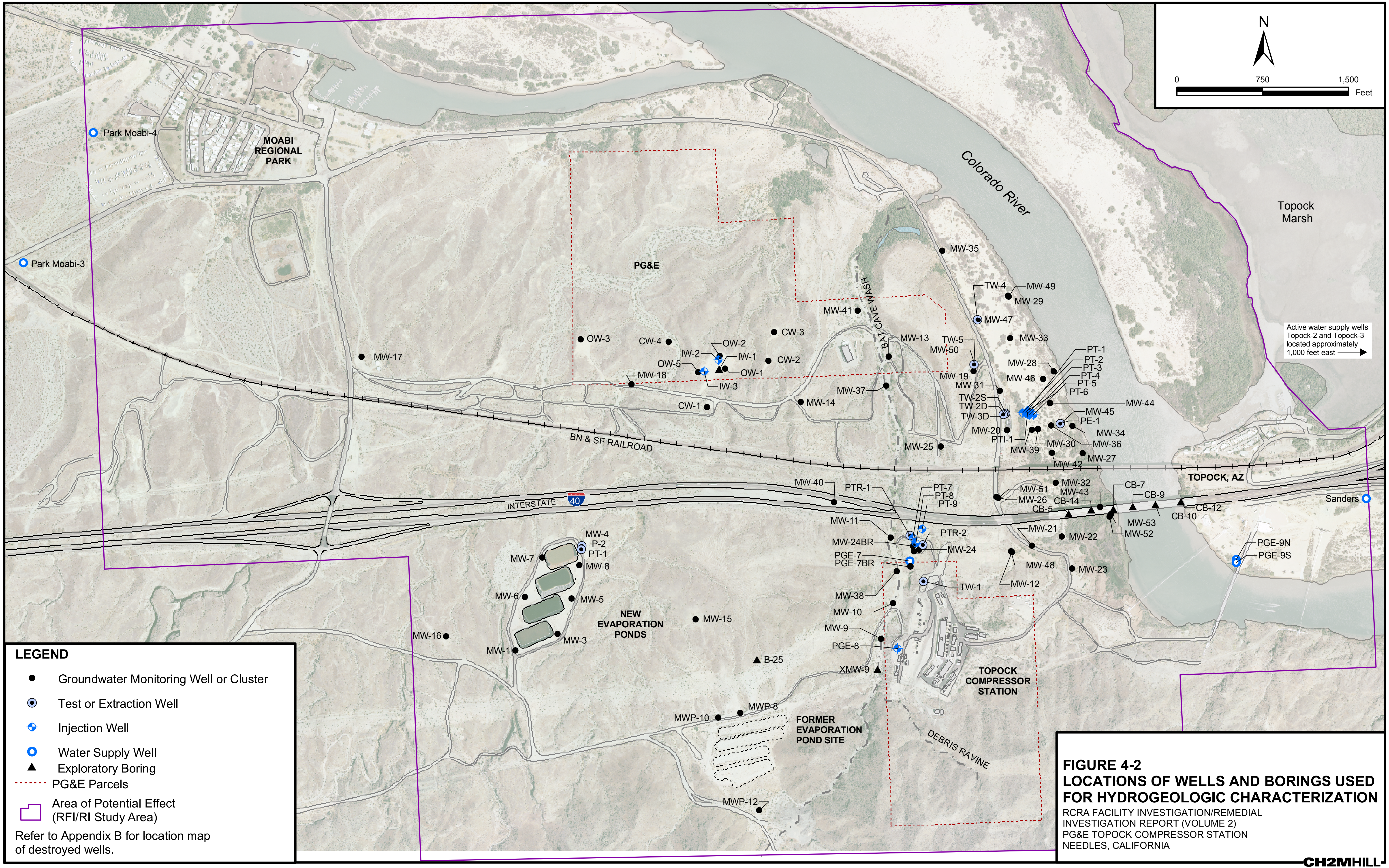
Volume 1 RFI/RI Report
August 2007

Volume 2 RFI/RI Report

LEGEND

QAPP	Quality Assurance Program Plan
WDR	Waste Discharge Requirements
GMP	Groundwater Monitoring Program
RMP	River Monitoring Program
CMP	Compliance Monitoring Program
PMP	Performance Monitoring Program

FIGURE 4-1
OUTLINE OF GROUNDWATER, SURFACE WATER, PORE WATER, AND RIVER SEDIMENT RFI/RI PHASES
RCRA FACILITY INVESTIGATION/REMEDIAL INVESTIGATION REPORT (VOLUME 2)
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA



LEGEND

- ● Groundwater Monitoring Well or Cluster
- ◉ Test or Extraction Well
- ⊕ Injection Well
- ○ Water Supply Well
- ▲ Exploratory Boring
- - - - PG&E Parcels
- ▭ Area of Potential Effect (RFI/RI Study Area)

Refer to Appendix B for location map of destroyed wells.

FIGURE 4-2
LOCATIONS OF WELLS AND BORINGS USED FOR HYDROGEOLOGIC CHARACTERIZATION

RCRA FACILITY INVESTIGATION/REMEDIAL
INVESTIGATION REPORT (VOLUME 2)
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

CH2MHILL

BAO \\ZINFANDEL\PROJ\PACIFICGASELECTRICCO\TOPOCKPROGRAM\GIS\MAPFILES\2007\RFI\FIGURE4-2.MXD FIGURE4-2.MXD 12/10/2008 13:15:36

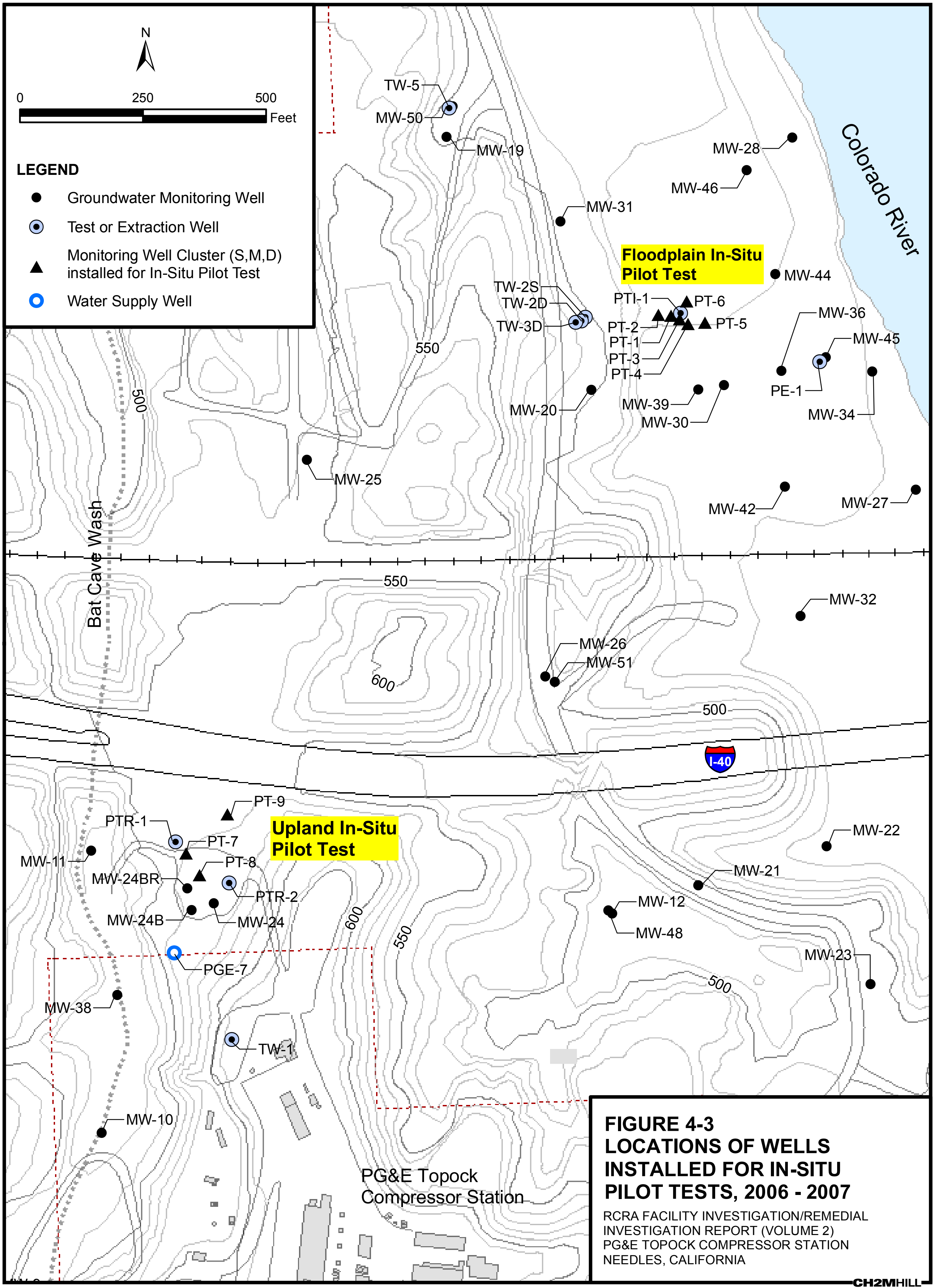
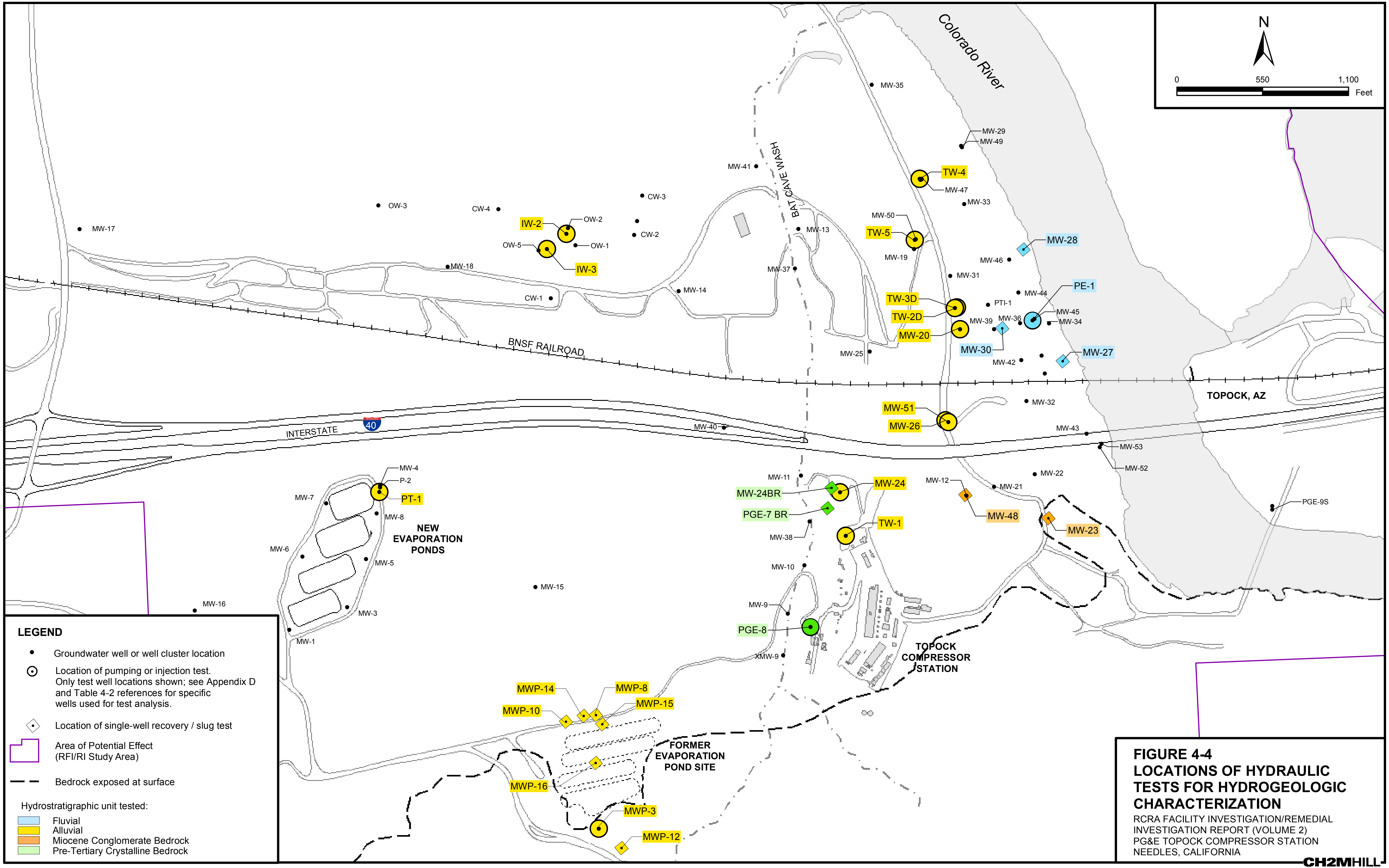


FIGURE 4-3
LOCATIONS OF WELLS INSTALLED FOR IN-SITU PILOT TESTS, 2006 - 2007

RCRA FACILITY INVESTIGATION/REMEDIAL INVESTIGATION REPORT (VOLUME 2)
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

CH2MHILL



LEGEND

- ● Groundwater well or well cluster location
- ⊙ Location of pumping or injection test. Only test well locations shown; see Appendix D and Table 4-2 references for specific wells used for test analysis.
- ◇ Location of single-well recovery / slug test
- ▭ Area of Potential Effect (RFI/RI Study Area)
- — — Bedrock exposed at surface

Hydrostratigraphic unit tested:

- 🟦 Fluvial
- 🟨 Alluvial
- 🟧 Miocene Conglomerate Bedrock
- 🟩 Pre-Tertiary Crystalline Bedrock

FIGURE 4-4
LOCATIONS OF HYDRAULIC TESTS FOR HYDROGEOLOGIC CHARACTERIZATION

RCRA FACILITY INVESTIGATION/REMEDIAL
INVESTIGATION REPORT (VOLUME 2)
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

CH2MHILL

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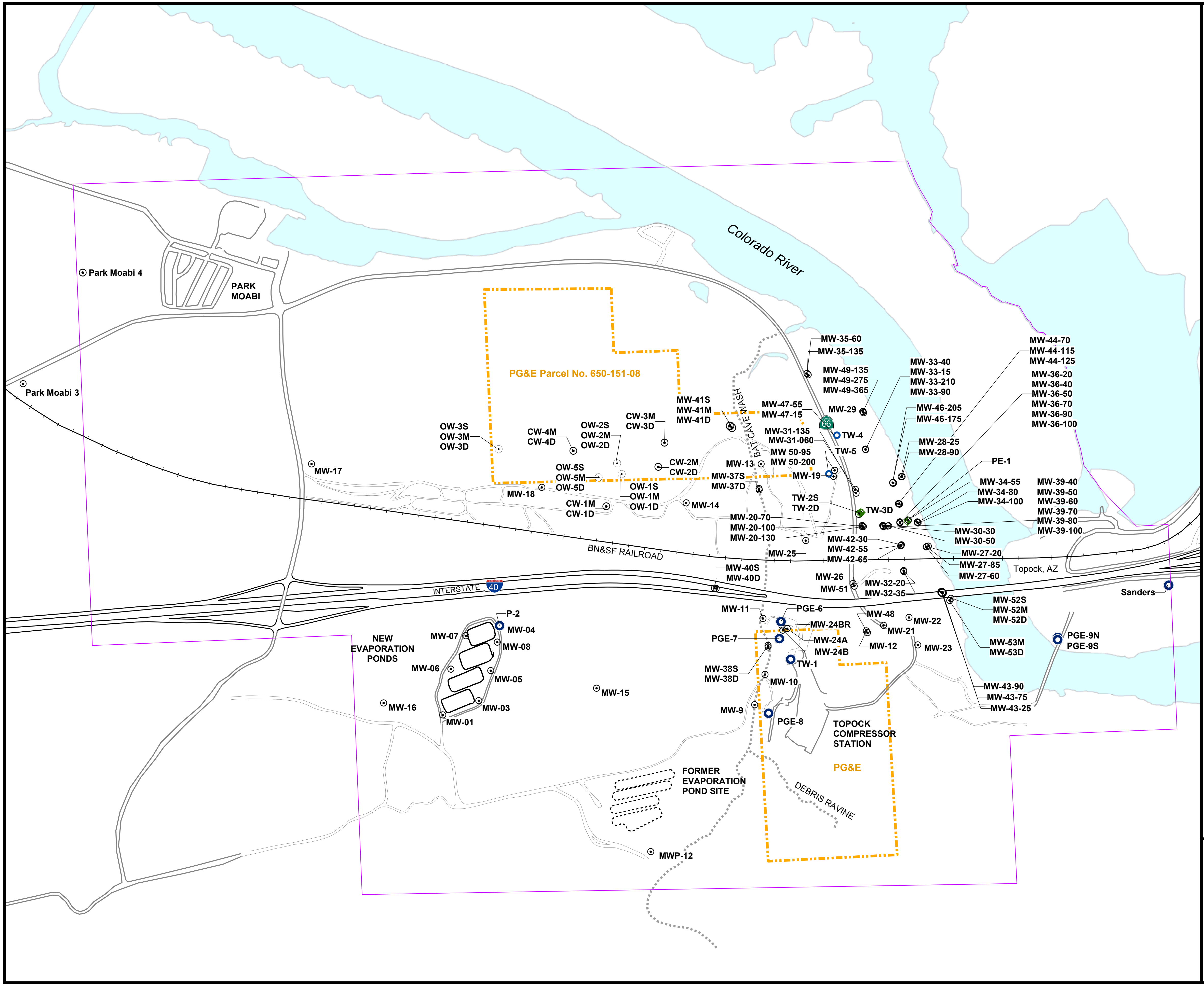

LEGEND

⊙ Groundwater Monitoring Well

○ Test Well or Supply Well (Inactive)

⊕ Extraction Well

- · - · PG&E Property Boundary

☐ Area of Potential Effect

Map shows all wells which provided the water quality data used for RFI/RI groundwater characterization (July 1997 to October 2007). Water quality data from baseline sampling of Floodplain and Upland In-situ Pilot Test wells was used. See Figure 4-3 for pilot test well locations.

FIGURE 4-5
GROUNDWATER SAMPLING LOCATIONS FOR RFI/RI CHARACTERIZATION

RCRA FACILITY INVESTIGATION/REMEDIAL INVESTIGATION REPORT (VOLUME 2)
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

CH2MHILL

\\ZINFANDEL\PROJ\PACIFICGASELECTRICCO\TOPOCKPROGRAM\GIS\MAPFILES\2007\RFI\FIGURE4-4.MXD FIG4-5GW_SAMPLING 1/22/2008 12:37:23

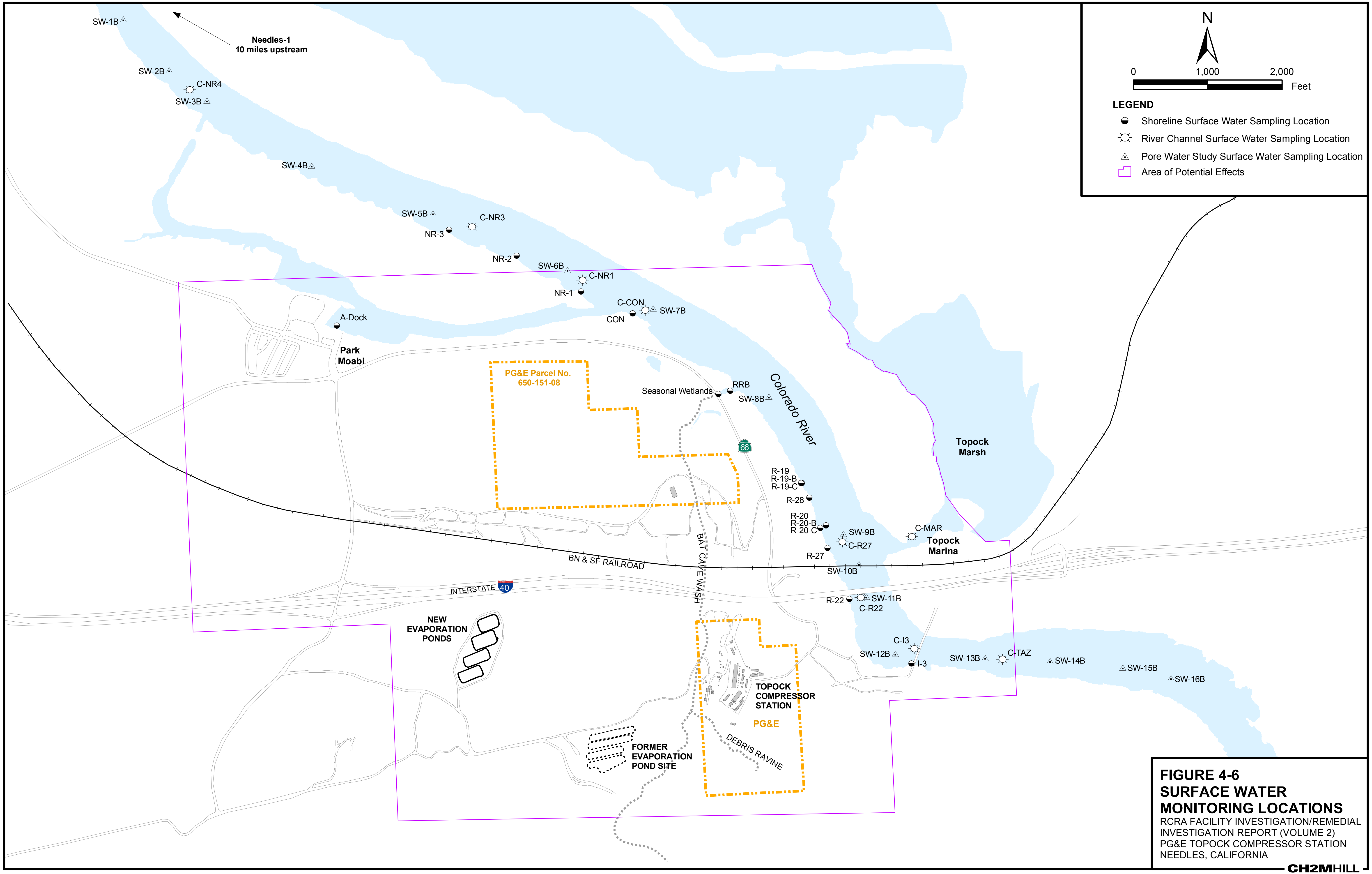

FIGURE 4-6
SURFACE WATER MONITORING LOCATIONS

RCRA FACILITY INVESTIGATION/REMEDIAL
INVESTIGATION REPORT (VOLUME 2)
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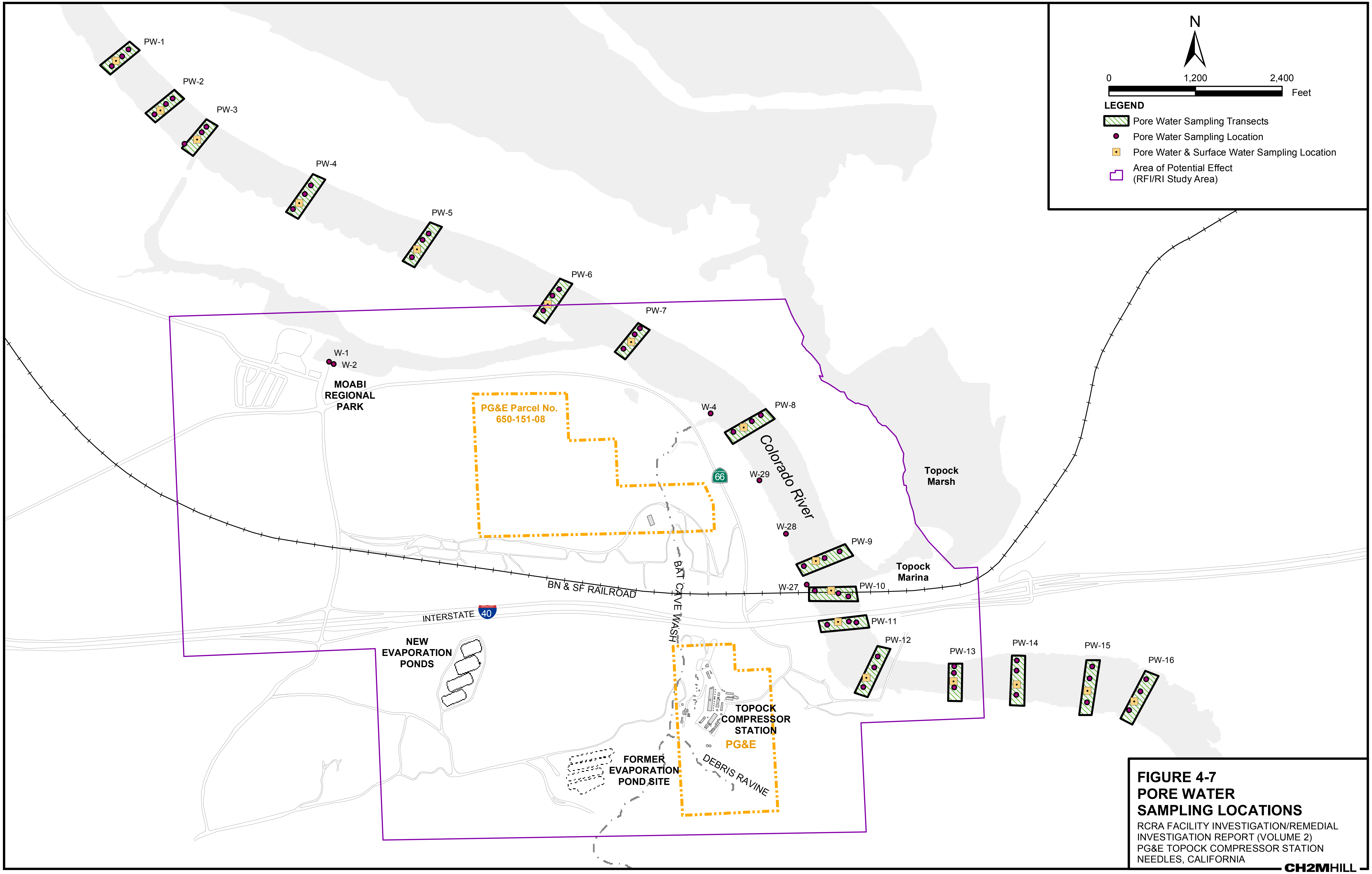

FIGURE 4-7
PORE WATER SAMPLING LOCATIONS

RCRA FACILITY INVESTIGATION/REMEDIAL
INVESTIGATION REPORT (VOLUME 2)
PG&E TOPOCK COMPRESSOR STATION
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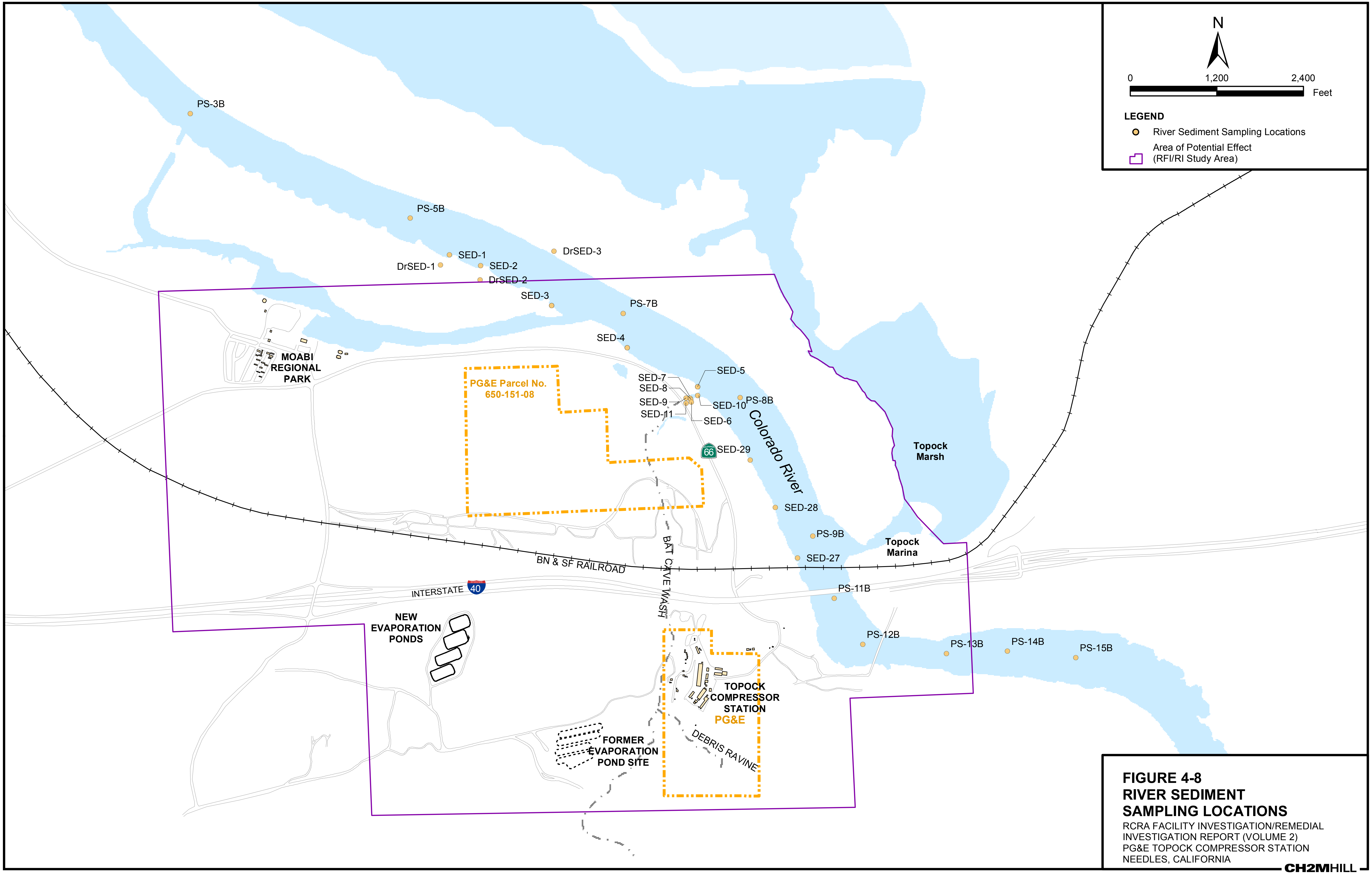

FIGURE 4-8
RIVER SEDIMENT SAMPLING LOCATIONS

RCRA FACILITY INVESTIGATION/REMEDIAL
INVESTIGATION REPORT (VOLUME 2)
PG&E TOPOCK COMPRESSOR STATION
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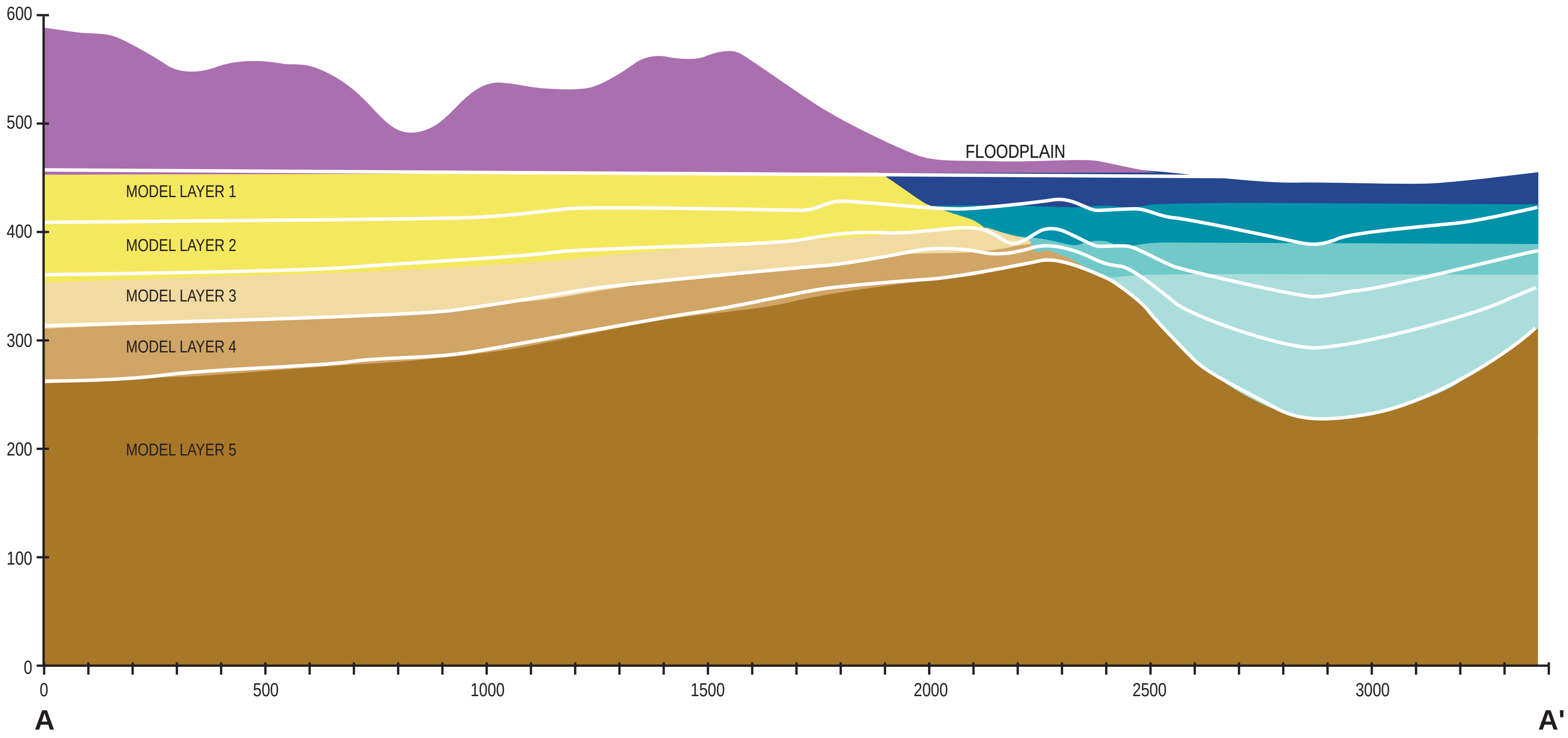
\\ZINFANDEL\PROJ\PACIFICGASELECTRICCO\TOPOCKPROGRAM\GIS\MAPFILES\2007\RFI\FIGURE_4-8PWS_SEDIMENT_LOCS.MXD PWS_SEDIMENT_LOCS.PDF BKAHLER 12/26/2008 16:20:02



LEGEND

- ■ VADOSE
- ■ Qr3
- ■ Qr2
- ■ Qr1
- ■ Qr0
- ■ Toa2
- ■ Toa1
- ■ Toa0
- ■ Bedrock

NOTES:

1. MODEL LAYERS CORRESPOND TO WELL CLUSTER SCREEN INTERVALS.
2. MODEL LAYERS ALSO CORRELATE WITH HSUs WHERE FEASIBLE.
3. HSUs ARE CALLED OUT IN BORING LOGS AND CONTACTS ARE KRIGED ACROSS MODEL DOMAIN.
4. REFER TO FIGURE 4-10 FOR MAP VIEW OF THIS SECTION.

FIGURE 4-9
MODEL LAYERS

RCRA FACILITY INVESTIGATION/REMEDIAL
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PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

ES102007005BAO_fig_4-9_ModelLayers.ai_012909_lho

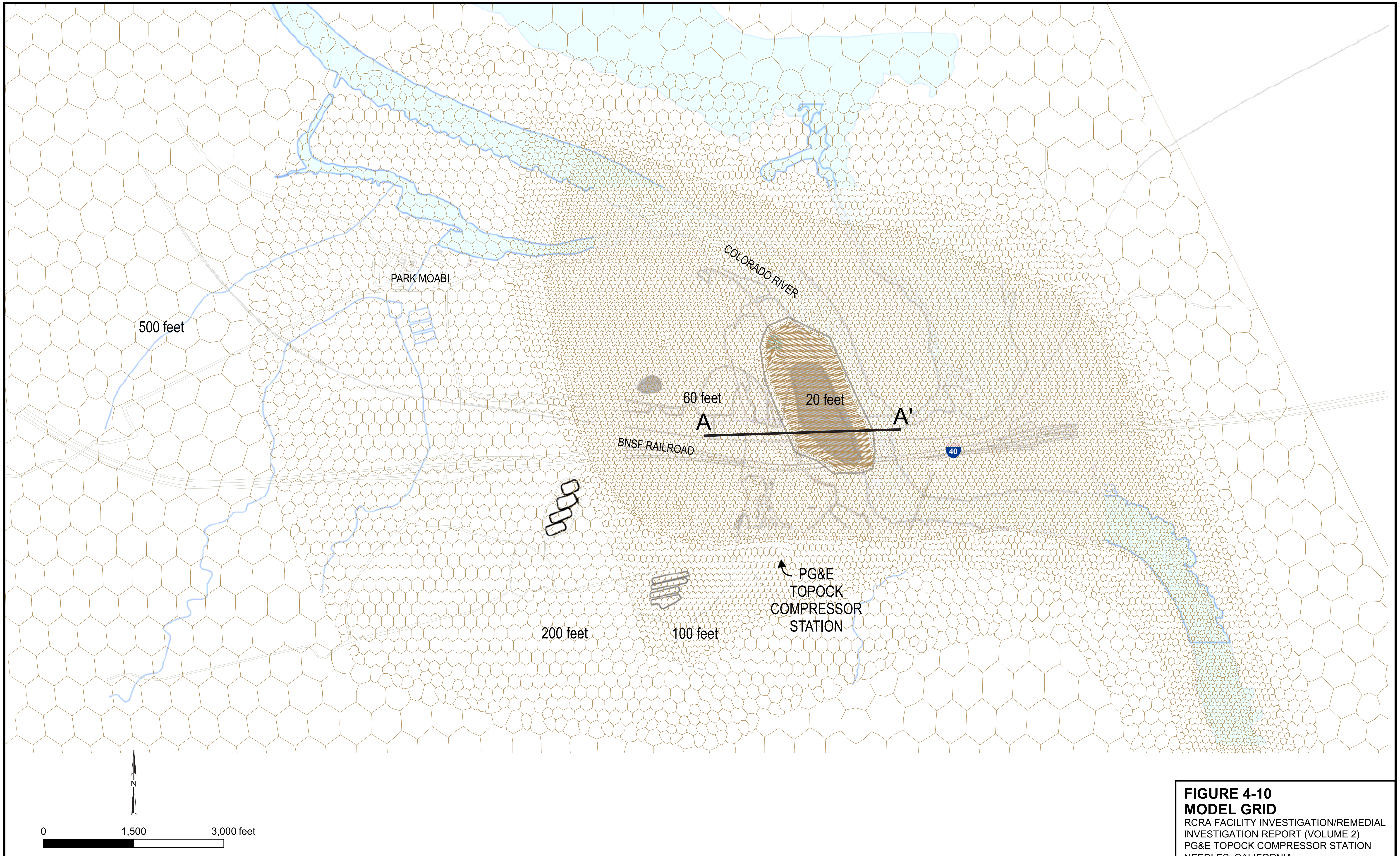


FIGURE 4-10
MODEL GRID

RCRA FACILITY INVESTIGATION/REMEDIAL INVESTIGATION REPORT (VOLUME 2)
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

CH2MHILL

RDD \\ODIN\PROJ\TOPOCK\FIGURES\MXD\0605TM_FIG02-10.MXD 0605TM_FIG02-09.PDF 7/22/2005 18:38:19
ES102007005BAO_fig_4-10_ModelGrid_v2.ai_010209_lho

5.0 Hydrogeologic Conditions and Conceptual Site Model

This section summarizes the results and findings of the RFI/RI drilling investigations and the hydrogeologic characterization activities and presents the hydrogeologic site conceptual model for the Topock site. The regional geologic and hydrologic setting is summarized in Section 3.3 and description and discussion of the Alluvial Aquifer and site HSUs are presented in Section 3.4. Surface water hydrology and hydrologic budget are discussed in Sections 3.5 and 3.6, respectively. The results of the groundwater investigation and monitoring of the nature and extent of the COPCs in groundwater are presented in Section 6.0.

5.1 Site Hydrogeology

5.1.1 Hydrogeologic Information

During the period June 1997 through October 2007, six phases of drilling, well installation, and hydrogeologic investigations and testing have been completed. Additional hydrogeologic data and information from other published sources and collected at the site by PG&E prior to the initiation of the RFI/RI in 1997 have been incorporated in this characterization. The RFI/RI phases of field investigation and pre-RFI activities are summarized in Section 4.1.

The RFI/RI hydrogeologic characterization activities completed July 1997 through October 2007 include:

- Drilling and installing 112 groundwater monitoring wells (including 27 well clusters), nine groundwater test/extraction/injection wells (IM projects), and five test and 27 monitoring wells (including nine well clusters) installed for the ISPT projects.
- Preparing lithologic boring logs for the RFI/RI/IM/ISPT drilling investigations.
- Collecting soil samples at selected boring locations for grain-size analysis, geotechnical testing (standard penetration tests), and chemical analysis for reductive capacity evaluation.
- Collecting borehole and/or cased-well geophysical logs at 21 of the well locations.
- Performing and evaluating hydraulic tests at selected wells, which include aquifer pumping tests (14 wells), clean-water injection tests (three wells), spinner test velocity logging (three wells), and single-well recovery/slug tests (seven wells).
- Evaluating water-level and river-level hydraulic data collected from an extensive network of over 80 groundwater wells and two river gauging stations using pressure transducers. Routine (continuous) collection of pressure transducer hydraulic data has

been maintained in the IM groundwater extraction area since 2004 and IM injection area since 2005.

- Compiling and reviewing drilling logs, geologic/hydrogeologic data, and test data collected in the study area by others (e.g., Caltrans bridge borings, PG&E's pre-RFI drilling investigations, and Park Moabi water supply wells).
- Incorporating the results of the 2004 seismic investigation conducted by the USGS on the Colorado River near the Topock site.

The results of an additional USGS seismic survey conducted in 2007 were not available in time for inclusion in the Volume 2 RFI/RI Report. The unpublished seismic profiles from the 2007 surveys, which are similar to the 2004 results, will be included in the Addendum to the Volume 2 RFI/RI Report.

Figures 4-2 and 4-3 show the locations of the drilling investigations completed at the Topock site through October 2007 and existing wells in the area used for site characterization. As summarized in Table 4-2, the majority of the RFI/RI wells were installed from 80 to 150 feet bgs. The deepest monitoring well installed for the RFI/RI is MW-24BR, completed at 437 feet bgs (elevation 127 feet above msl).

Appendices B and C of this report contain supportive documentation used for the RFI/RI site characterization. The drilling and hydrogeologic data are included in the following data compilations:

- Appendix B1—Drilling summary, well construction, and survey location data tables and maps for the RFI/RI wells and borings.
- Appendix B2—Boring logs and well construction logs for the RFI/RI groundwater wells (existing wells and decommissioned/destroyed wells).
- Appendix B3—Drilling logs for the exploratory and test borings in the study area, including the Caltrans I- 40 Bridge borings (Caltrans, 1962) and Park Moabi investigations (Crandall and Associates, 1986a-b).
- Appendix B4—Drilling depth data inventory for hydrostratigraphic units and summary of grain-size analyses for selected borings.
- Appendix B5—Pre-RFI geological and geotechnical investigations conducted at the Topock site for siting and evaluation of the Old and New Evaporation Ponds and regional geologic information.
- Appendix C1—Wireline geophysical logs for selected test, extraction, and injection wells.
- Appendix C2—Cased-well geophysical logs for selected monitoring wells.
- Appendix C3—Technical summary and results of the September 2004 Colorado River seismic reflection profiling survey conducted in the study area by the USGS (USGS, 2005).

There are six existing water supply wells in the RFI/RI study area as shown on Figure 4-2. The inactive supply wells include PGE-7, PGE-9N, and PGE-9S. The three active water supply wells in the study area include Park Moabi-3 (active supply for the regional park facilities), Park Moabi-4 (backup supply for the regional park facilities), and the Sanders well (private domestic well in Topock, Arizona). Two additional active water supply wells, Topock-2 and Topock-3 (operated by the City of Needles), are located in Arizona immediately east of the study area (Figure 4-2). Table 4-2 lists the status and well information for the existing and decommissioned water supply wells in the study area.

5.1.2 Hydrogeologic Cross-sections

A series of cross sections have been prepared to illustrate the site hydrogeology, hydrostratigraphy, bedrock structure, and aquifer distribution and geometry. Figure 5-1 shows the locations of seven hydrogeologic sections, designated Cross Sections A-A′ through G-G′. The hydrostratigraphic data obtained from the boring logs that were used for preparing the cross-sections are summarized in Appendix B4. The hydrogeologic features shown on these cross sections are summarized below.

Hydrogeologic Cross Section A-A′ (Figure 5-2) extends northward from the bedrock outcrop of the Chemehuevi Mountains, along the upper part of Bat Cave Wash, and farther north to the Colorado River floodplain. Wells shown include the former injection well PGE-8 (SWMU 2), the well clusters in the upland area (MW-24), IM extraction area (TW-2, TW-3, MW-20), and the floodplain (MW-34, MW-36, MW-39). Also shown on this cross section are the southward pinch-out of the saturated Alluvial Aquifer, the Alluvial Aquifer HSUs (defined in Table 3-1), and the inferred depiction of bedrock contacts and the projected trace of the regional Chemehuevi detachment fault (see Section 3.3.2).

Hydrogeologic Cross Section B-B′ (Figure 5-3) extends along the axis of Bat Cave Wash and illustrates the progressive south-to-north thickening of the saturated Alluvial Aquifer. The Alluvial Aquifer consists of the older alluvial fan deposits of the Tertiary Alluvium and Basal Alluvium.

Hydrogeologic Cross Section C-C′ (Figure 5-4) extends from the MW-40 well cluster installed in the median of I-40, across the Colorado River, to the shoreline and freeway embankment at Topock, Arizona. Features shown on this cross section include the inferred bedrock structure, the buried paleo-channel, eroded into Miocene bedrock, underlying the Colorado River, and the projected depths of the multi-level monitoring wells in slant wells MW-52 and MW-53. The shallow depth of Miocene bedrock encountered in borings immediately adjacent to I-40 (MW-12, MW-22, CB-5, CB-14) supports the interpretation of a buried paleo-ridge (or fault block) of Miocene bedrock, as shown on this cross section.

Hydrogeologic Cross Section D-D′ (Figure 5-5) extends northward from bedrock monitoring well MW-23, south of I-40 to monitoring well cluster MW-35 installed adjacent to Park Moabi Road. As illustrated on this cross section, the thickness of the Alluvial Aquifer ranges from approximately 20 feet at well MW-21 to an inferred thickness over 370 feet at well cluster MW-35. Other features shown on this cross section include the screen depths for the active IM extraction well TW-3D and other monitoring well clusters in the MW-20 bench site area. The Alluvial Aquifer underlying the Park Moabi Road alignment consists solely of the alluvial fan deposits of the Basal Alluvium, Tertiary Alluvium, and younger Quaternary Alluvium.

Hydrogeologic Cross Section E-E′ (Figure 5-6) extends from the IM-3 injection area eastward to the Colorado River. Key features shown include the generalized Miocene bedrock structure and the inferred distribution and depositional contacts of the alluvial fan deposits (Toa0, Toa) and the younger fluvial sediments of the Colorado River (Qr1, Qr2, Qr3). As shown on this cross section, the injection interval at the injection well field (wells IW-2 and IW-3) span the mid-depth and deep portions of the Alluvial Aquifer.

Hydrogeologic Cross Section F-F′ (Figure 5-7) extends eastward from the MW-20 bench across the floodplain to the MW-34 monitoring well cluster adjacent to the Colorado River. Features shown include the screen depths of the two active IM extraction wells (TW-3D and PE-1) and the distribution and depositional contacts of the alluvial fan deposits (Toa0, Toa) and the younger fluvial sediments of the Colorado River (Qr1, Qr2, Qr3). Refer to Table 3-1 for lithologic descriptions of the alluvial fan and fluvial HSUs that comprise the Alluvial Aquifer in the floodplain area.

Hydrogeologic Cross Section G-G′ (Figure 5-8) is located on the floodplain and is oriented parallel to the Colorado River. Features shown on this cross section include the buried plunging Miocene bedrock surface and the inferred distribution and depositional contacts for the fluvial and alluvial HSUs that underlie the floodplain along this line of section. Due to the orientation of this cross-section, the depths of five of the monitoring screens in the slant monitoring wells MW-52 and MW-53 are projected onto this section at their respective elevations. All monitoring screens in the slant wells are completed in the fluvial deposits east of the buried bedrock ridge underlying the California shoreline.

5.1.3 Site Hydrostratigraphic Maps

The drilling and hydrogeologic investigations conducted during the RFI/RI have generated a substantial set of geologic and hydrostratigraphic information that has been used to develop a detailed hydrogeologic conceptual model for the site. The data obtained from the lithologic logging of over 120 borings, geophysical logging at selected locations, sediment grain-size/textural analyses, and other drilling and testing information are used to characterize the setting and hydrogeologic features of the Alluvial Aquifer.

Figure 4-2 shows the drilling locations where geologic data from boring logs are available for site characterization. The boring/well locations where geophysical and grain-size data were collected are listed in Table 4-2. The supporting data are compiled in Appendices B2 and B3 (boring logs), Appendix B4 (drilling summary and grain-size analyses for HSUs), and Appendix C (geophysical logs and seismic survey results). Discussed below are several geologic and site hydrostratigraphic maps that illustrate bedrock structure and the thickness and distribution of the Alluvial Aquifer.

5.1.3.1 Top Miocene Bedrock Structure Map

Figure 5-9 presents a structure elevation contour map of the Miocene bedrock surface at the Topock site. As described in Section 3.4, the Miocene bedrock surface defines the base of unconsolidated alluvial and fluvial deposits that comprise the Alluvial Aquifer. The interpreted bedrock surface elevation map (Figure 5-9) was prepared using data from the RFI/RI and ISPT drilling investigations and the 1962 Caltrans' Topock I-40 bridge exploratory borings (Caltrans, 1962). The bedrock structure contours shown on Figure 5-9 underlying the Colorado River are inferred based on a reconnaissance seismic reflection survey conducted by the USGS in September 2004 (Appendix C3 and USGS, 2005). The drilling locations where the bedrock elevations are estimated from projections from site cross-sections are noted in Figure 5-9. Appendix Table B-4 provides a listing of the drilling data used to prepare the bedrock elevation map. A second seismic reflection survey of the Colorado River was performed by the USGS in June 2007. Due to USGS budget constraints, a final report, with completed geophysical interpretation displays, was not published or available for incorporating in the RFI/RI Report. The unpublished seismic profiles from the 2007 surveys, which are similar to the 2004 results, will be included in the Addendum to the Volume 2 RFI/RI Report.

As shown on the Miocene structure map, the bedrock surface slopes to the north and northeast from the Chemeheuvi Mountains (Figure 5-9). The bedrock surface steepens to the north and northeast underlying the northern portion of the floodplain and along the California shoreline. The results of the 2004 USGS seismic survey suggest that a paleo-channel has been eroded into Miocene bedrock under the river north and south of the I-40 bridge and that a shallow bedrock structural rise or “saddle” exists underneath the river at the I-40 bridge (Figure 5-9). The pronounced structural relief of the bedrock surface influences groundwater flow in the southern portion of the floodplain. The bedrock surface underlying most of the floodplain comprises a north-plunging structural ridge. In the southern portion of the floodplain, the Alluvial Aquifer pinches out above this bedrock ridge. Groundwater gradient and flow direction across the Topock site and floodplain are discussed in Section 5.2.

The Miocene bedrock surface shown on Figure 5-9 is intended to depict the generalized structure for the study area. Evaluation and mapping of additional structural features, such as lineaments and faulting within the bedrock formations have not been conducted as part of the RFI/RI. The Miocene bedrock surface map has been incorporated in the site hydrogeologic conceptual model (discussed in Section 5.4) and groundwater numerical model (Section 4.2.7).

5.1.3.2 Alluvial Aquifer Isopach Map

As previously described, the Alluvial Aquifer is comprised of unconsolidated fluvial and alluvial deposits (HSUs) that are hydraulically connected. The distribution and thickness of the total Alluvial Aquifer is shown on Figure 5-10a. The Alluvial Aquifer isopach map was prepared by contouring the measured thicknesses of the saturated HSUs at the drilling locations. Additional control for contouring aquifer thicknesses for the study area shown in Figure 5-10a was obtained by estimating and extrapolating the interval thickness between the Miocene bedrock surface (Figure 5-9) and the average elevation of the groundwater table at the site (455 feet msl).

As shown on Figure 5-10a, the saturated thickness of the Alluvial Aquifer ranges from less than 30 feet in the southern floodplain (MW-32 location) to 260 feet in the IM injection area, and to more than 350 feet in the northern floodplain (MW-49 location). The Alluvial Aquifer thins to the south and pinches out where the Miocene bedrock surface is shallower than elevation 455 feet msl. Based on projecting the bedrock surface north of the Topock site, the total saturated alluvial/fluvial basin deposits are more than 600 feet thick along the northern boundary of the area shown in Figure 5-10a.

5.1.3.3 Saturated Fluvial Deposits Isopach Map

The distribution and thickness of the saturated Colorado River fluvial deposits in the study area are shown in Figure 5-10b. The fluvial deposits within the saturated zone are confined to the areas bordering the Colorado River and underlying the Topock Marsh. In the IM floodplain drilling area, no saturated fluvial deposits have been identified west of the MW-39 well location (see Figure 5-1). In the area north of the Topock site, the total thickness of fluvial deposits is estimated, by projecting the mapped bedrock surface northward, to be more than 250 feet thick in the Topock Marsh area.

5.1.4 Hydraulic Properties of Hydrostratigraphic Units

This section summarizes the hydraulic testing activities at the Topock Compressor Station and aquifer parameters that were calculated from the test data. A historical summary of the testing was presented in Table 4-3.

5.1.4.1 Methods of Measuring Parameters

Aquifer parameters may be estimated by observing changes in groundwater levels in response to any stress on the aquifer. This stress may take the form of pumping, injection, rapid injection or extraction of a fixed volume or “slug” in a well or changing levels in a nearby surface water body (such as the Colorado River) in communication with the aquifer. All of these methods have been used to estimate aquifer parameters at the Topock Compressor Station. Pumping and injection tests are considered to be higher-quality data sets than slug tests because slug tests affect only the area immediately surrounding the well and, therefore, are strongly influenced by the properties of the filter pack around the well.

Long-term pumping tests have been conducted in wells in the area surrounding MW-20 (the MW-20 bench) on several occasions. As more wells have been added to the floodplain, the number of available monitoring wells for each test has increased; therefore, the most recent tests are considered the most valuable. In May 2006, tests were run by pumping test wells TW-4 and TW-5, and observations were recorded using transducers in nearby wells, including well clusters MW-44, MW-46, MW-47, MW-49, and MW-50. Initial estimates of hydraulic properties may be made from specific capacity data of the pumped well. More sophisticated methods use the data from numerous observation wells. For this project, the aquifer test analysis program MLU was used to estimate properties of the various HSUs screened by the observation wells. These estimates are input to the numerical groundwater flow model, and model calibration methods are used to further adjust the MLU estimates in the model environment, which provides a more realistic simulation of complex groundwater flow conditions than the simple assumptions and analytical equations used in MLU.

Response of groundwater levels to changing levels in the Colorado River are also used to help better fit hydraulic parameters to HSUs. Analytical solutions have been developed that take into account the distance of the well from the river, groundwater level change relative to that of the river, and lag time between river and groundwater changes. However, these solutions are of limited use for assigning hydraulic properties in the model because they only provide a ratio of transmissivity (T) to storativity (S), not the individual values for T and S. The transient fluctuations in river and groundwater levels data have proven to be useful in the groundwater model calibration stage where river stage is imposed as a changing boundary condition, and observed changes in groundwater levels are matched by adjusting aquifer parameters.

Spinner tests (or velocity logs) involve insertion of a sensitive flow meter into a pumping well to measure vertical velocity of the water at different depths in the well. Spinner tests were used to measure relative production from different depths in the aquifer at wells TW-1, IW-2, and IW-3. While this method does not provide direct measurement of aquifer hydraulic properties, it can provide an estimate of the relative permeability of different aquifer zones.

5.1.4.2 Hydraulic Conductivity of HSUs

This section summarizes the hydraulic properties from well and aquifer testing. A summary of data from tested wells is provided in Table 5-1, including the specific capacity data from each pumped well and corresponding hydraulic parameter estimates. Table 5-2 presents the hydraulic parameter estimates for each HSU based on observation well data collected during aquifer tests. These data are considered to be of superior quality and will be used as initial estimates prior to numerical model calibration. The default values listed at the end of Table 5-2 represent either average values from recent aquifer tests or estimates based on previous testing described below.

Hydraulic conductivity (K)—a measure of the relative ease with which groundwater flows through a given aquifer material—has been estimated based on aquifer tests. Similarly, the ratio of horizontal to vertical hydraulic conductivity (K_h/K_v) has also been calculated from observed data.

Bedrock Units. Groundwater occurs in secondary fractures in both the Miocene conglomerate and metadiorite bedrock. Monitoring wells screened in these zones (PGE-7BR, MW-23, MW-24BR, and MW-48) are purged dry during sampling and require several hours to several days to fully recover. The sample purge rates at which these wells quickly pump dry are between 2 and 5 gpm. Well PGE-8 was constructed as an injection well and is screened across a 150 interval of bedrock. During a pumping test in 2007, PGE-8 yielded a sustained pumping rate of about 13 gpm. The PGE-8 testing is described in more detail below.

Hydraulic testing at MW-23 and MW-24BR has yielded very low hydraulic conductivities on the order of 0.003 foot per day (ft/d) (E&E, 2002). More recent bedrock testing was performed on wells MW-48, PGE-7BR, and PGE-8 (CH2M HILL, 2008i-j), and is summarized below.

Well PGE-7 was originally screened in alluvial material and was later deepened to bedrock in order to monitor injection at PGE-8 in the early 1970s. As a result, the well was open to both the base of the Alluvial Aquifer and the bedrock. The well was altered in 2007 so that it was open to bedrock groundwater only, to facilitate more accurate bedrock hydraulic testing (CH2M HILL, 2008i). The well was renamed PGE-7BR, and hydraulic conductivity of the bedrock at this location was estimated to be 0.0009 ft/d (CH2M HILL, 2008j). This value is considered to be more accurate than the 2002 estimate, since the alluvial material contributed to the earlier conductivity estimate. Hydraulic conductivity at MW-48 is estimated to be even lower than that at PGE-7BR, at 0.0004 ft/d.

Well PGE-8 was tested in 1969 shortly following installation. Dames & Moore (1969) reported an estimated transmissivity of 10,000 gpd/ft (about 1,300 ft^2/d). Examination of the data reveals a 2-foot jump in drawdown between 45 and 50 minutes into the test, followed by a much gentler slope in drawdown for the remainder of the test. This suggests a recharge boundary, most likely the Alluvial Aquifer. This would suggest that the reported transmissivity for bedrock was overestimated due to hydraulic communication with the overlying alluvium. Numerical modeling was used to evaluate the 2007 hydraulic data from the PGE-8 testing (CH2M HILL, 2008j). Data from PGE-8 pumping and injection indicated discernable response in alluvial wells over 1,000 feet away. On the basis of specific capacity data and aquifer test data, hydraulic conductivity in the bedrock at PGE-8 was estimated to be 0.09 ft/d. Test analysis suggests a vertical hydraulic conductivity of 0.04 ft/d at this location. Responses in nearby alluvial wells to PGE-8 testing were stronger than other bedrock wells, suggesting a stronger hydraulic connection between bedrock and alluvium than within the bedrock itself.

These results are consistent with the well-consolidated nature and moderately fractured and weathered characteristics of the Miocene conglomerate and metamorphic and igneous bedrock outcrops at the site (Figure 3-5). In the ravines and slopes south of the compressor station, many of the fractures in the metamorphic bedrock outcrops exhibit weathering and vein filling.

Alluvial Aquifer – Fluvial Deposits. Over 25 monitoring wells have been completed within the fluvial sediments on the floodplain. Hydraulic testing has been conducted at many of these wells. Data are summarized in Table 4-2.

In 2002, rising head slug tests were conducted at MW-27, MW-28, and MW-30-30. The results indicated hydraulic conductivity of the shallow fluvial sediments between 3 and 14 ft/d ($1x10^{-5}$ and $5x10^{-5}$ meters per second [m/s]) and transmissivities between 100 and 500 ft/d (E&E, 2002). These hydraulic conductivities are consistent with well-sorted, fine- to medium-grain sands (Driscoll, 1986).

Hydraulic testing conducted in 2004 has included short-duration pumping tests during well development and sampling. Pumping rates ranged from 1.2 to 6.3 gpm, and the test durations were between 10 and 250 minutes. Drawdown was monitored with pressure transducers in both the pumped well and, if available, the other well in the nested pair (e.g., MW-34-55 and MW-34-80). Notable drawdown, however, was rarely measured in the observation well. Hydraulic conductivities estimated from pumped well data ranged from 10 to 110 ft/d ($4x10^{-5}$ to $4x10^{-4}$ m/s), and transmissivities ranged from 400 to 4,000 ft^2/d. As is often observed, the results of these short-duration pumping tests yielded hydraulic conductivity estimates nearly an order of magnitude larger than the slug tests conducted in 2002. The pumping test estimates are considered to be more accurate due to their longer duration and larger area of influence.

Testing performed more recently with the IM extraction wells TW-2D and TW-3D provide the highest-quality data used to estimate hydraulic properties beneath the floodplain. Although these extraction wells are screened in alluvial deposits, their influence extends throughout the fluvial zone. Estimates were made based on several different pumping and shutdown tests involving these wells between 2004 and 2006. Further description of these wells and their testing is provided in the Alluvial Fan Deposits section below.

Alluvial Aquifer – Alluvial Fan Deposits. In 2002, several slug tests and short-duration pumping tests were conducted at selected monitoring wells. In 2003 and 2004, additional pumping tests were conducted at monitoring wells and the new test wells TW-1, TW-2S, and TW-2D. In addition, groundwater extraction from the MW-20 wells was closely monitored to obtain hydraulic data.

The hydraulic testing at the TW-1 and TW-2 wells yields some of the better estimates of hydraulic properties of the alluvial deposits due to the higher pumping rates used in those tests. In addition, an extensive pressure transducer network was installed for the TW-2 testing, thereby providing detailed and accurate drawdown measurements at nearby monitoring wells.

Installation and testing of test well TW-1 on PG&E property occurred in fall 2003 CH2M HILL, 2003i). The well was completed within the oldest alluvium unit (Toa) and the Basal Saline unit (Tsu). Testing at this well included geophysical logging during installation and velocity (spinner) logging and a variable-rate step drawdown test following completion.

TW-1 was completed across nearly the entire saturated alluvial thickness with 60-slot polyvinyl chloride screen from 169 to 269 feet bgs (water table at approximately 165 feet bgs). Step testing consisted of pumping at 22, 35, 62 and 88 gpm for 30 minutes each and indicated a specific capacity of between 11 and 16 gpm/ft (specific capacity decreasing with increasing flow rates). Drawdown was measured with pressure transducers in nearby monitoring wells MW-24A, MW-24B, and MW-10. The aquifer transmissivity was estimated to be 2,000 to 3,000 ft^2/d, and the hydraulic conductivity was estimated to be between 20 and 90 ft/d ($7x10^{-5}$ and $3x10^{-4}$ m/s). The velocity (spinner) logging identified three zones of preferential flow within the alluvium, though distinct aquifers and aquitards were not inferred. The Basal Saline unit was found to contribute minimal flow to the well. Select figures and results from this testing and evaluation are provided in Appendix D2.

Groundwater extraction from the MW-20 bench as part of IM No. 2 initially involved pumping two 4-inch-diameter MW-20 monitoring wells. The combined pumping rate was less than 20 gpm due to limited well efficiency. The modest pumping rate and fluctuations in floodplain groundwater levels from changes in river level limited the interpretation of the hydraulic data. The subsequent testing of the nearby TW-2 wells provided better estimates of aquifer properties for a similarly-screened portion of the alluvial aquifer.

TW-2S and TW-2D were completed as 6-inch-diameter test wells at the MW-20 bench in spring 2004. Similar to test well TW-1, approximately 100 feet of saturated alluvium were encountered. During TW-2D drilling, an interval of very silty gravel thought to be an aquitard was encountered at approximately 95 to 105 feet bgs. To maintain flexibility for extraction from different levels in the aquifer, a pair of extraction wells, rather than a single extraction well, was installed at the TW-2 location. TW-2S was completed across the upper portion of oldest alluvium unit (Toa) from 45 feet (near the water table) to 95 feet bgs. TW-2D was completed from 113 to 153 feet bgs across the oldest alluvium (Toa) and Basal Saline unit (Tsu).

Step drawdown and longer-term aquifer tests were conducted at both the TW-2S and TW-2D wells. Several tests included pulses designed to coincide with minima or maxima in river levels so that drawdown could be better observed in monitoring wells. A 5-hour constant-rate test was also conducted, where both TW-2S and TW-2D were pumped simultaneously at 60 and 90 gpm, respectively (150 gpm combined rate). Many nearby monitoring wells were instrumented with pressure transducers, and drawdown was measured in wells up to several hundred feet away. Evaluation of the data yielded an estimated average transmissivity of 3,000 ft^2/day and average hydraulic conductivity of 30 ft/d ($1x10^{-4}$ m/s). Velocity (spinner) logging, similar to TW-1, indicated variable flow into the well and reduced flow towards the bottom of the well. Selected results and figures from the TW-2S and TW-2D completion and testing are provided in Appendix D2.

Hydraulic testing was completed at the test wells installed for the 2006 IM drilling program at well locations TW-5, TW-4, and MW-51/MW-26. These wells were all 4-inch-diameter wells designed for testing purposes. Constant-rate aquifer tests were conducted at TW-4, TW-5, and MW-26, and a step drawdown test was conducted at TW-5.

TW-5 has 40 feet of screen in the Tertiary Alluvium (Toa). The well was pumped at flow rates of 18, 40, 60 gpm for 30 minutes, 77 gpm for 60 minutes for the step test, and at 70.1 gpm for 135 minutes for the constant-rate test. Estimates of hydraulic parameters based on observation well data are provided in Table 5-2.

TW-4, with 40 feet of screen in the Basal Alluvium (Toa0), was initially pumped at 70 gpm, but this resulted in dewatering. When the pumping rate was reduced to 28 gpm, drawdown stabilized at 43.4 feet. Water levels were recorded in the pumping wells and the MW-47 monitoring wells. Estimates of hydraulic parameters based on observation well data are provided in Table 5-2.

Well MW-51 was completed adjacent to MW-26. This location was originally planned to have a 4-inch test well with a 40-foot screen installed, but shallow bedrock here resulted in a modified design with a 15-foot screen. Pumping during development suggested that this well would have low yield, so a step test was not conducted at this location. A pump test was attempted at MW-51, but the well dewatered at the minimum operational pumping rate of 4 gpm.

Adjacent well MW-26 has a longer screen, deeper pump placement, and greater available drawdown; therefore, the hydraulic tests at this location were conducted at MW-26. A constant-rate test was conducted at MW-26 in May, 2006. The well was pumped for 85 minutes at 4.8 gpm. The test was scheduled for 180 minutes, but stabilized drawdown was never achieved, and the well screen began to dewater approximately 75 minutes into the test (cascading water was noted in the well with a more rapid decline in water level in the pumping well at about 75 minutes).

5.1.4.3 Storativity

Storativity (S or the storage coefficient) represents the volume of water released from a unit area of aquifer material per unit drop in head. Storativity values are somewhat time-dependent, as the release of water is not instantaneous. As such, values derived from a test or stress to an aquifer will depend on the duration of that test. Values from longer-duration tests are typically larger than those for shorter-duration tests. Additionally, storage values are larger in unconfined aquifers where dewatering of a portion of the aquifer occurs in response to a drop in water levels. This dewatering does not occur in confined aquifers.

Estimation of S is based on the simulation of four events: (1) injection testing at IW-2 and IW-3, (2) aquifer testing at wells TW-4 and TW-5, (3) step test at well TW-1 near the compressor station, and (4) data from a constant rate aquifer test at well PT-1 near the New Evaporation Ponds. The duration of Tests 1, 2, and 4 was on the order of hours, while that for the TW-1 test was on the order of 30-minute intervals. Estimated storativity for these events are provided in Table 5-2. Typical values of storativity are on the order of 10^{-3} for the shallow zones and 10^{-5} for deeper zones. In the process of model calibration, storativity was adjusted during simulation of aquifer testing as well as monthly river fluctuation effects on groundwater levels.

5.2 Groundwater Gradients and Flow

5.2.1 Horizontal Gradients in Alluvial Aquifer

Since March of 2004, transducers have been installed in all of the wells in the floodplain and in selected wells elsewhere on the site. Beginning in March 2004, groundwater has been pumped from wells on the MW-20 bench as part of IM activities at the site (see Section 1.2).

Groundwater elevations for the shallow, mid-depth, and deep zones of the alluvial aquifer in June 2006 are shown on Figures 5-11a, b, c, and for December 2006 in Figures 5-12 a, b, c. Along the mountain front to the south of the compressor station, there is a northern component to the gradient, reflecting mountain-front recharge from the Chemehuevi Mountains. This is best illustrated by noting the decreasing groundwater elevations in wells MW-9, MW-10, and MW-38S in a northerly direction, paralleling the occasional surface flow down Bat Cave Wash. Note that bedrock intersects each depth interval at a different elevation and location. During June 2006, the average pumping rates from PE-1 and TW-2D were about 34 and 96 gpm, respectively, and during December, the rates were about 34 and 100 gpm. Injection was entirely in well IW-2 in June 2006, with an average rate of 117 gpm. In December 2006, most injection was applied to well IW-3 (111 gpm average), with a small amount injected in IW-2 (13 gpm average).

Figure 5-11a and 5-12a present data for shallow wells from manual water-level measurements taken as “snapshots” on June 14 and December 14, 2006, respectively. For these snapshots, manual water levels were obtained from wells outside the floodplain monitoring network within a short period of time (several hours) to minimize the effects of daily changes in water level due to river fluctuations. These manual measurements from upland wells were combined with average water levels calculated from the transducer data (over the same time period of manual measurements) from floodplain wells to produce the contour maps shown on Figures 5-11a and 5-12a. At both times, gradients in the floodplain show the influence of the IM pumping and are therefore generally steeper than the natural gradients in areas outside the influence of the pumping wells. As expected, the capture zone is more robust during the summer, when high river levels result in more pronounced landward gradients. However, even during low water conditions (December), landward gradients are maintained by IM pumping across the area where the plume is present in the floodplain.

Groundwater moves very slowly at the site due to minimal local recharge causing the low gradients observed in Figures 5-11a and 5-12a. The approximate average groundwater velocity for the shallow zone can be calculated from the observed hydraulic gradients, hydraulic conductivity values, and estimates of porosity. Away from the IM pumping areas, the horizontal groundwater gradient varies between about 0.0003 and 0.0005 seasonally (based on Figures 5-11a and 5-12a). Average hydraulic conductivity for the fluvial and upper alluvial sediments is about 30 ft/d, and the average effective porosity has been estimated at 0.12 on the basis of unpublished analysis of injection well data and floodplain *in-situ* data. Using the range of gradient values, the average groundwater velocity is calculated to be between 27 and 46 ft/yr. This is a rough estimate but serves to illustrate that the groundwater does not move very fast throughout most of the study area. In the areas of IM extraction, the gradients are much steeper and groundwater velocities are much faster. During original discharge of blowdown water in Bat Cave Wash, stronger induced gradients were created due to groundwater mounding associated with the discharge. Northward gradients were further enhanced by pumping from the former water supply wells located near where I-40 crosses Bat Cave Wash. A summary of plume evolution as projected by the groundwater model is provided in Section 6.6.

Figures 5-11b and 5-12b present groundwater elevation data taken with pressure transducers during the month of June and December for the mid-depth zone, along with the contours from the June and December 2006 Performance Monitoring Reports. Strong landward gradients towards the pumping center from the floodplain are observed in both June and December, with a stronger gradient in June.

Figure 5-11c and 5-12c present groundwater elevation data taken with pressure transducers during the month of June and December for wells in the deep interval, along with the contours from the June and December 2006 Performance Monitoring Reports. Induced landward gradients are evident throughout the floodplain. Seasonal differences in gradients are less noticeable in the deep interval.

5.2.2 Vertical Gradients

Several monitoring well clusters are available at the Topock site to evaluate vertical hydraulic gradients within the Alluvial Aquifer and between bedrock and the Alluvial Aquifer. Table 5-3 presents a summary of the vertical hydraulic gradients measured at well clusters in the floodplain, the MW-20 bench extraction area, and the IM-3 injection area. The data summarized in Table 5-3 represent average water levels based on 30-minute interval pressure transducer measurements over the time interval indicated in the table, except where indicated. Since the commencement of IM extraction in 2004, the naturally upward vertical gradient beneath the floodplain has become downward due to the deep screen intervals of the pumping wells. Figure 5-13 shows a cross section through the floodplain area, with average groundwater elevations and contours from October 2007. The figure illustrates the vertically downward gradients now present in this area.

5.2.2.1 Within Alluvial Aquifer

Throughout the majority of the study site, vertical hydraulic gradients in the alluvial aquifer are primarily upward. Water levels in well clusters at MW-20, MW-24, MW-32, MW-33, and MW-34 typically display upward hydraulic gradients up to an order of magnitude greater than the horizontal gradients. The gradients and details of groundwater flow in the region of extraction system are well characterized in the recent 2006 IM performance monitoring reports (CH2M HILL, 2007g-h).

5.2.2.2 Between Alluvial Aquifer and Bedrock

Available data from bedrock wells at three locations indicate an upward gradient from bedrock groundwater to alluvial groundwater (MW-24BR to MW-24B; PGE-8 to MW-9; MW-48 to MW-12). As described in Section 3.6, the limited amount of rainfall recharge in the nearby mountains enters the Alluvial Aquifer via upward seepage from the bedrock underlying the Alluvial Aquifer. Upward gradients continue as this water moves upward within the Alluvial Aquifer. There are no apparent continuous aquitards present at the site. Previous reports have also documented upward hydraulic gradients from bedrock to the alluvial aquifer at well locations MW-24BR and PGE-8 (CH2M HILL, 2006p). This and data summarized on Table 5-3 indicate that the study area is primarily an area of groundwater discharge, with flow upward and to the east/northeast (as discussed in Section 3.6).

5.2.3 Groundwater Flow Directions

Based on the observed gradients discussed in Sections 5.2.1 and 5.2.2, natural groundwater flow directions across most of the Topock site are generally upward and toward the floodplain. IM-3 pumping creates localized flow in the direction of the extraction wells, such that in the floodplain, groundwater moves toward the extraction wells and away from the river. As mentioned above, local flow at the southern edge of the Alluvial Aquifer has a northern component, reflecting mountain-front recharge.

5.2.4 Water Level Variations and Effects of River Level Fluctuations

The Colorado River has strong influence on groundwater levels at the Topock site, and its influence is seen over multiple time scales. The BOR controls the river levels by controlling releases from Davis Dam upstream of the site and Parker Dam downstream. The average monthly river level at the Topock Site is strongly correlated to Davis Dam release and the water level maintained in Lake Havasu behind Parker Dam. The amount of water that is released from these dams is largely dependent on agricultural needs in downstream areas of the Colorado River Basin, particularly in the Yuma, Arizona area. If rainfall is unusually high in that area, then releases from the dams are diminished to prevent flooding downstream. As a result, river levels at Topock tend to be lower during the winter months. During the winter of 2004 and 2005, rains were unusually heavy, and the local river levels were at their lowest in several decades. As the need for agricultural water increases in late spring and summer, dam releases increase, and Topock river levels are higher. Davis Dam releases are increased daily between morning and late evening to generate additional power for peak demand. Releases are diminished during the night as power demand drops. As a result, the river shows a daily fluctuation in water level, similar to a tidally-influenced system.

Figure 5-14 shows that the cyclic changes in Colorado River stages drive similar cyclic changes in groundwater levels across the site on both seasonal (upper chart) and daily (lower chart) frequencies. Due to these river fluctuations, groundwater gradient changes nearly continuously in the floodplain area. Hydrographs for other wells completed in the floodplain are provided in Appendix E.

Wells located near the river often show substantial influence due to river stage fluctuations caused by Davis Dam release patterns. For a foot change in river level, some wells, such as the MW-28 wells, respond with a corresponding head change of over 0.6 foot. The head change observed at the well is, in some cases, clearly a function of distance from the river. Figure 5-15 shows hydrographs for selected wells in the floodplain and inland areas of the site. Data shown on this figure illustrate that the amplitude of groundwater fluctuations diminishes with distance from the river. This is also true in the vertical direction, with the exception of the shallowest wells. Figure 5-16 shows the MW-33 well cluster as an example. The shallow well MW-33-40 has the smallest range of groundwater level for each 24-hour period, due to its unconfined nature with higher storativity. Wells screened at the middle depth (e.g., MW-33-90) show a much greater range, owing to the semi-confined nature of the aquifer at depth. As screen depth increases, the increased distance from the river bottom results in a gradual decline in water-level amplitude. Figure 5-15 also demonstrates the upward groundwater gradient in floodplain groundwater. Closer to the IM-3 extraction wells, there is a downward gradient due to the extraction wells being screened at lower depths.

5.3 Groundwater/Surface Water Quality and Geochemistry

The alluvial material in the Topock-Needles area is derived primarily from the metadiorite and gneissic rocks comprising the mountains to the south and west. In addition, there are also fluvial deposits from the ancient Colorado River evident in some areas above the current floodplain, along with more recent river deposits in the floodplain. These fluvial materials were derived from a large number of sources in the Colorado River basin and were transported to this area in the relatively recent geologic past.

The chemistry of groundwater associated with these parent materials is described below. The categories for interpretation are (1) general chemistry parameters, which include major ions, TDS, and oxidation-reduction state, (2) stable isotopes of oxygen and hydrogen, and (3) temperature. In addition, chemical characteristics of site groundwater are compared to surface water from the Colorado River and to regional groundwater summarized in the groundwater background study (CH2M HILL, 2008b).

The discussions below apply to the Topock Site groundwater in general. For a discussion of plume geochemistry, refer to Section 6.5.

5.3.1 General Chemical Parameters

General chemical parameters are used to describe the characteristics of waters in each hydrogeologic group and are used to identify water sources, key chemical processes, and reactions that may be occurring along flowpaths. These parameters consist of:

- The major cations (positively charged ions): sodium, potassium, calcium, and magnesium.
- The major anions (negatively charged ions): chloride, bicarbonate, and sulfate.

- TDS and associated parameters of specific conductance and salinity.
- Temperature.
- Redox-sensitive parameters: oxidation-reduction potential (ORP), dissolved oxygen, nitrate, ammonia, manganese, iron, sulfide, and total organic carbon.

A general discussion of concentrations and interpretation by hydrogeologic group is presented below.

5.3.1.1 Alluvial Aquifer – Alluvial Fan Deposits

Alluvial deposits constitute the majority of the unconsolidated aquifer from the north and west of the site to where they pinch out beneath the present floodplain (Figure 5-4). In general, groundwater in the alluvial deposits is of sodium-chloride nature and ranges from relatively low TDS (<1,000 mg/L) in many shallow wells to high TDS (>10,000 mg/L) in deeper zones. Figures 5-17a-c display Piper chemical diagrams by geologic material (Figure 5-17a) and by depth zones in alluvial material (Figure 5-17b). A Piper diagram shows, for each sample, relative percentages of cations on the left triangular plot and anions to the right, with a central diamond-shaped field showing the combined plot of overall water chemistry. Locations of samples on the three fields may be compared to note distinctions between different groups of samples.

In addition, Stiff chemical diagrams, which capture a chemical “fingerprint” of water chemistry, are provided in Appendix F1. In those figures, the dominant ions are shown as peaks to the left (cations) or right (anions) of the central axis. For diagrams plotted on the same concentration scale, a larger diagram indicates relatively higher TDS. Note that different scales are used for upper and lower alluvial aquifer wells, demonstrating the very large difference in TDS between the two depth zones.

Water chemistry is plotted according to geologic material in Figure 5-17a. Samples labeled as “offsite” are from wells used in the background study (CH2M HILL, 2008b), which were not used as site monitoring wells. Site alluvial wells are generally dominated by sodium and chloride, with a few exceptions. In the western portions of the site, the chemistry of the Active Ponds wells (MW-1, MW-3 through -8) is characterized by a sodium-chloride/sulfate dominance. Nearby monitoring well MW-16 is of a similar composition. Well MW-17 has a pronounced sodium-sulfate character, quite different from other site wells (Figure 5-17a).

Offsite Wells. Offsite alluvial groundwater samples tend to show more of a mixed-ion chemistry compared to site alluvial monitoring well data (Figure 5-17a). Nearly all of the offsite wells are used for water supply purposes and are therefore screened in superior water quality zones. The different water chemistry (and lower TDS, described below) reflect this bias. The Park Moabi well, reportedly screened in the Bouse Formation as opposed to the alluvium (Metzger and Loeltz, 1973), shows a similar chemistry to alluvial wells in the western part of the site such as MW-18, suggesting this well is actually screened in alluvial material. Also shown in the Stiff diagram plots of Appendix F1 are older published analyses of two wells in the vicinity of Park Moabi (PG&E, 1993). Well 7N/24E-6B1 was located in the floodplain area and displays a higher TDS mixed-ion chemistry. Well 7N/24E-6F1 (designated well PM-1 in Table 4-2) was close to the present Park Moabi well and was likely screened in a similar interval. It shows a similar chemistry to the present well, though with higher TDS.

Variation of General Chemistry with Depth in Alluvial Material. Chemistry of site alluvial wells is plotted according to shallow, middle, and deep depth intervals on Figure 5-17b. Mixed-ion chemistry is present in shallow samples from the western portion of the site, as described above, whereas shallow samples between Bat Cave Wash and the floodplain are consistently sodium chloride waters. Middle- and deep-zone samples are dominated by sodium and chloride in all areas of the site. There is also a drop in sulfate percentage in the middle and deeper wells, which likely correlates to the increase in sodium-chloride dominance and TDS.

5.3.1.2 Alluvial Aquifer – Fluvial Deposits

Although the fluvial deposits are of different origin than the alluvial deposits, the two are in direct hydraulic communication, and local groundwater flows from the alluvial materials into the fluvial zone. General groundwater chemistry in the fluvial wells is similar to alluvial groundwater chemistry: sodium-chloride dominated with highly variable TDS. Wells very close to the river and screened in shallow zones (e.g., MW-27-20 and MW-28-25) reflect Colorado River chemistry, which is low TDS (about 600 mg/L) and a mixed-ion chemistry (Figure 5-17a).

Two shallow floodplain wells, MW-30-30 and MW-22, represent the high TDS, sodium-chloride end-member for floodplain wells. Well MW-30-30 is believed to represent a shallow groundwater zone influenced by concentration of salts through evaporation from a former shallow pond that existed in this area prior to the deposition of dredge spoils along the river. The elevated TDS in well MW-22 is attributed to the salt-concentrating effects of evapotranspiration in the southern floodplain, where a dense stand of salt cedar is present. Other shallow floodplain wells with similar characteristics are MW-32-20, MW-32-35, MW-36-20, MW-39-40, and MW-42-30.

Variation of General Chemistry with Depth in Fluvial Material. Water chemistry variation with depth interval in fluvial material is shown in Figure 5-17c. Shallow wells influenced by the river have similar chemistry and TDS to river water, and the sodium-chloride, higher-TDS nature of fluvial groundwater increases with depth, as shown in Figure 5-17c and in the Stiff diagrams in Appendix F1.

5.3.1.3 Bedrock Units

Groundwater samples from both metadiorite bedrock and the Miocene conglomerate are sodium-chloride-dominated with high TDS, ranging from about 8,000 to 13,000 mg/L. Well MW-23 is the only well screened solely in the Miocene conglomerate, and has a distinctly sodium-chloride chemistry with TDS in the 10,000 to 13,000 mg/L range. Wells MW-24BR and PGE-8 are screened in the metadiorite bedrock. The chemistry of MW-24BR is the most purely sodium-chloride in nature, but with lower TDS (8,000 to 9,000 mg/L); PGE-8 has small percentages of calcium and sulfate and higher TDS (11,000 to 13,000 mg/L). Well PGE-7 was screened across alluvium, Miocene conglomerate, and metadiorite bedrock prior to being converted to a bedrock well (CH2M HILL, 2008i). The historical general chemistry at this well was similar to the other deep alluvial wells. The Piper diagram on Figure 5-17a compares bedrock well chemistry with that of alluvial and fluvial samples. Appendix F1 presents Stiff water chemistry diagrams for the bedrock wells.

5.3.1.4 Total Dissolved Solids Distribution

TDS of site groundwater varies considerably, ranging from as low as 300 mg/L (at MW-1) to over 40,000 mg/L (MW-30-30 and MW-32-20). Most site monitoring wells are in the 1,000 to 10,000 mg/L range. In general, high TDS is associated with: (1) bedrock wells, (2) deep alluvial/fluvial wells, and (3) a few shallow fluvial wells. Low TDS is found in shallow fluvial wells close to the river and in shallow alluvial wells in the western parts of the site. Distribution of TDS in groundwater at the site is provided in Figures 5-18a, b, and c, including panels for each depth interval. In addition, TDS values are displayed in three cross-sectional views in Figure 5-19.

Groundwater from shallow alluvial wells in the southwestern area of the site (e.g., New Ponds wells, MW-15, MW-16, MW-18) ranges between approximately 350 and 1,000 mg/L. Further east, groundwater beneath Bat Cave Wash groundwater ranges between 1,600 and 2,000 mg/L (wells MW-9, MW-10, and MW-11). The greater TDS in these wells is not believed to be due to their association with the plume footprint, since historical samples collected outside the RFI/RI from the Old Evaporation Ponds wells ranged between 500 and 10,000 mg/L. This shallow groundwater TDS along the southern area of the site likely represents mountain front recharge, which would be expected to vary with the local ephemeral recharge sources in the vicinity of each well. Further discussion of plume TDS characteristics and how they compare to non-plume wells is provided in Section 6.5.1.

In the northern part of the site away from the mountain front, there is an increasing trend in shallow groundwater TDS from west to east (in the general direction of regional groundwater flow), from OW-3S (674 to 1,120 mg/L) to slightly higher values at OW-1S, OW-2S, and OW-5S (between 900 to 1,500 mg/L), and greater TDS further east in MW-41S (average of 2,810 mg/L) and MW-35-60 (4,180 mg/L average).

Alluvial wells show a trend of increasing TDS with depth, with middle depth wells showing a range of 2,700 to 5,100 mg/L in the western area, and deep wells up to 24,800 mg/L at MW-49-365 in the east (Figure 5-18b, 5-18c, and 5-19). A more distinct correlation is evident when TDS is compared to the height of the well screen above bedrock. As shown in Figure 5-20, average TDS is greater in wells screened closer to bedrock. TDS appears to be more closely correlated with distance above bedrock than with the more conventional depth or elevation-based upper, middle, and lower well distinctions. This follows from a hydrogeologic standpoint, as the alluvial material at the base of the aquifer represents the oldest in the depositional sequence, which would be expected to have been segregated from the hydrologic cycle the longest and has accumulated the most dissolved solids.

Fluvial wells also show a general increase in TDS with depth, although some shallow floodplain wells have TDS greater than 10,000 mg/L (MW-22, MW-30-30, MW-32 cluster, and MW-42-30). As described above, these wells represent the shallow fluvial source of TDS: a combination of evaporation from shallow ponds that may have existed prior to deposition of dredge spoil material and evapotranspiration associated with the more vegetated areas in the southern floodplain. With the exception of the river-influenced MW-27-20 and MW-28-25, shallow floodplain wells are all higher in TDS than shallow alluvium wells.

5.3.1.5 Groundwater Temperature

Figure 5-21 summarizes the average groundwater temperatures measured in alluvial and bedrock wells for 1997 through 2007 monitoring events. Average groundwater temperatures at the site range from 70 to 89°F. Figure 5-21 also presents the monitoring well average temperature data separated out on the basis of depth (shallow, mid- and deep wells). In each case, the coldest groundwater temperatures are observed in wells closest to the Colorado River, with temperatures increasing as the horizontal distance away from the river increases. Increasing groundwater temperature with increasing distance from the river occurs in wells at each depth. It should be noted that groundwater temperatures collected during routine groundwater sampling are measured in the well purging discharge line at land surface (e.g., not *in-situ* measurements) and hence may be biased somewhat by ambient air temperature conditions.

Figure 5-21 also plots the average temperature of surface water stations along the Colorado River between 1997 and 2007. The average temperature of the river is reasonably stable along this stretch, varying from 64.4 to 64.9°F. This temperature stability along a relatively short distance of river reach results from the rapid movement of water within the Colorado River. Two surface water stations, RRB and A-Dock, have average water temperatures of 68.5 and 70.4°F, respectively. Each of these stations is located on a tributary to the Colorado River and likely has a warmer average temperature due to restricted circulation and increased exposure time to solar radiation and elevated air temperatures. The average Colorado River water temperature is 5°F cooler than the minimum groundwater temperature, and over 24°F cooler than the warmest average groundwater temperature. While the amount of connection can not be quantified, it is reasonable to assume that wells with average temperature closer to the low end of the average temperature range (70°F) are more likely affected by river water than wells closer to the high end of the average groundwater temperature range (89°F).

Away from the river, groundwater temperatures generally increase with depth. Average temperatures obtained from clustered wells of varying depth, including clustered wells OW-3S, OW-3M and OW-3D (85.1, 86.4, 86.8°F), wells MW-40S and MW-40D (87.3, 89.0°F), wells MW-38S and MW-38D (85.2, 86.8°F), and wells MW-33-40, MW-33-90, MW-33-150 and MW-33-210 (80.9, 82.2, 82.6, 83.1°F) show this relationship. Closer to the river and the extraction wells, groundwater temperatures no longer increase uniformly with depth. Mixed temperature profiles can be seen in clustered wells MW-36-20, MW-36-40, MW-36-50, MW-36-70, MW-36-90 and MW-36-100 (78.1, 77.8, 77.6, 78.6, 77.8, 78.9°F), wells MW-39-40, MW-39-50, MW-39-60, MW-39-70, MW-39-80 and MW-39-100 (79.8, 80.0, 80.1, 79.8, 79.8, 80.4°F), and wells MW-27-20, MW-27-60 and MW-27-85 (70.4, 74.3, 73.7°F).

5.3.1.6 Groundwater Reductive Zones

Reducing groundwater zones are defined in this report as those oxidation-reduction (redox) conditions that favor the reduction of Cr(VI) to Cr(III). For groundwater sampled at the Topock site and in the Background Study region, these conditions generally correspond to ORP readings of -90 mV or less (i.e. more negative). Groundwater redox data show a distinction between alluvial and shallow fluvial zones of the Alluvial Aquifer. Field measurements of ORP in alluvial wells tend to indicate non-reducing conditions, with millivolt (mV) readings in the 0 to 300 mV range. In contrast, groundwater in shallow and mid-depth fluvial wells, located in the floodplain, show significantly more reducing conditions, with ORP measurements in the -220 to -90 mV range.

These findings are supported by other chemical data. Nitrate, the oxidized form of nitrogen in the environment, is present in alluvial well samples at concentrations ranging from less than 1 mg/L to over 20 mg/L (as Nitrogen). Although not calculated for the Background Study report, which focused on nitrate as a general chemistry parameter, the background UTL for nitrate can be calculated, with a result of 5.03 mg/L, using the same calculation techniques as those used for the Background Study (CH2M HILL, 2008b) and data in that data set. Elevated nitrate is observed in several portions of the study area, including the New Ponds wells (MW-1 through MW-8) and upper Bat Cave Wash wells (MW-9, MW-10). The nitrate in these wells may be associated with mountain front recharge, as the wells lay at the base of an alluvial fan within or near incised drainage channels running northward. Numerous studies have documented nitrate generation through lightning discharges in thunderstorms. One study (Shepon et al., 2007) provides estimates for the annual nitrate deposition rates across the globe based on a computer simulation. This study projects a nitrate deposition rate of about 36 pounds per square mile in the Mohave Desert area around the Topock site. Atmospheric nitrate not taken up by plants in the sparsely vegetated Chemehuevi Mountains could become concentrated in the mountain front recharge and cause the elevated nitrate concentrations seen in the wells near the mountains.

Recent research has shown that a significant reservoir of nitrate can accumulate in the soil beneath areas of desert pavement in the Mohave Desert (Graham, 2008). Areas of desert pavement shed rainwater and therefore experience little or no net infiltration to leach nitrate from the soils. When the desert pavement is disturbed, infiltration increases and this reservoir of stored nitrate can begin to leach through the unsaturated zone, eventually reaching groundwater. Desert pavement has been disturbed across the site due to construction of roadways, railroads, pipelines, the compressor station, and the evaporation ponds. In addition, large areas of desert pavement were partially disturbed across the area of the Topock maze. This disruption of the desert pavement might increase the nitrate flux to groundwater in the area of the site.

Another potential source of nitrate is historical blasting associated with railroad, freeway, compressor station, and pipeline construction, and with the quarry behind the Old Evaporation Ponds. Blasting materials commonly contain ammonium nitrate, and undetonated material has been observed to be an ongoing source of nitrate in groundwater at a site in the Mojave Desert (Maxwell, 1997). Other potential nitrate sources include animal grazing, which historically took place on portions of the site, and evaporative concentration of natural nitrate in blowdown water at the facility.

Nitrate is consistently below reporting limit in shallow fluvial wells, indicating redox conditions below nitrate stability. Ammonia, the reduced form of nitrogen, has been detected in these wells. The transition between nitrate and ammonia is gradual, as conditions become more reduced, and involves one or more transitional species, such as nitrogen gas and nitrite. By comparison, thermodynamic data indicate that Cr(VI) is transformed into Cr(III) at less reducing conditions than those that initiate the reduction of nitrate to ammonia (Brookins, 1988). This means that for an equilibrated system, nitrate would be the expected form of nitrogen to be present alongside Cr(VI), and the presence of Cr(VI) would not be expected when ammonia is present. Precise redox equilibrium is not the typical case in natural systems, but these indicators are consistent at the Topock site, as will be further discussed in Section 6.0.

Although iron and manganese may be found in non-reducing wells at the pH range (typically 7.0 - 8.5) of the Topock site, they have limited solubility in this environment (Brookins, 1988). As a result, the number of reducing zone fluvial wells with elevated iron and manganese far outnumber the non-reducing alluvial wells. The presence of either of these reduced metals indicates even stronger reducing conditions than does the absence of nitrate. Generally speaking, the presence of Cr(VI) and nitrate is characteristic of aerobic conditions (oxygen-rich), whereas the absence of Cr(VI) and presence of ammonia, manganese, or iron indicates anaerobic conditions (oxygen-poor or absence of oxygen). As noted in Section 5.1.3, the fluvial sediments in the floodplain are relatively recent in origin and contain abundant organic material from several sources. Following the construction of Parker Dam in 1938, the river channel near Topock began to accumulate silt. The river level rose approximately 27 feet, and the channel near Topock became a braided stream. Organic material, probably from vegetation in the Topock marsh area, was incorporated into the fluvial sediments. Some of these organic-rich sediments were deposited directly on the floodplain. In addition, dredging operations resulted in placement of additional organic-rich river bottom materials on the floodplain. The reducing conditions observed in the floodplain sediments are likely caused by microbial breakdown of the organic carbon present (regardless of the source) in these shallow fluvial deposits. These reducing conditions in the fluvial deposits play a key role in the attenuation of Cr(VI), as will be discussed in Section 6.7.

Field measurements of ORP in the deeper bedrock wells MW-24BR, PGE-7BR, and PGE-8 are consistently strongly negative, indicating reducing conditions in the bedrock in the vicinity of those well locations. Injection of treated wastewater occurred in PGE-8 during the period 1970-1973. Reducing conditions indicated from the recent measurements suggest that remnant Cr(VI) that may have been present in the treated discharge would have been reduced to Cr(III) and precipitated out of solution assuming similar reducing conditions were prevalent during the discharge period. Wells screened in the near-surface bedrock downgradient of the facility, MW-23 and MW-48, have displayed mixed ORP readings and indicate a variable redox environment.

The contrast between non-reducing and reducing sediments is best illustrated at the transition zone in the floodplain (Figures 5-22). At the MW-20 bench, non-reducing conditions prevail at all depths of the aquifer, composed entirely of alluvial materials at this location. To the east, fluvial material appears at shallow depths and becomes thicker towards the river. When the MW-39 well cluster was first installed in 2004, reducing conditions were limited to the uppermost well in the cluster, MW-39-40, screened in shallow fluvial material. Subsequently, IM-3 extraction has drawn shallow fluvial groundwater westward and downward in this area, so that by the end of 2007, several of the middle zone wells have become more reducing (Figure 5-23), including wells MW-39-60, MW-30-50, and MW-34-55. Further east at the MW-36 well cluster, all subsurface material was logged as fluvial in origin, yet the bottom 20 feet has remained non-reducing. This is likely due to one of two factors: (1) the fluvial sediments are old enough for their original organic carbon to have been used up, or (2) the oldest fluvial material was carbon-poor, gravel-rich material from a recent post-glacial Colorado River that drained a more barren watershed. Closer to the river, the MW-27 cluster provides further indications of less reducing conditions with depth, with ORP above -100 mV in the deepest MW-27-85, compared to ORP averaging below -150 mV in MW-27-20 (Figure 5-22). Further to the south, the reducing conditions extend down to bedrock beneath the river, as evidenced by analytical and field results from the slant well clusters MW-52 and MW-53. As will be discussed in Section 8.0, 63 out of 64 pore water samples collected from shallow river sediments (Figure 4-7) showed ORP readings of -88 mV or lower, and all 10 samples analyzed for dissolved iron and ammonia showed concentrations well above reporting limits (Appendix H5, Tables 8-1, 8-2). Pore water data indicate predominantly reducing conditions in the river bottom, consistent with upper and middle zone groundwater samples in the floodplain.

Anaerobic conditions have been documented during drilling by observing core material collected for well logging. These conditions are typified by darker-colored, gray-green core material that quickly turns red-brown on exposure to the atmosphere. The color change indicates reduced iron being oxidized to ferric iron, which forms red-hued iron oxide solids rapidly at the oxygen-rich surface.

Samples of anaerobic core material, collected during drilling of the MW-28 and MW-36 well clusters, were analyzed in the laboratory in late 2004 (CH2M HILL, 2005d). The cores were tested for various properties and exposed to Cr(VI)-containing site groundwater under anaerobic conditions in the laboratory. The experiment was designed to simulate the non-reducing plume groundwater migrating into the reducing zone of the shallow floodplain. The results verified that the cores had significant capacity to reduce Cr(VI) and that this reaction is likely to be biologically mediated. Additional anaerobic cores were collected in 2007 using nitrogen glove boxes to minimize exposure of core material to the atmosphere. Additional core testing has provided further estimates of reducing capacity (CH2M HILL, 2008a). Note that uncertainties remain regarding the extent to which reducing conditions in fluvial deposits provide a pervasive and permanent barrier to Cr(VI) contaminant migration to the river.

5.3.2 Stable Isotopes

Stable isotope data are useful in characterizing different groundwater chemistry sources and for estimating mixing of these sources. Although the common atomic mass of oxygen is 16 atomic mass units (amu), denoted as ^{16}O, there is a small fraction that has a mass of 18 amu (^{18}O). The same is true for hydrogen, with the common form being protium or ^{1}H and the rare form deuterium or ^{2}H. The fractions of ^{18}O and ^{2}H in a water sample can vary slightly depending on the water source or the water's history. The fractions are measured as ratios of $^{18}O/^{16}O$ and $^{2}H/^{1}H$ and compared to an international standard, Vienna Standard Mean Ocean Water (VSMOW). The difference between the sample's ratio and the VSMOW ratio is expressed as $\delta^{18}O$ and $\delta^{2}H$, in units of part per thousand, or ‰. Ratios in most water samples are less than in the VSMOW standard, so that $\delta^{18}O$ and $\delta^{2}H$ values are commonly negative numbers. The less negative the value, the "heavier" the isotopic signature, or the more enriched in the heavier isotope (^{18}O or ^{2}H). Samples may be plotted on a graph of $\delta^{2}H$ vs. $\delta^{18}O$ for grouping and comparison.

Figure 5-24a shows the distribution of average values of $\delta^{18}O$ and $\delta^{2}H$ for each well based on samples collected between 2004 and 2007. The figure depicts samples by geologic material in which the well is screened (alluvial, fluvial, or bedrock), and provides offsite wells from the groundwater background study (CH2M HILL, 2008b) for comparison. This figure is available with all well names in Appendix F2.

There are three main sources of water for the groundwater samples: river water, local natural alluvial sources, and industrial water from the Topock Facility. The estimated extents of these three groups are shown on Figure 5-24a. The samples are plotted relative to the Global Meteoric Water Line, about which most global rainfall would plot. Available isotopic data for rainfall in the Needles-Topock area show a range of signatures that span the range between river water and industrial water (Figure 5-24a) and appear to have a significant seasonal variation (Guay et al., 2006; Friedman et al., 1992; John Izbicki, 2008, personal communication). Samples plotting some distance below and to the right of this line may indicate evaporative processes in the water sample's history, which may have enriched the water in ^{18}O and ^{2}H. Water discharged from the cooling towers at the Topock facility had undergone some degree of evaporation, with a much greater amount in the early period of facility operation (CH2M HILL, 2005a). The "industrial water" group has the heaviest (i.e., least negative) isotopic signature range likely due to this evaporation history. Note that samples in some floodplain wells, such as the MW-32 and MW-42 clusters, do not contain detectable chromium (and therefore are not classified as "plume" wells), yet the isotopic signature indicates evaporatively concentrated water. This could be due to chromium being removed from industrial water by the reductive fluvial material beneath the floodplain, as described in the previous section. Alternatively, the samples could indicate that natural evapotranspiration has resulted in the heavier isotopic signature. Further discussion of the plume samples and stable isotopes will be provided in Section 6.0.

The water of the Colorado River forms a light signature endpoint for the distribution, and shallow wells close to the river (MW-27-20, MW-28-25) have a similar isotopic composition. The lighter signature of river water reflects the main sources upstream in the Rocky Mountains. In general, the isotopic signature becomes lighter with increasing elevation and latitude of the source water.

The middle group, the non-industrial alluvium source, has a range of isotopic signatures that likely reflect local rainfall recharge. There are several fluvial wells that fall into this middle category. For many of the fluvial wells, the middle group represents a mixing zone between the river water and either the alluvial and/or industrial water groups. There are any number of combinations of water groups from which a fluvial well's signature may be derived, and better definition of the sources must be assisted by other geochemical analysis and groundwater modeling. Interim Measures pumping over the last several years has accelerated this mixing in many wells, and a more quantitative discussion of mixing will be presented in Section 6.0.

5.3.2.1 Variation of Isotopic Data with Depth

Stable isotope composition of alluvial groundwater falls into two groups: shallow wells and medium/deep wells. The vast majority of shallow alluvial wells are grouped tightly on Figure 5-24b, between δ^{18}O values of -8.0 and -10.0‰. In contrast, deep alluvial wells show a broader range of isotopic composition, with δ^{18}O values ranging from -8.4 to -11.8‰. As with the shallow wells, there appears to be no correlation with geographic location. The data suggest that deep alluvial wells receive recharge of variable composition, possibly reflecting the fractured nature of the underlying bedrock that provides a portion of recharge. The similar signature of bedrock well MW-24BR to deeper alluvial wells suggests that some recharge may be derived from bedrock in this area. Figure 5-24c includes both plume and non-plume wells distinguished by depth, for comparison. Further discussion of stable isotopes as they relate to the chromium plume is presented in Section 6.5.2.

Fluvial well clusters close to the river (MW-27, MW-28, MW-43) tend to show a heavier signature in the deep wells, reflecting a decreased river influence with depth. Other fluvial clusters tend to have the opposite trend, similar to the alluvial wells, although most of these are influenced by industrial water and will be discussed in the next section.

5.3.3 Surface Water Quality Characteristics

Water quality sampling has been conducted at up to 18 surface water monitoring locations along the Colorado River during the RFI/RI. Colorado River water is characterized by its mixed-ion water chemistry as shown on Figure 5-17a and low TDS (about 600 mg/L, see Figure 5-18a). A summary of surface water quality characteristics for representative Colorado River Stations, R-28 and I-3, is presented in Table 5-4. The stable isotopes of oxygen and hydrogen in river water show a distinctly lighter signature compared to typical alluvial groundwater, as discussed in Section 5.3.2 and shown in Figure 5-24a. Shallow fluvial wells close to the river have water chemistry and stable isotope signatures similar to river water, indicating the presence of a mixing zone between Alluvial Aquifer and the river. Estimation of the degree of mixing is complicated by the presence of plume groundwater and IM groundwater extraction in the floodplain. A discussion of the use of water quality data to characterize this mixing zone is presented in Section 6.0.

5.4 Site Hydrogeologic Conceptual Model

The Topock site is situated in a basin-and-range geologic environment in the Mohave Valley. The Colorado River is the main source of water to this groundwater basin, but at the southern end where the site is located, a modest amount of local recharge from mountain thunderstorms contributes to the groundwater. The Alluvial Aquifer consists of (1) alluvial sands and gravels shed from local mountain chains that ring the valley and (2) fluvial material deposited by the Colorado River over time. A generalized oblique-view relief map and cross section are provided in Figure 5-25.

Although there are no low-permeability, continuous confining layers identified at the site that hydraulically segregate the aquifer, the alluvium has been observed to consist of three HSUs. Hydraulic conductivity varies considerably in all three HSUs but averages between 20 and 35 ft/d. A younger alluvial deposit, Qoa, is generally found in the unsaturated zone above the water table. The fluvial material is split into four HSUs, with the lower two generally having the highest conductivity (average around 50 ft/d). The interface between alluvial and fluvial material occurs near the western edge of the floodplain, with no continuous aquitards at the interface. Together, the alluvial and fluvial material make up the Alluvial Aquifer (Figure 3-9).

The site is located at the southern (downstream) end of the Mohave Valley groundwater basin. While groundwater in the northern and central area of the valley is recharged primarily by the Colorado River, most of this groundwater discharges back to the river in the southern area, above where the Alluvial Aquifer thins near the entrance to Topock

Gorge. The groundwater directly beneath the Topock site is derived mostly from the relatively small recharge from the nearby mountains. Under natural conditions, groundwater flows from west/southwest to east/northeast across the site. Gradients are very small due to the limited recharge, with a typical value of 0.0005 ft/ft in the alluvial area. Under average conditions, groundwater velocity is about 45 ft/yr.

As groundwater enters the fluvial material in the floodplain, its elevation and gradient become increasingly influenced by fluctuations in river level. Dam operations on the Colorado River cause the river level to fluctuate on daily and seasonal cycles. Groundwater levels in the floodplain follow the same cycles. Groundwater naturally discharges to the river during lower river stages in fall and winter, whereas the river recharges groundwater during the spring and summer months. Since 2004, IM groundwater extraction has maintained a consistent landward direction in the floodplain area.

Groundwater quality at the Topock site is variable but is mostly brackish water with TDS between 1,000 and 10,000 mg/L. In general, TDS increases with depth, with the highest TDS found in deepest alluvium and bedrock wells. The predominant ions are sodium and chloride in nearly all of the alluvial groundwater samples. Fluvial groundwater quality is less saline in shallow wells close to the Colorado River, with a mixed-ion chemistry and TDS below 1,000 mg/L. TDS in fluvial groundwater increases with distance away from the river and with depth, becoming more similar to alluvial groundwater quality. Some shallow zones in fluvial groundwater contain very high TDS (up to 35,000 mg/L). Stable isotope data (oxygen and deuterium) have been used to identify three water groups: (1) river water and river-influenced groundwater, (2) local alluvial groundwater, and (3) industrial water from historical facility discharges. The groundwater groups are intermixed to varying degrees on the edges of the plume, especially in the floodplain. Interim measures groundwater extraction has drawn river-influenced groundwater westward and downward, causing mixing with industrial water at the edge of the floodplain, and isotopic data have been used to demonstrate the degree of mixing over time.

Under non-pumping conditions, as groundwater flows through the floodplain, the non-reducing alluvial groundwater enters the reducing material in the fluvial sediments and becomes more reducing, with nitrate converted to ammonia and detectable manganese and iron observed. The reducing conditions are derived from organic carbon in the river deposits, which supports microbial communities that maintain the reduced conditions. In some of the older fluvial sediments, non-reducing conditions still prevail, owing to the shortage of organic carbon at depth. IM extraction has diminished this non-reducing zone in recent years. The reducing zone acts to remove Cr(VI) from groundwater as plume water approaches the floodplain area in the absence of IM extraction. This will be discussed further in Section 6.0.

TABLE 5-1

Summary of Hydraulic Testing and Estimated Hydraulic Properties

RCRA Facility Investigation/Remedial Investigation Report (Volume 2)

PG&E Topock Compressor Station

Well ID	HSU[1]	Date	Type of Hydraulic Test [2]	Pumping Rate (gpm)	Duration of Pumping (minutes)	Specific Capacity (gpm/ft)	Estimated Transmissivity (ft^2/day)	Casing Diameter (inches)	Approximate Borehole Diameter (inches)	Estimated Saturated Thickness [6] (at well, feet)	Estimated Hydraulic Conductivity (ft/day)	Reference
Fluvial HSUs												
MW-27	Qrd	Jan-02	Slug	--	--	--	500	2	6	30	15	E&E, 2002
MW-28-25	Qr3	Jan-02	Slug	--	--	--	300	2	6	30	10	E&E, 2002
MW-28-90	Qr1, Qr2	Apr & Jun-04	Devel./Purge	1.2 - 2	50 - 248	2 - 6.3	1,100	2	6	50	20	
MW-30-30	Qr3	Jan-02	Slug	--	--	--	100	2	6	30	3	E&E, 2002
MW-30-30	Qr3	Feb-04	Purge[3]	1.5	--	1.4	400	2	6	33	10	
MW-30-50	Qr2	Feb-04	Purge[3]	1.5		5	1,300	4	8	21	60	
MW-32-35	Qr2	Feb-04	Purge[3]	1.4		0.6	200	4	8	16	10	
MW-34-55	Qr2	Feb-04	Purge[3]	3.5 - 6.3		12 - 16	4,000	4	8	35	110	
MW-34-80	Qr1	Feb & Jun-04	Purge[3]	1.4 - 3		1.1 - 1.3	300	4	8	16	20	
Alluvial HSUs												
MW-20-100	Toa	Jan-02	Pumping	3.1	525	0.1	100 - 600	4	8	86	1-7	E&E, 2002
MW-20-130	Toa0	Jan-02	Pumping	6.9	600	0.4	1,200 - 3,400	4	8	86	14 - 40	E&E, 2002
MW-24B	Toa0	Jan-02	Pumping	6.3	215	0.4	200	4	8	115	2	E&E, 2002
MW-31-135	Toa	Apr & Jun-04	Devel./Purge	3	21 - 187	1.3 - 1.5	400	2	6	21	20	
MW-33-90	Qoa	Feb & Jun-04	Purge[3]	1.5 - 3		4.3 - 6.4	1,400	4	8	63	20	
MW-35-60	Qoa	May & Jun-04	Purge	2 - 3.5	18 - 77	2.5 - 3.4	800	2	6	32	20	
MW-35-135	Toa	Apr & Jun-04	Devel./Purge	3 - 3.5	31 - 81	2.1 - 2.3	600	2	6	20	30	
MW-36-100	Qoa	May & Jun-04	Purge	2	24 - 29	0.7	200	2	6	11	20	
MW-37S	Qoa	May & Jun-04	Devel./Purge	2 - 3	18 - 76	5.8 - 10	2,100	2	6	56	40	
MW-37D	Toa	Apr & Jun-04	Devel./Purge	3	37 - 99	5.1 - 5.6	1,400	2	6	20	70	
MW-38S	Qoa	May & Jun-04	Devel./Purge	2 - 5	24 - 30	1 - 1.1	300	2	6	28	10	
MW-38D	Toa0	Apr & Jun-04	Devel./Purge	3	23 - 136	2.1 - 6.8	1,200	2	6	32	40	
MW-39-100	Toa	Apr & Jun-04	Devel./Purge	1.5 - 2	23 - 157	2.6 - 6.8	1,300	2	6	27	50	
MW-40D	Toa0	May-04	Develop	4.5	55			2	6			
TW-1	Toa0	Dec-03	Step	22 - 88	120	11-16	2,200 - 3,300	5	10.5	100	20 - 90	CH2M HILL, 2003e
TW-2S	Qoa	Apr-04	Pumping	85	825	4 - 5		6	10.5	55		CH2M HILL, 2005a
TW-2D	Toa, Toa0	May-04	Pumping	98	480	1 - 2		6	10.5	40		CH2M HILL, 2005a
TW-2S & 2D	Qoa, Toa, Tsu	May-04	Pumping	150	300	1 - 2	3,000	6	10.5	100	300	CH2M HILL, 2005a

TABLE 5-1
Summary of Hydraulic Testing and Estimated Hydraulic Properties
RCRA Facility Investigation/Remedial Investigation Report (Volume 2)
PG&E Topock Compressor Station

Well ID	**HSU**[1]	**Date**	**Type of Hydraulic Test** [2]	**Pumping Rate** (gpm)	**Duration of Pumping** (minutes)	**Specific Capacity** (gpm/ft)	**Estimated Transmissivity** (ft^2/day)	**Casing Diameter** (inches)	**Approximate Borehole Diameter** (inches)	**Estimated Saturated Thickness** [6] (at well, feet)	**Estimated Hydraulic Conductivity** (ft/day)	**Reference**
TW-4	Toa0	May-06	Pumping	28	180	0.7	175	4	8	250	1	CH2M HILL, 2006o
TW-5	Toa	May-06	Step	18-70	30-135	2.9	780	4	8	180	4	CH2M HILL, 2006o
MW-26	Toa	May-06	Pumping	5	85	< 0.3	80	2	6	68	1	CH2M HILL, 2006o
IW-2	Toa	Dec-04	Pumping/MLU	140	350	--	2,000 - 11,000[4]	6	10.5	260	7 - 40[4]	CH2M HILL, 2005w
IW-3	Toa	Dec-04	Pumping/MLU	251	290	--		6	10.5			CH2M HILL, 2005w
IW-2	Toa	Dec-04	Step	72-185	146	31-34	8,200 - 9,000	6	10.5	267	30	CH2M HILL, 2005w
IW-3	Toa	Dec-04	Step	80-195	155	41-48	11,000-13,000	6	10.5	255	40 - 50	CH2M HILL, 2005w
PT-1	Toa	Jan-87	Pumping					4	8			PG&E-TES, 1995
Bedrock / Miocene Conglomerate												
MW-23	Tmc	Jan-02	Slug	--	--	--	0.1	4	8	27	0.004	E&E, 2002
MW-48	Tmc	Nov-07	Slug	--	--	--		2	6		0.001	CH2M HILL, 2008i
Bedrock / Pre-Tertiary Metamorphic Rocks												
MW-24BR	pTbr	Jan-02	Slug	--	--	--	0.2	4	8	60	0.003	E&E, 2002
PGE-7BR	pTbr	Aug-07	Slug	--	--	--		6.75	6.75		0.02	CH2M HILL, 2008i
PGE-08	pTbr	Aug-07	Injection	14.7	2682	--		4	6.7		see note 5	CH2M HILL, 2008i
PGE-08	pTbr	Aug-07	Pumping	13.6	4522	0.08		4	6.7		see note 5	CH2M HILL, 2008i

Notes:

[1] See Table 3-1 for description and explanation of hydrostratigraphic units (HSU).

[2] Slug - slug injection or removal test; Devel. - testing during development; Purge - testing during purging/sampling; Step - variable rate step test; Pumping - constant rate pumping/aquifer test; MLU - (Multi Layer Unsteady state) is a program for drawdown calculations and inverse modeling (pumping tests and recovery tests) of transient well flow in layered aquifer systems. MLU computes the set of aquifer parameters that achieves the best match to observed drawup in all monitoring wells and the pumping well.

[3] For well purging data, aquifer properties determined from calculated specific capacity.

[4] The MLU analyses here were conducted iteratively using test data from the injection of water at IW-2 and IW-3.
Analyses of the injection test data using the Cooper-Jacob method yielded similar results (T: 2,000 - 14,500 ft2/d, pumping wells only), also reported in CH2M HILL, 2005w.

[5] Transmissivity and/or hydraulic conductivity estimates to be provided in upcoming model report.
Abbreviations: gallons per minute (gpm), feet per day (ft/day), square feet per day (ft^2/day), transmissivity (T)

[6] The saturated thicknesses used for estimating hydraulic properties were based on well construction data, or HSU thickness in vicinity of the wells (obtained from site hydrogeologic cross-sections).

TABLE 5-2
Estimated Aquifer Hydraulic Parameters
RCRA Facility Investigation/Remedial Investigation (Volume 2)
PG&E Topock Compressor Station, Needles, California

Area of Model	**HSU**	**Kh (ft/d)**	**Kv (ft/d)**	**S (unitless)**	**Source**
Floodplain/Park Moabi Road	Qr3	22	2	9E-03	TW-4/TW-5 testing, May 2006
	Qr2	5	1	1E-06	
	Qr1	46	1	3E-05	
	Upper Toa2	22	2	9E-03	
	Middle Toa2	5	1	1E-06	
	Lower Toa2	46	1	3E-05	
	Upper Toa1	5	1	3E-05	
	Lower Toa1	46	1	3E-05	
	Upper Toa0	36	2	3E-04	
	Lower Toa0	6	0.4	6E-05	
IM3 Injection Area	Toa2	18	1.4	6E-03	IW-2/IW-3 testing, December 2004
	Toa1	34	1	1E-04	
	Toa0	240	1.7	3E-04	
Topock Compressor Station Area	Toa2	7	2.7	4E-03	TW-1 step-drawdown test, December 2003
	Toa1	52	4.9	1.5E-04	
	Toa0	11	0.6	1.5E-04	
New Ponds Area	Toa2	85	8	0.1	PT-1 test, January 1987
	Toa1	85	8	1E-07	
	Toa0	85	8	1E-07	

Notes: feet per day (ft/day), horizontal conductivity (Kh), vertical conductivity (Kv), storativity (S)

TABLE 5-3

Vertical Hydraulic Gradients in Monitoring Well Clusters

RCRA Facility Investigation/Remedial Investigation Report (Volume 2)

PG&E Topock Compressor Station, Needles, California

Shallower Well	Deeper Well	Aquifer Depth Interval	Vertical Distance between Screens (feet)	Start Date	End Date	Average Vertical Hydraulic Gradient (feet/foot)	Standard Deviation	Minimum	Maximum
Well Clusters in Bat Cave Wash Area									
MW-24A	MW-24B	SA-DA	91	Jan-04	Feb-04	0.001	1.6E-04	9.0E-04	1.1E-03
MW-24B	MW-24BR	DA-Tmc	205	Aug-01	May-05	0.004	8.8E-04	2.5E-03	6.0E-03
MW-24A	MW-24BR	DA-Tmc	297	Aug-01	May-05	0.003	6.5E-04	2.0E-03	4.4E-03
MW-9	PGE-8	SA - pTbr	338	Jun-03	May-05	0.004	8.0E-04	3.0E-03	5.0E-03
Well Clusters in Floodplain									
MW-34-055	MW-34-080	SA-MA	28	Jan-04	Feb-04	0.015	6.3E-03	1.9E-03	3.1E-02
MW-43-025	MW-43-075	SA-MA	50	Jun-05	Jun-06	0.004	1.1E-03	3.8E-04	7.1E-03
MW-43-075	MW-43-090	MA-DA	15	Jun-05	Jun-06	0.010	3.8E-03	8.7E-04	1.7E-02
MW-43-025	MW-43-090	SA-DA	65	Jun-05	Jun-06	0.005	1.2E-03	1.2E-03	8.8E-03
Well Clusters along Park Moabi Road									
MW-35-060	MW-35-135	SA-DA	75	Apr-04	Jun-06	-0.002	3.2E-03	-1.1E-02	6.1E-03
MW-47-055	MW-47-115	SA-DA	60	Apr-06	Jun-06	0.001	9.5E-04	-4.2E-03	2.9E-03
MW-26	MW-51	SA-MA	44	May-06	Jun-06	0.001	6.0E-04	-2.1E-04	2.9E-03
MW-12	MW-48	SA-Tmc	89	May-07	Sept-07	0.003	3.1E-04	2.7E-03	4.2E-03
MW-19	MW-50-095	SA-MA	37	May-06	Jun-06	-0.001	3.2E-03	-1.2E-02	7.8E-03
MW-50-095	MW-50-200	MA-DA	105	May-06	Jun-06	0.002	4.3E-04	7.5E-04	3.4E-03
MW-19	MW-50-200	SA-DA	143	May-06	Jun-06	0.002	1.5E-03	-2.1E-03	6.9E-03
Well Clusters in the East Mesa									
CW-02M	CW-02D	within DA	133	Nov-04	Jun-05	0.004	2.3E-04	3.3E-03	4.5E-03
CW-03M	CW-03D	within DA	98	Nov-04	Jun-05	0.007	3.3E-04	5.9E-03	7.6E-03
CW-04M	CW-04D	within DA	113	May-05	Jun-05	0.003	1.8E-04	2.5E-03	3.2E-03

Notes:

1. All groundwater elevations measured in wells have been normalized to freshwater head by adjusting for salinity and temperature.
2. The distance between mid-points of well screens is used to calculate vertical gradients at well pairs.
3. Positive values denote upward gradients, and negative values denote downward gradients.
   Values < |0.001| are neutral and considered to denote negligible vertical gradients.
4. Values for MW-9, MW-24A, MW-24B, MW-24BR, MW-12, MW-48, & PGE-8 were calculated from hand measured data, not transducers
5. All head measurements were converted to equivalent fresh water heads with corrections for salinity and temperature prior to gradient calculations.

TABLE 5-4

Colorado River Surface Water Quality Results

RCRA Facility Investigation/Remedial Investigation (Volume 2)

PG&E Topock Compressor Station, Needles, California

Analyte	Units	River Sampling Station R-28			River Sampling Station I-3		
		# of Samples (1)	Average Detected Concentration (2)	Range of Detected Values	# of Samples (1)	Average Detected Concentration (2)	Range of Detected Values
Field Measurements							
Dissolved oxygen	mg/L	48	10.0	3.60 - 13.0	49	10.2	5.87 - 14.3
Oxidation reduction potential	mV	48	110	-130 - 287	46	129	-30 - 258
pH	pH units	51	8.21	5.90 - 9.86	49	8.07	5.67 - 9.59
Salinity	%	48	0.0794	0.00 - 0.54	48	0.0823	0.00 - 0.55
Specific conductance	µS/cm	49	1,092	587 - 3020	50	1100	591 - 2160
Temperature	°C	52	18.0	8.00 - 24.8	51	18.2	7.72 - 36.9
Turbidity	NTU	50	14.4	0.00 - 207	47	23.9	0.00 - 420
Anions							
Bromide	mg/L	15	NA	ND (0.50)	0	---	---
Chloride	mg/L	16	91.4	80.2 - 106	5	79.6	74.0 - 84.0
Fluoride	mg/L	3	0.380	0.38	5	0.324	0.30 - 0.34
Nitrate	mg/L	0	---	---	1	0.78	0.78
Nitrate as Nitrogen	mg/L	15	0.426	0.35 - 0.53	4	0.583	0.36 - 0.89
Nitrite	mg/L	0	---	---	1	0.01	0.01
Nitrite as Nitrogen	mg/L	0	---	---	2	0.006	0.006
Sulfate	mg/L	16	256	223 - 296	5	232	221 - 242
General Chemistry							
Alkalinity hydroxide	mg/L	3	NA	ND (5.00)	1	NA	ND (5.00)
Alkalinity, as carbonate	mg/L	15	NA	ND (5.00)	5	NA	ND (5.00)
Alkalinity, bicarb as CaCO3	mg/L	15	136	122 - 167	5	143	130 - 167
Alkalinity, total as CaCO3	mg/L	16	134	122 - 146	2	139	137 - 140
Ammonia	mg/L	0	---	---	3	0.20	0.10 - 0.30
Ammonia as nitrogen	mg/L	5	NA	ND (0.50)	2	NA	ND (0.50)
Bicarbonate	mg/L	1	149	149	0	---	---
Carbonate	mg/L	1	NA	ND (5.00)	0	---	---
Deuterium	0/00	15	-95.9	-102 - -83	1	-98	-98
Orthophosphate	mg/L	2	NA	ND (0.50)	2	NA	ND (0.50)
Oxidation reduction potential	mV	0	---	---	3	250	194 - 306
Oxygen 18	0/00	15	-12.1	-13 - -11.1	1	-12.1	-12.1
Perchlorate	µg/L	0	---	---	1	NA	ND (4.00)
pH	pH units	31	8.20	7.09 - 8.51	35	8.18	7.71 - 8.48

TABLE 5-4
Colorado River Surface Water Quality Results
RCRA Facility Investigation/Remedial Investigation (Volume 2)
PG&E Topock Compressor Station, Needles, California

		River Sampling Station R-28			**River Sampling Station I-3**		
Analyte	**Units**	**# of Samples (1)**	**Average Detected Concentration (2)**	**Range of Detected Values**	**# of Samples (1)**	**Average Detected Concentration (2)**	**Range of Detected Values**
General Chemistry							
Phosphate	mg/L	0	---	---	3	0.0433	0.02 - 0.06
Soluble silica	mg/L	1	8.93	8.93	0	---	---
Specific conductance	µS/cm	32	1,018	740 - 2200	37	951	594 - 1190
Sulfide	mg/L	1	NA	ND (0.40)	4	1.30	1.30
Total dissolved solids	mg/L	16	656	580 - 710	5	595	532 - 648
Total organic carbon	mg/L	3	7.70	3.90 - 14.2	5	3.90	3.20 - 4.90
Metals							
Barium, dissolved	µg/L	1	NA	ND (500)	5	125	110 - 170
Chromium	µg/L	1	13.3	13.3	1	13.4	13.4
Chromium, dissolved	µg/L	63	12.4	3.50 - 31.0	66	5.46	1.60 - 13.5
Copper, dissolved	µg/L	22	4.53	2.60 - 6.10	26	5.08	3.50 - 11.0
Hexavalent chromium	µg/L	63	19.2	19.2	66	24.6	24.6
Lead, dissolved	µg/L	0	---	---	3	NA	ND (5.00)
Molybdenum, dissolved	µg/L	1	5.40	5.40	3	4.73	4.20 - 5.00
Nickel, dissolved	µg/L	22	6.33	0.98 - 30.0	26	2.46	1.00 - 4.90
Vanadium, dissolved	µg/L	1	253	253	3	2.30	2.20 - 2.40
Zinc, dissolved	µg/L	22	116	4.40 - 1060	26	48.4	3.90 - 158
Boron, dissolved	mg/L	15	NA	ND (200)	0	---	---
Calcium, dissolved	mg/L	16	81.5	72.0 - 88.1	5	76.3	66.0 - 98.8
Iron	mg/L	0	---	---	2	0.03	0.03
Iron (+2)	mg/L	0	---	---	3	0.26	0.26
Iron, dissolved	mg/L	3	NA	ND (500)	2	NA	ND (500)
Magnesium, dissolved	mg/L	16	29.9	26.0 - 32.1	5	26.6	25.2 - 28.0
Manganese, dissolved	mg/L	3	NA	ND (500)	5	0.00533	0.004 - 0.007
Potassium, dissolved	mg/L	16	5.30	4.04 - 6.36	5	4.73	4.08 - 5.89
Sodium, dissolved	mg/L	16	95.1	76.8 - 108	5	93.5	80.5 - 114

TABLE 5-4

Colorado River Surface Water Quality Results

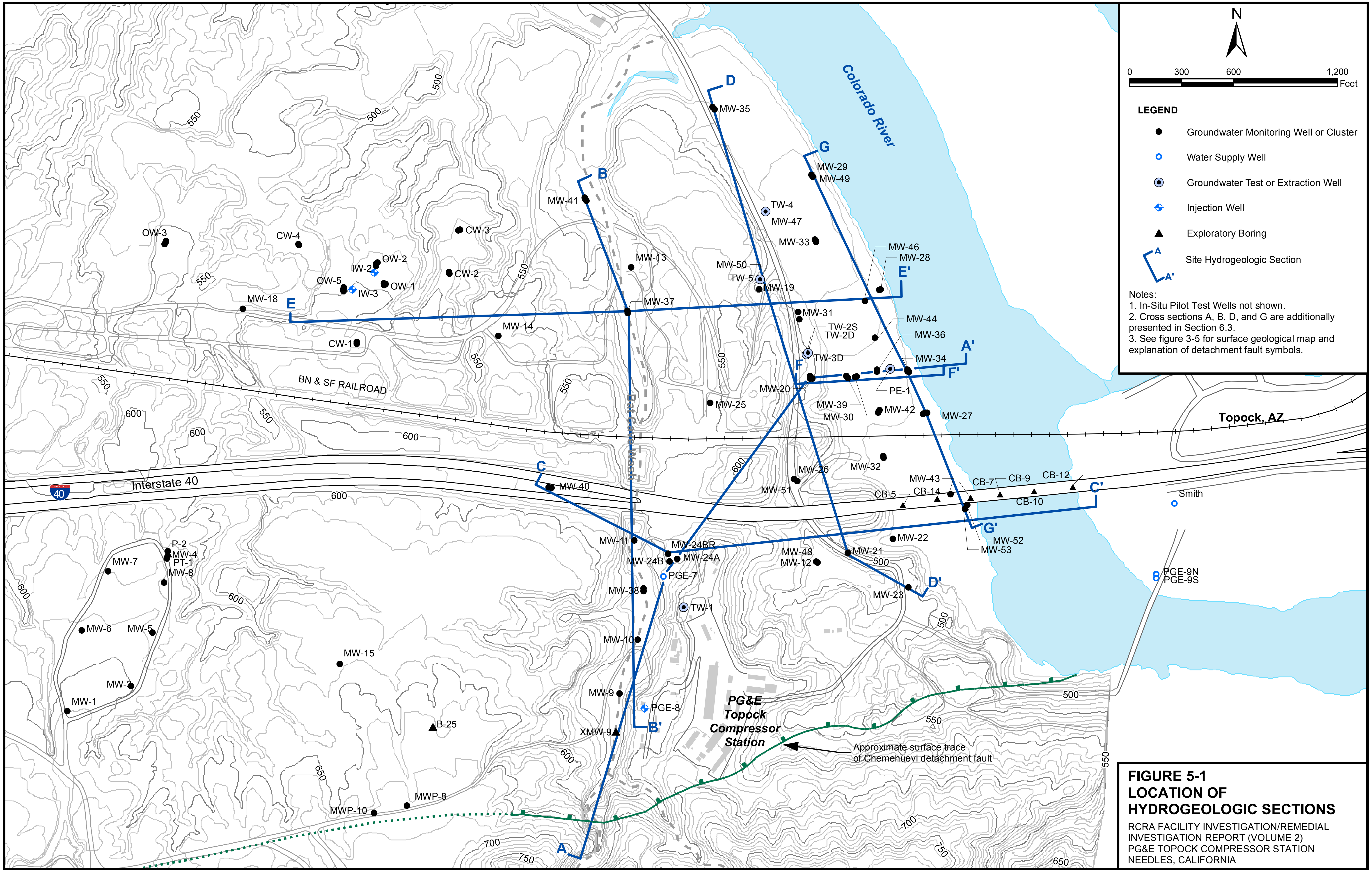
RCRA Facility Investigation/Remedial Investigation (Volume 2)
PG&E Topock Compressor Station, Needles, California

Notes:

Results from PG&E groundwater monitoring program, sampling events from July 1997 through October 2007.

[1] Number of analyzed samples includes only the primary lab or field sample. Field duplicates are not included. Rejected data not included
[2] Average concentration of detected concentrations only.

---	not analyzed
NA	not applicable
ND	parameter not detected at maximum reporting limit listed.
mg/L	milligrams per liter
µS/cm	microSiemens per centimeter
mV	millivolt
µg/L	micrograms per liter
0/00	parts per thousand
NTU	nephelometric turbidity unit



LEGEND

● Groundwater Monitoring Well or Cluster

○ Water Supply Well

◉ Groundwater Test or Extraction Well

⌖ Injection Well

▲ Exploratory Boring

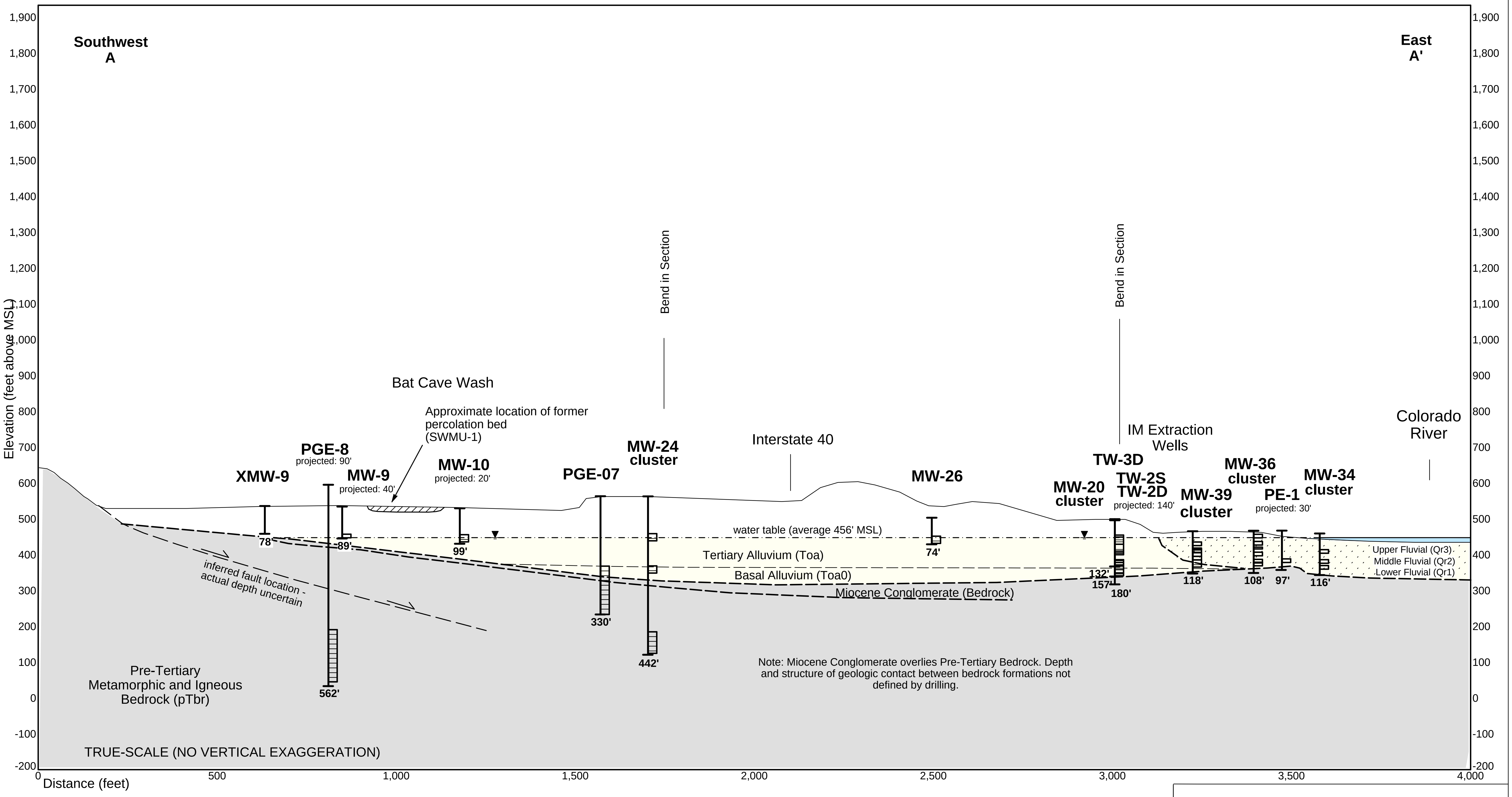
A A' Site Hydrogeologic Section

Notes:
1. In-Situ Pilot Test Wells not shown.
2. Cross sections A, B, D, and G are additionally presented in Section 6.3.
3. See figure 3-5 for surface geological map and explanation of detachment fault symbols.

FIGURE 5-1
LOCATION OF HYDROGEOLOGIC SECTIONS

RCRA FACILITY INVESTIGATION/REMEDIAL
INVESTIGATION REPORT (VOLUME 2)
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

BAO \\ZINFANDEL\PROJ\PACIFICGASELECTRICCO\TOPOCKPROGRAM\GIS\MAPFILES\2008\RFI\HYDRO_CROSS_SECTIONS.MXD 12/3/2008 16:30:25



Notes:
Refer to Figure 5-1 for location of cross-section.
Refer to Table 3-1 for hydrostratigraphic unit descriptions.
MSL = mean sea level

12/3/08

FIGURE 5-2
SITE HYDROGEOLOGIC SECTION A-A'
BAT CAVE WASH TO FLOODPLAIN

RCRA FACILITY INVESTIGATION/REMEDIAL INVESTIGATION REPORT (VOLUME 2)
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

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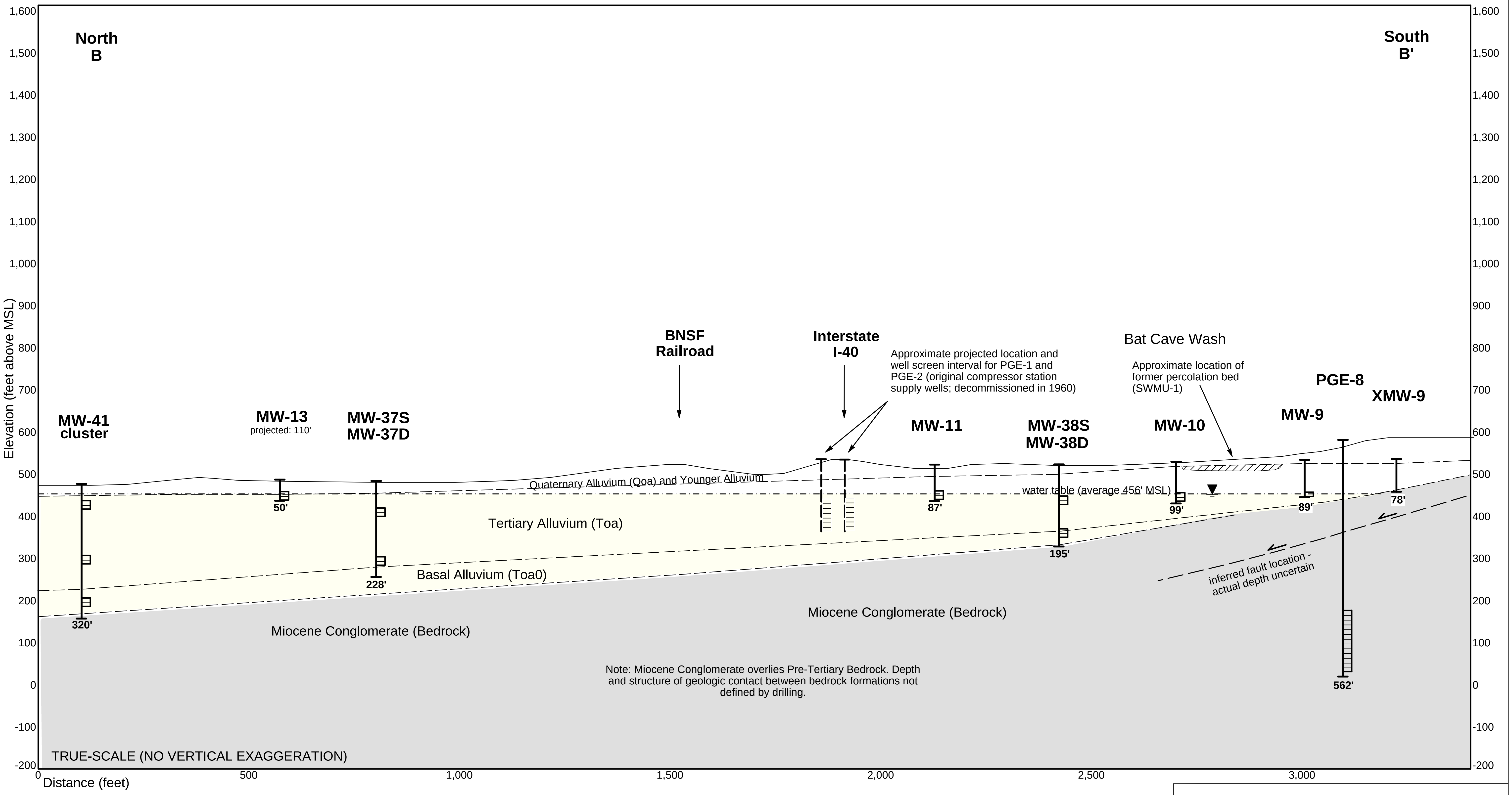
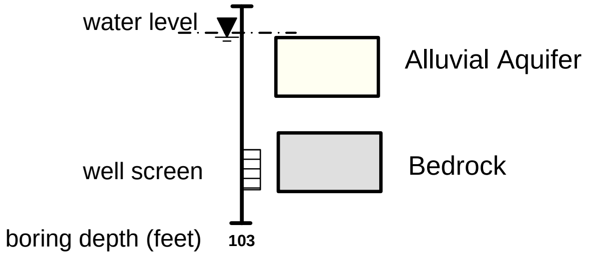
P:\INPUT\GINT_WORK_FILE_TYPES\GDW\X-SECTIONS\RFI_2007\12-2008_FINALREVISIONS\FIGURE5-2_XSECA.GDW;





Notes:
Refer to Figure 5-1 for location of cross-section.
Refer to Table 3-1 for hydrostratigraphic unit descriptions.
MSL = mean sea level

FIGURE 5-3
SITE HYDROGEOLOGIC SECTION B-B'
BAT CAVE WASH ALIGNMENT

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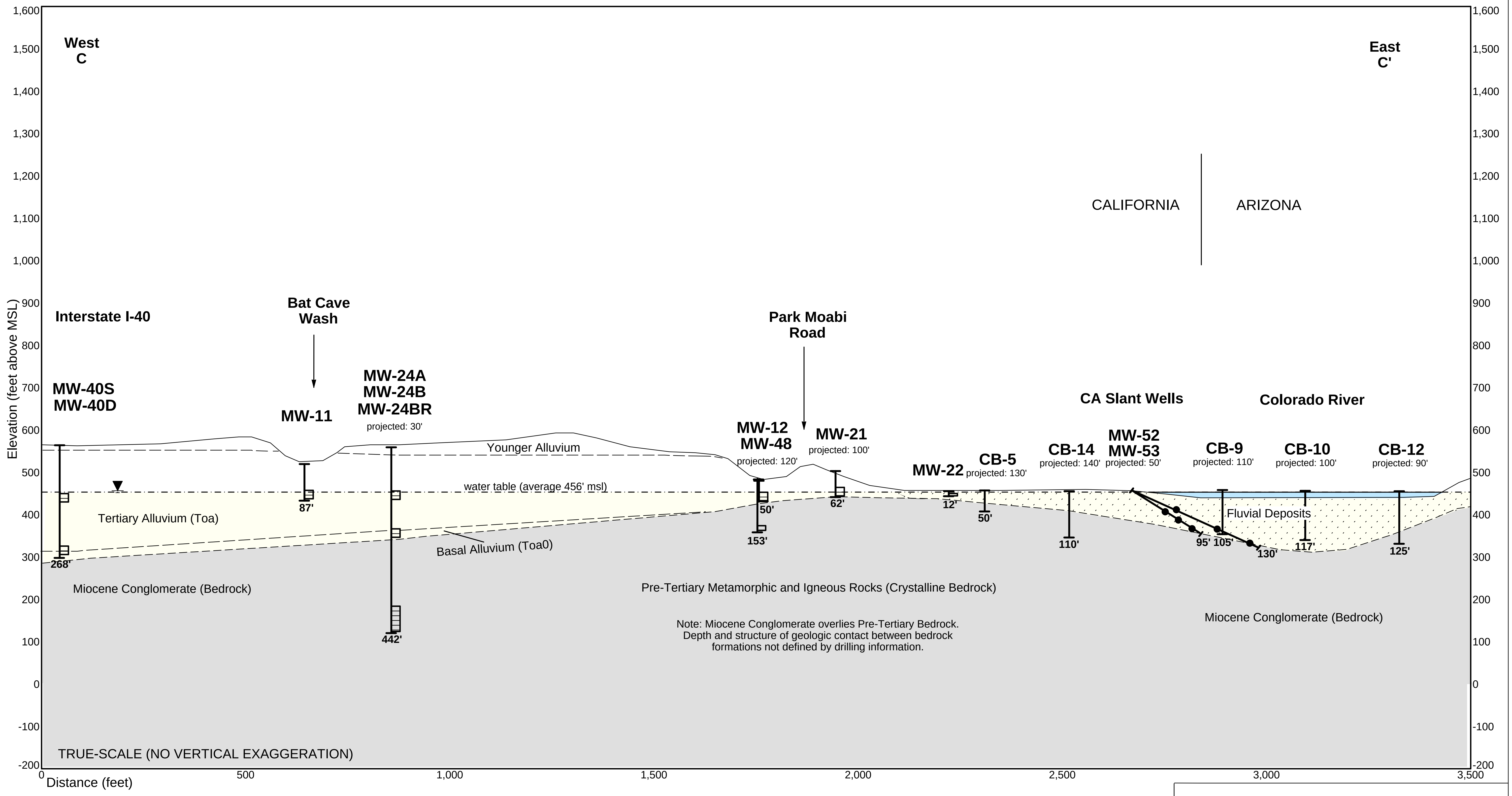
\\ZINFANDEL\PROJ\PACIFICGASELECTRICCO\TOPOCKPROGRAM\GINT\INPUT\GINT_WORK_FILE_TYPES\GDW\X-SECTIONS\RFI_2007\12-2008_FINALREVISIONS\FIGURE5-3_XSECB.GDW;



water level ▼

well screen on slant wells MW-52 & MW-53 ●

well screen

boring depth (feet) 103

☐ Alluvial Aquifer

⁘ Fluvial Deposits (within Alluvial Aquifer)

▨ Bedrock

Notes:
Refer to Figure 5-1 for location of cross-section.
Refer to Table 3-1 for hydrostratigraphic unit descriptions.
MSL = mean sea level

12/3/08

FIGURE 5-4
SITE HYDROGEOLOGIC SECTION C-C'
HIGHWAY I-40 ALIGNMENT

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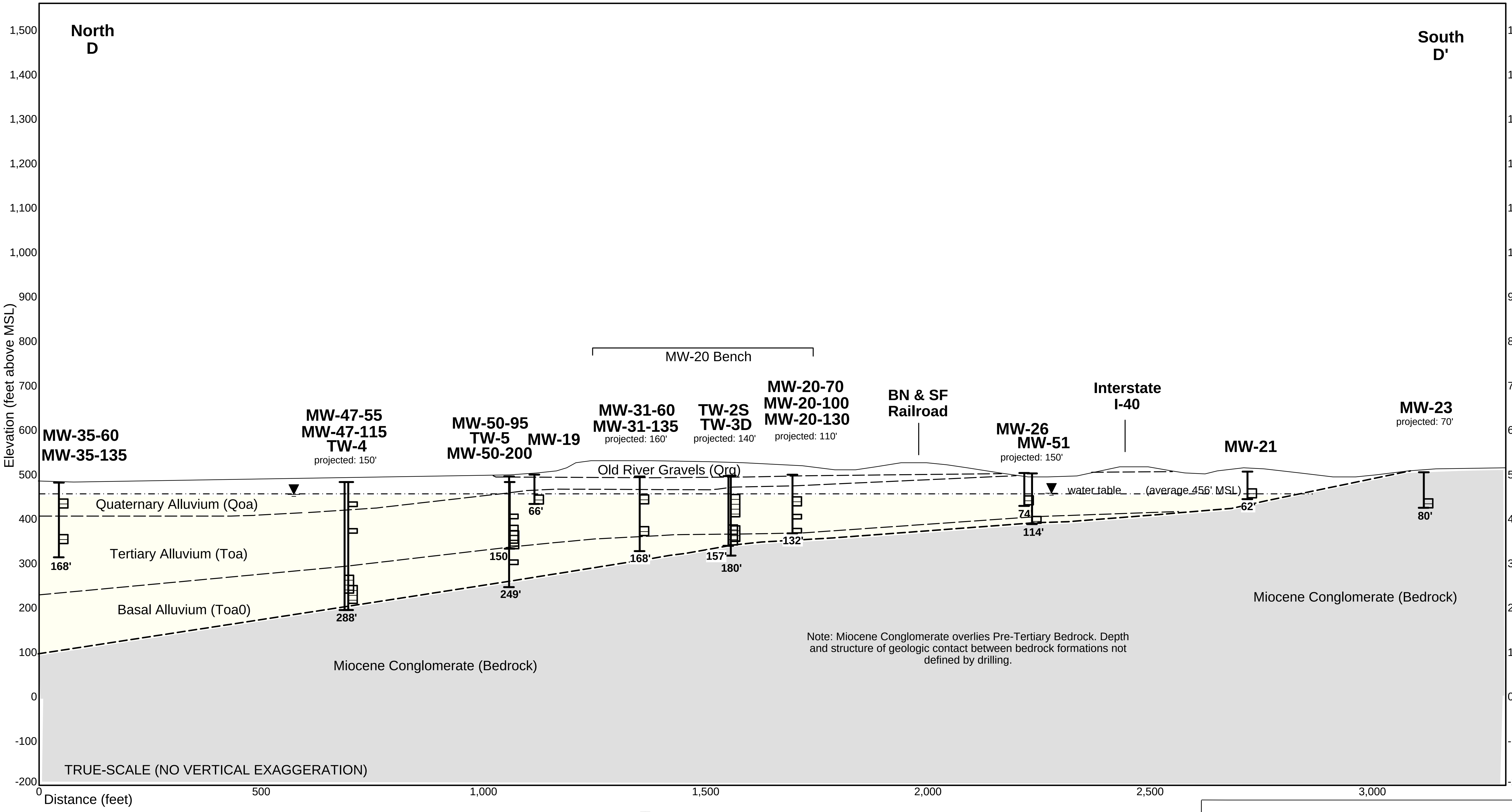

Notes:
Refer to Figure 5-1 for location of cross-section.
Refer to Table 3-1 for hydrostratigraphic unit descriptions.
MSL = mean sea level

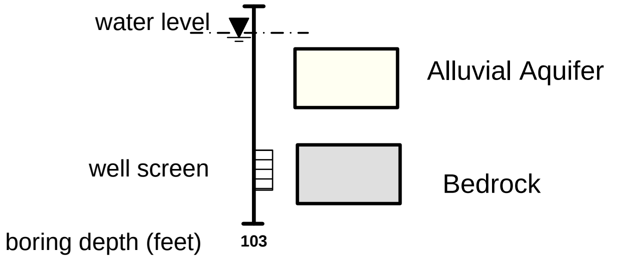

FIGURE 5-5
SITE HYDROGEOLOGIC SECTION D-D'
PARK MOABI ROAD ALIGNMENT

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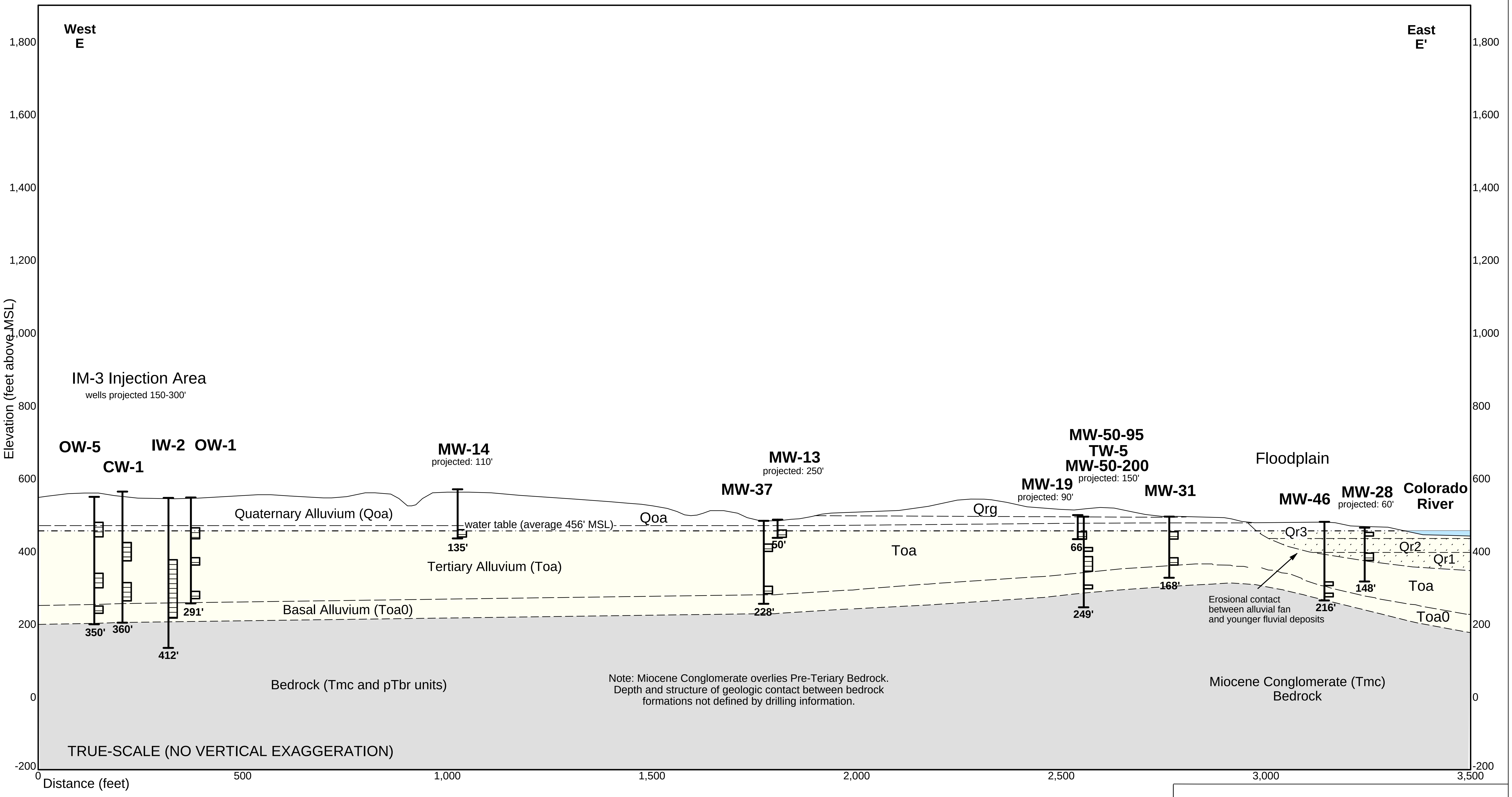
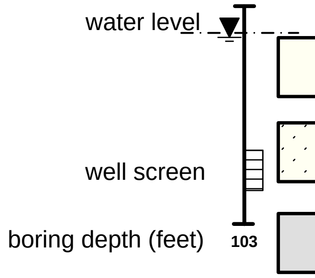
P:\INPUT\GINT_WORK_FILE_TYPES\GDW\X-SECTIONS\RFI_2007\12-2008_FINALREVISIONS\FIGURE5-5_XSECD.GDW;



Notes:
Refer to Figure 5-1 for location of cross-section.
Refer to Table 3-1 for hydrostratigraphic
unit descriptions.
MSL = mean sea level



□ Alluvial Aquifer

▨ Fluvial Deposits (within Alluvial Aquifer)

■ Bedrock

FIGURE 5-6
SITE HYDROGEOLOGIC SECTION E-E'
INJECTION AREA TO FLOODPLAIN

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INVESTIGATION REPORT (VOLUME 2)
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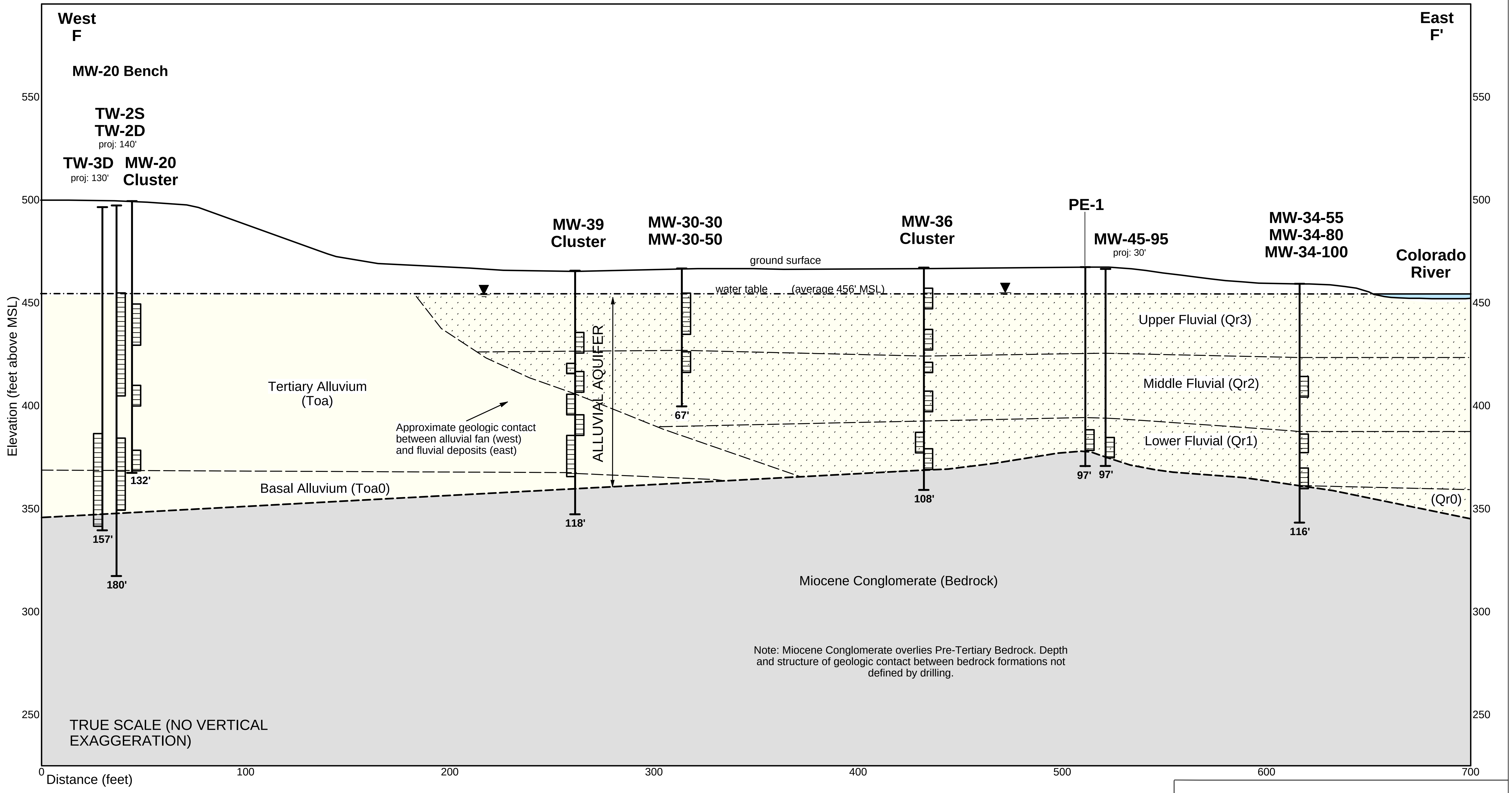
P:\INPUT\GINT_WORK_FILE_TYPES\GDW\X-SECTIONS\RFI_2007\12-2008_FINALREVISIONS\FIGURE5-6_XSECE.GDW;



Notes:
Refer to Figure 5-1 for location of cross-section.
Refer to Table 3-1 for hydrostratigraphic
unit descriptions.
MSL = mean sea level

water level
well screen
boring depth (feet) 103

☐	Alluvial Aquifer
⸬	Fluvial Deposits (within Alluvial Aquifer)
▨	Bedrock

1/9/08

FIGURE 5-7
FLOODPLAIN HYDROGEOLOGIC CROSS SECTION F-F' IM EXTRACTION AREA

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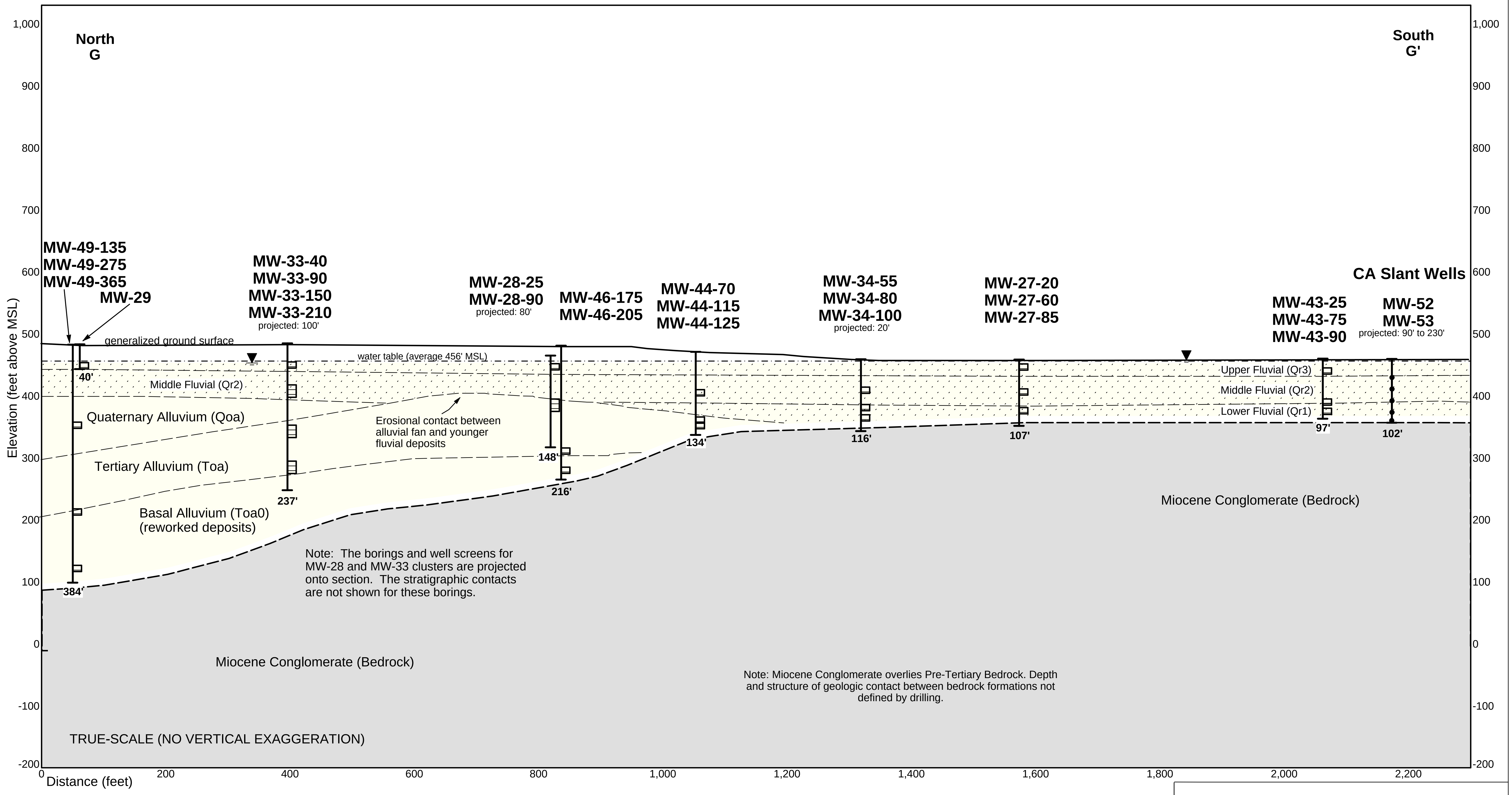

Notes:
Refer to Figure 5-1 for location of cross-section.
Refer to Table 3-1 for hydrostratigraphic unit descriptions.
MSL = mean sea level

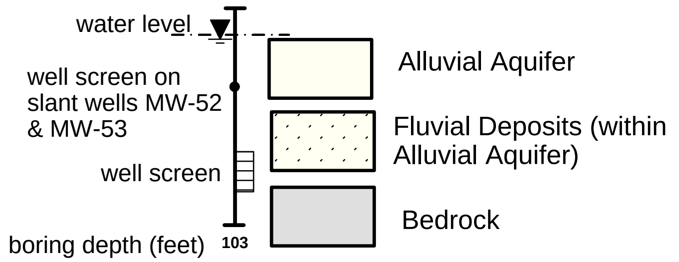

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FIGURE 5-8
FLOODPLAIN HYDROGEOLOGIC CROSS-SECTION G-G' PARALLEL TO RIVER

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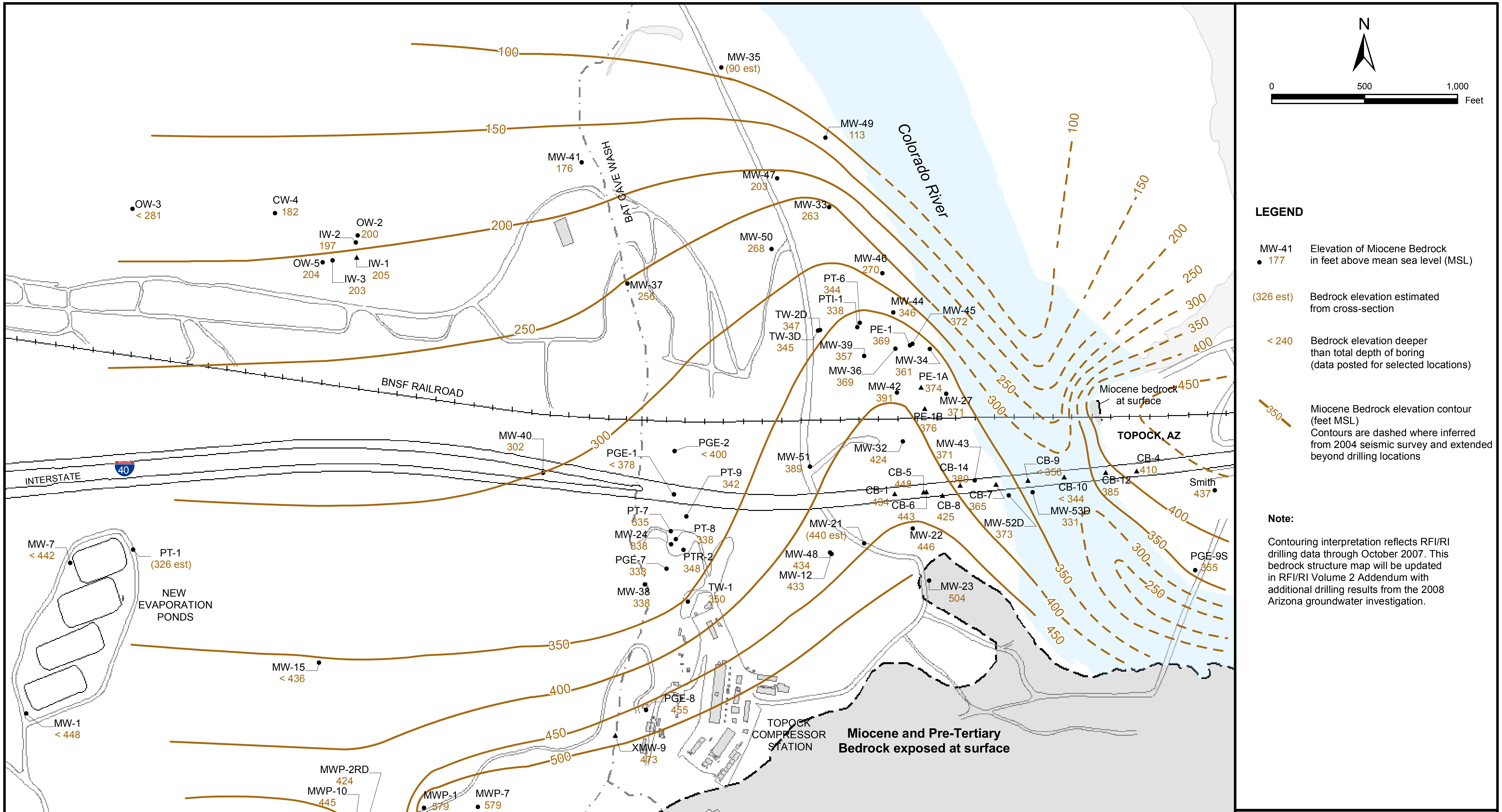

LEGEND

MW-41 ● 177	Elevation of Miocene Bedrock in feet above mean sea level (MSL)
(326 est)	Bedrock elevation estimated from cross-section
< 240	Bedrock elevation deeper than total depth of boring (data posted for selected locations)
350	Miocene Bedrock elevation contour (feet MSL) Contours are dashed where inferred from 2004 seismic survey and extended beyond drilling locations

Note:

Contouring interpretation reflects RFI/RI drilling data through October 2007. This bedrock structure map will be updated in RFI/RI Volume 2 Addendum with additional drilling results from the 2008 Arizona groundwater investigation.

FIGURE 5-9
ELEVATION CONTOUR MAP FOR TOP OF MIOCENE BEDROCK

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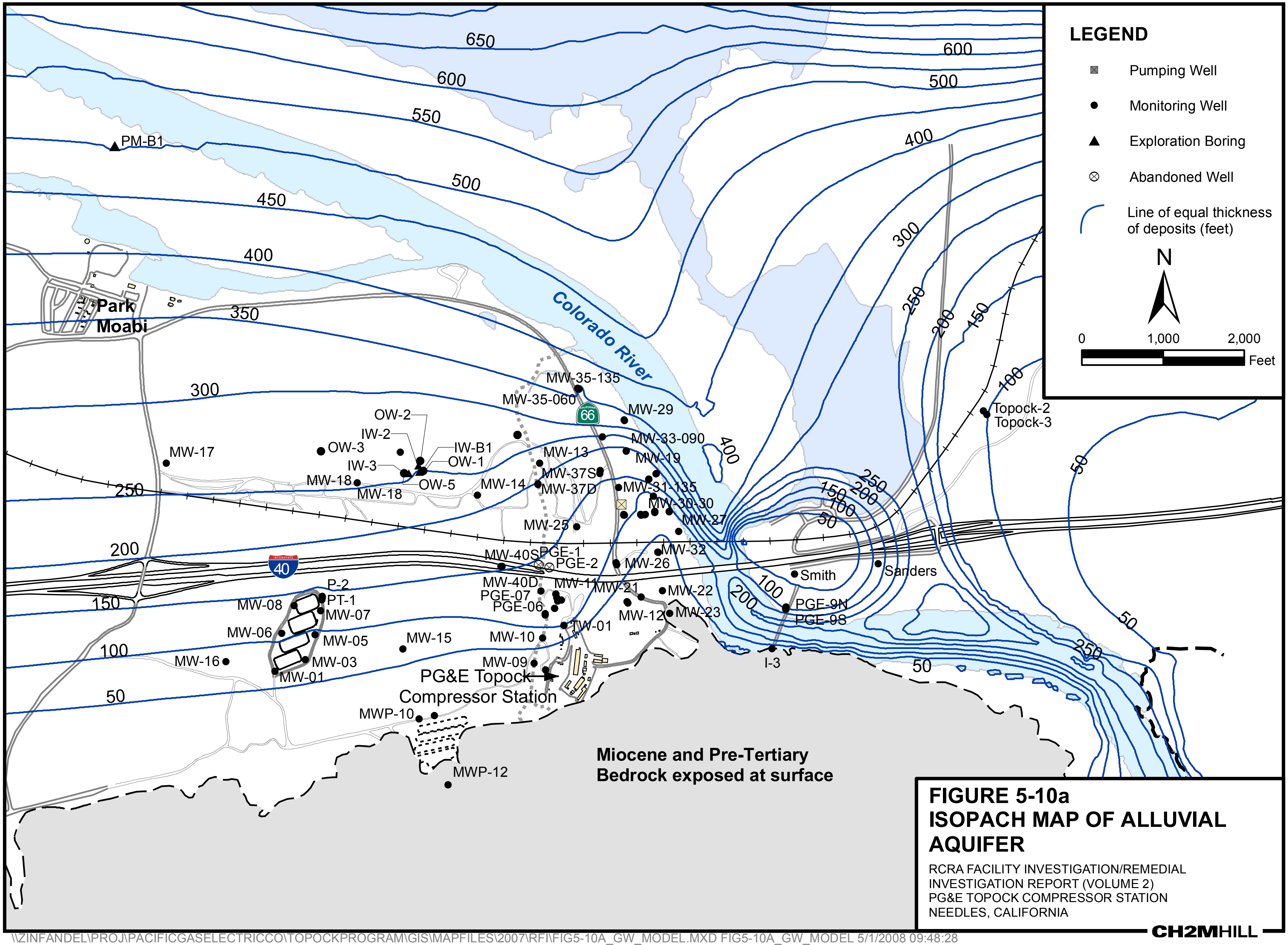

FIGURE 5-10a ISOPACH MAP OF ALLUVIAL AQUIFER

RCRA FACILITY INVESTIGATION/REMEDIAL INVESTIGATION REPORT (VOLUME 2)
PG&E TOPOCK COMPRESSOR STATION
NEDLES, CALIFORNIA

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\\ZINFANDEL\PROJ\PACIFICGASELECTRICCO\TOPOCKPROGRAM\GIS\MAPFILES\2007\RFI\FIG5-10A_GW_MODEL.MXD FIG5-10A_GW_MODEL 5/1/2008 09:48:28

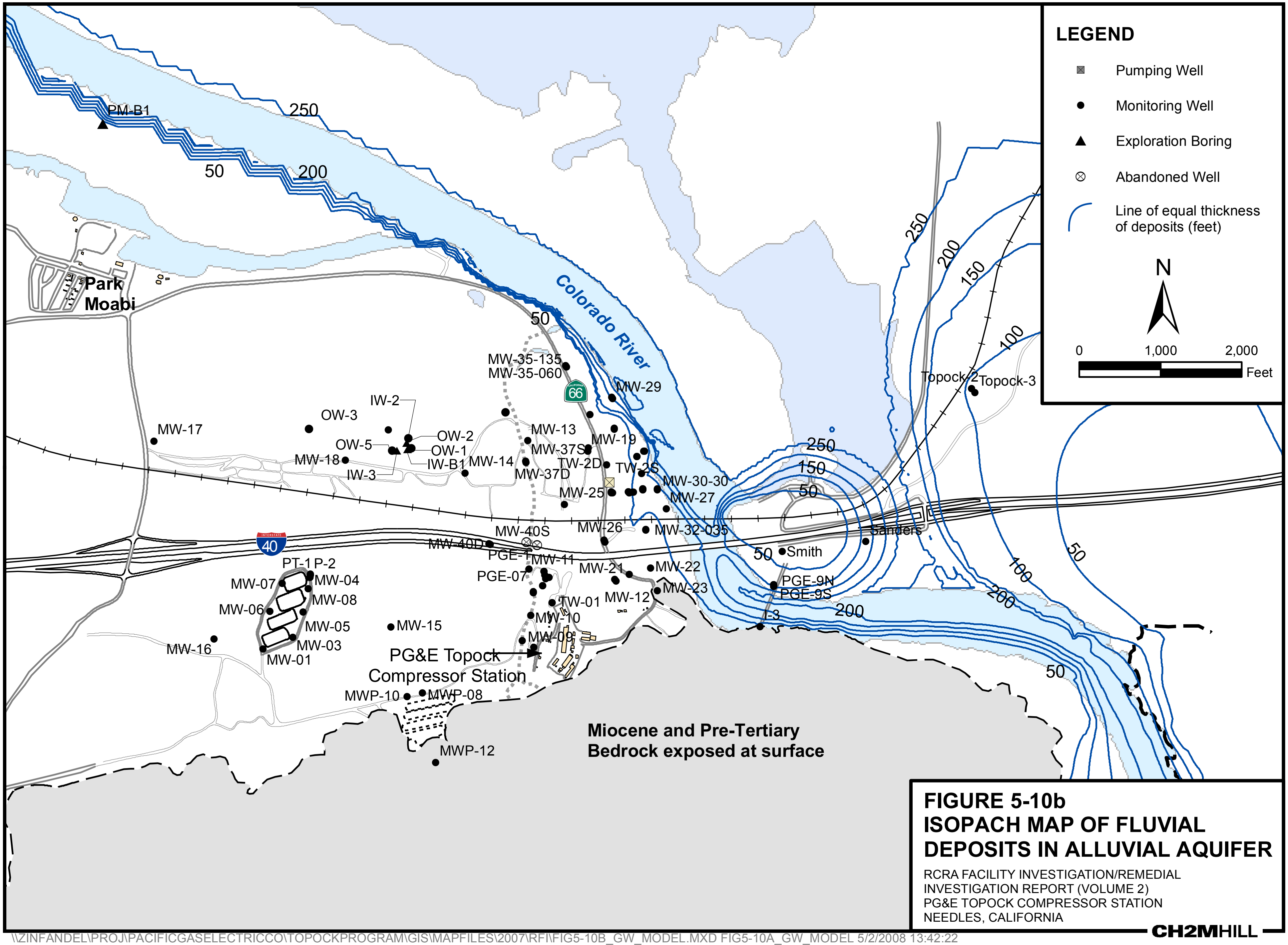

FIGURE 5-10b
ISOPACH MAP OF FLUVIAL DEPOSITS IN ALLUVIAL AQUIFER

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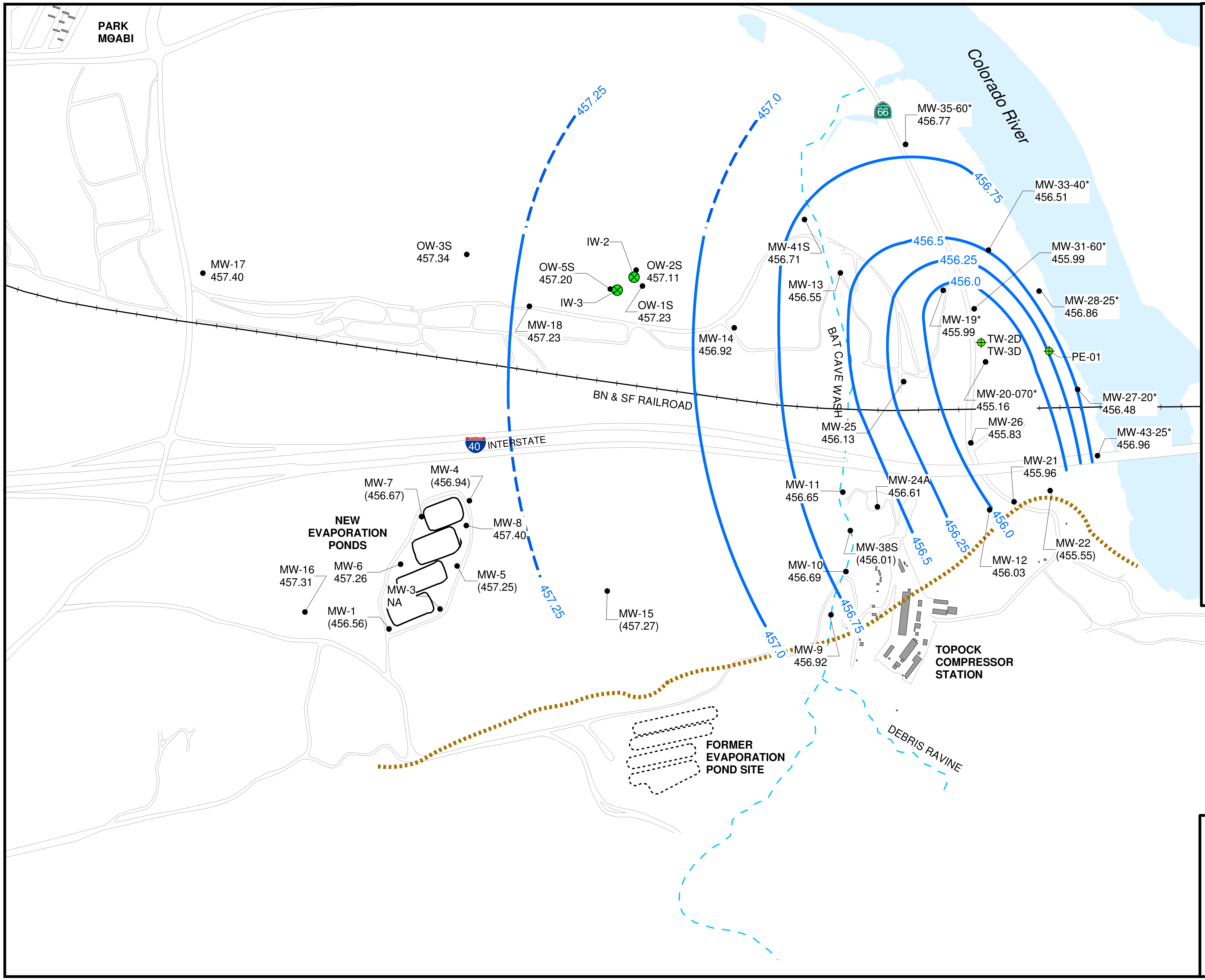
\\ZINFANDEL\PROJ\PACIFICGASELECTRICCO\TOPOCKPROGRAM\GIS\MAPFILES\2007\RFI\FIG5-10B_GW_MODEL.MXD FIG5-10A_GW_MODEL 5/2/2008 13:42:22



N

0 700 1,400 Feet

LEGEND

⊕ Extraction well

⊗ Injection Well

● Groundwater monitoring / observation well

MW-20-100 **454.75**	Well name with water level elevation (ft MSL)
MW-20-100 **(454.75)**	Well name with water level elevation (ft MSL) not used in contouring
MW-20-100* **454.75**	Groundwater Elevation from Transducer
▬	Groundwater Elevation Contour 0.25 ft
▬ ▪	Inferred or Approximate Groundwater Elevation Contour 0.25 ft
NA	Data not available
▪▪▪▪▪	Approximate bedrock / Alluvial Aquifer contact at elevation 455 ft MSL

Notes:

1. Groundwater elevations measured June 14, 2006 during GMP manual water level survey. Additional data from pressure transducers at time of manual measurements (6:00 am) used for contouring.

2. Extraction wells TW-3D and PE-1 were pumping from lower interval of Alluvial Aquifer during June 2006. (see IM Performance Monitoring Reports).

3. Gradients shown on this figure show transient conditions in the aquifer at the time of measurement and may not reflect the expected average groundwater flow directions.

FIGURE 5-11a
GROUNDWATER ELEVATION MAP SHALLOW ZONE OF ALLUVIAL AQUIFER (WATER TABLE), JUNE 2006

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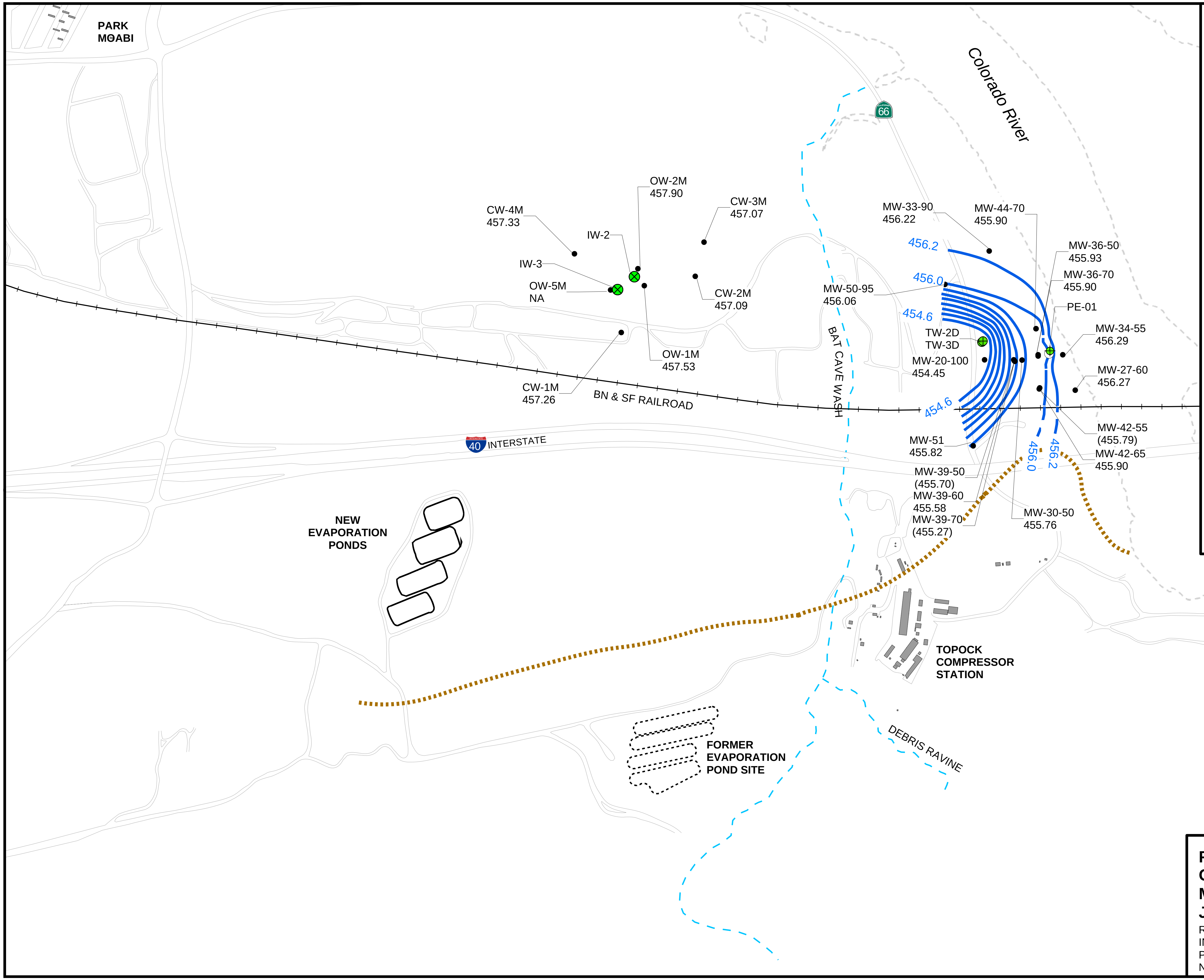
INVESTIGATION REPORT (VOLUME 2)
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

\\ZINFANDEL\PROJ\PACIFICGASELECTRICCO\TOPOCKPROGRAM\GIS\MAPFILES\2007\RFI\RFI_GWELEV_JUN06_UA.MXD FIGURE_5-11A_GWELEV_JUN06_UA 2/7/2008 14:53:37



N

0 700 1,400
Feet

LEGEND

⊕	Extraction well
⊗	Injection well
●	Groundwater monitoring / observation well
MW-20-100 454.75	Well name with water level elevation (ft MSL)
MW-20-100 (454.75)	Well name with water level elevation (ft MSL) not used in contouring
─	Groundwater Elevation Contour 0.2 ft
╌	Inferred or Approximate Groundwater Elevation Contour 0.2 ft
NA	Data not available
┈	Approximate bedrock / Alluvial Aquifer contact at elevation 425 ft MSL

Notes:

1. Posted groundwater elevations are average values measured with pressure transducers at 30 minute intervals during June 2006 monthly monitoring.

2. Extraction wells TW-3D and PE-1 were pumping, and IW-2 was injecting, in the lower interval of the Alluvial Aquifer during June 2006.

3. Groundwater elevation contours from June 2006 IM Performance Monitoring Report. See IM Compliance Monitoring Reports for groundwater gradient maps for IM No.3 injection area.

FIGURE 5-11b
GROUNDWATER ELEVATION MAP MID-DEPTH ZONE OF ALLUVIAL AQUIFER, JUNE 2006

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INVESTIGATION REPORT (VOLUME 2)
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

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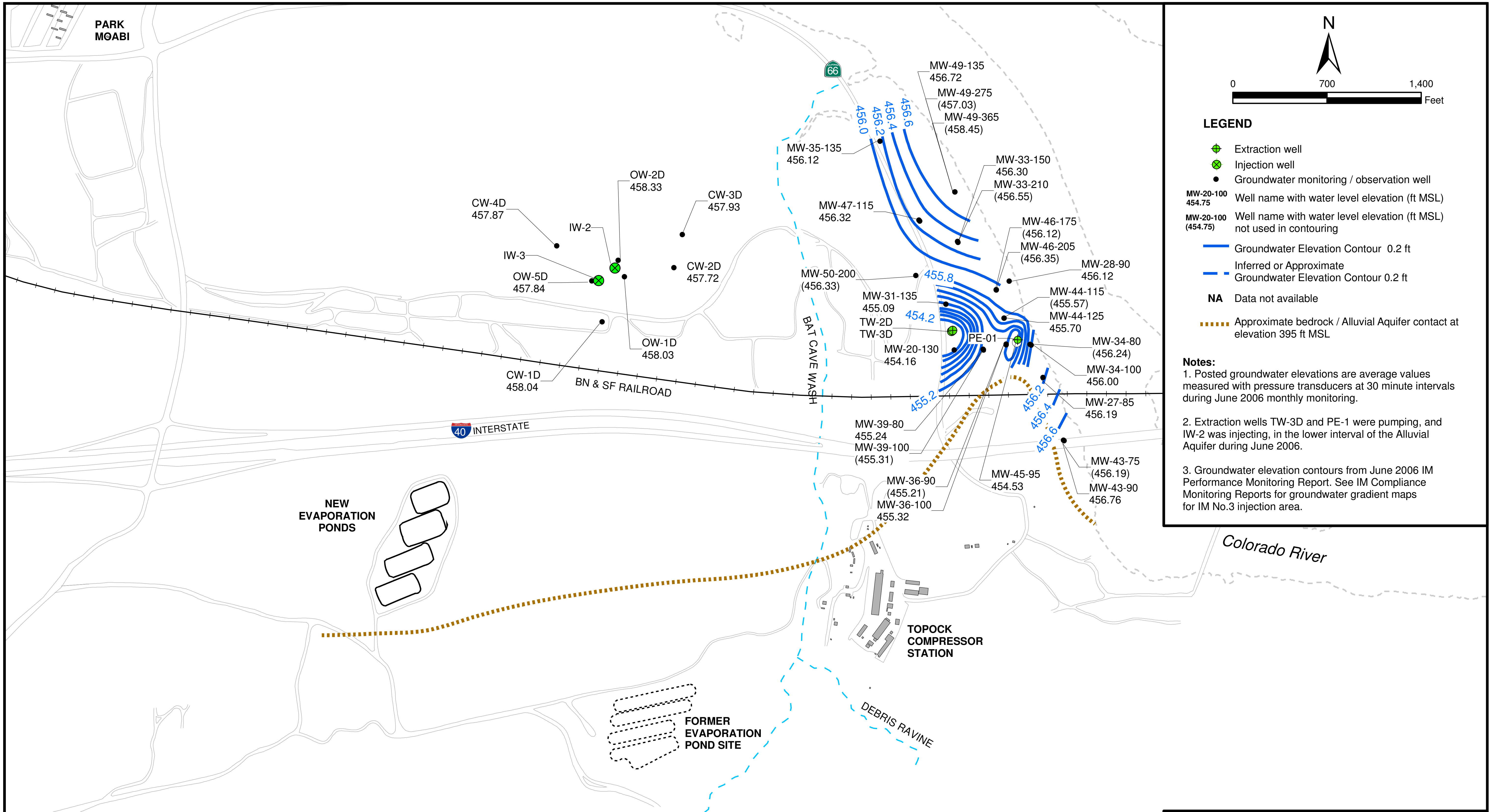
\\ZINFANDEL\PROJ\PACIFICGASELECTRICCO\TOPOCKPROGRAM\GIS\MAPFILES\2007\RFI\RFI_GWELEV_JUN06_MA.MXD FIGURE_5-11B_GWELEV_JUN06 5/2/2008 14:45:26



LEGEND

⊕	Extraction well
⊗	Injection well
●	Groundwater monitoring / observation well
MW-20-100 454.75	Well name with water level elevation (ft MSL)
MW-20-100 (454.75)	Well name with water level elevation (ft MSL) not used in contouring
━	Groundwater Elevation Contour 0.2 ft
╍	Inferred or Approximate Groundwater Elevation Contour 0.2 ft
NA	Data not available
┅	Approximate bedrock / Alluvial Aquifer contact at elevation 395 ft MSL

Notes:

1. Posted groundwater elevations are average values measured with pressure transducers at 30 minute intervals during June 2006 monthly monitoring.

2. Extraction wells TW-3D and PE-1 were pumping, and IW-2 was injecting, in the lower interval of the Alluvial Aquifer during June 2006.

3. Groundwater elevation contours from June 2006 IM Performance Monitoring Report. See IM Compliance Monitoring Reports for groundwater gradient maps for IM No.3 injection area.

FIGURE 5-11c
GROUNDWATER ELEVATION MAP DEEP ZONE OF ALLUVIAL AQUIFER JUNE 2006

RCRA FACILITY INVESTIGATION/REMEDIAL
INVESTIGATION REPORT (VOLUME 2)
PG&E TOPOCK COMPRESSOR STATION
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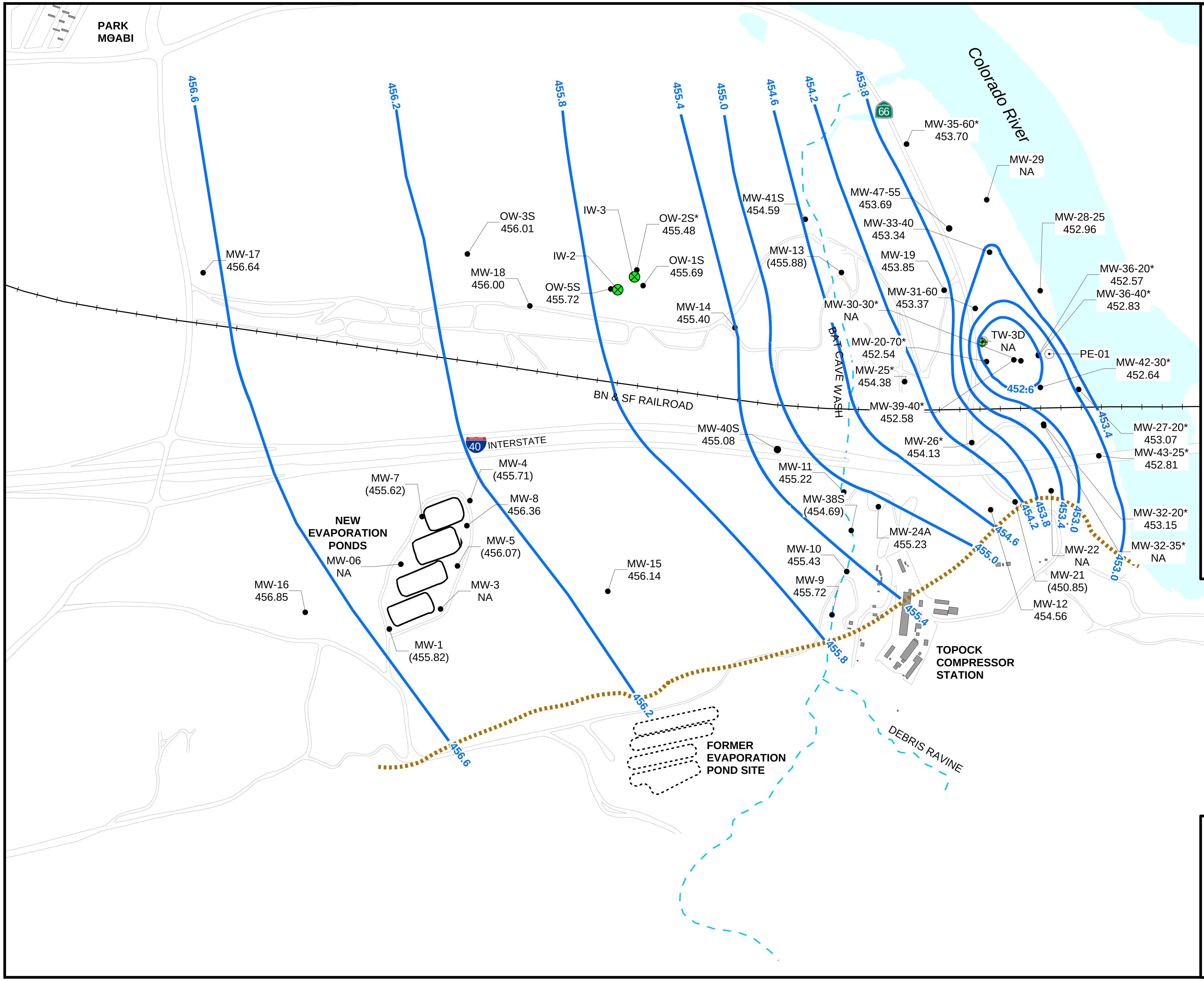

N

0 700 1,400 Feet

LEGEND

⊕	Extraction well
⊗	Injection Well
●	Groundwater monitoring / observation well
MW-20-100 454.75	Well name with water level elevation (ft MSL)
MW-20-100 (454.75)	Well name with water level elevation (ft MSL) not used in contouring
MW-20-100* 454.75	Groundwater Elevation from Transducer
━	Groundwater Elevation Contour 0.25 ft
╍	Inferred or Approximate Groundwater Elevation Contour 0.25 ft
NA	Data not available
┅	Approximate bedrock / Alluvial Aquifer contact at elevation 455 ft MSL

Notes:

1. Groundwater elevations measured December 18, 2006 during GMP manual water level survey. Additional data from pressure transducers at time of manual measurements used for contouring.

2. Extraction wells TW-3D and PE-1 were pumping from lower interval of Alluvial Aquifer during December 2006. (see IM Performance Monitoring Reports).

3. Gradients shown on this figure show transient conditions in the aquifer at the time of measurement and may not reflect the expected average groundwater flow directions.

FIGURE 5-12a
GROUNDWATER ELEVATION MAP FOR SHALLOW ZONE OF ALLUVIAL AQUIFER (WATER TABLE), DECEMBER 2006

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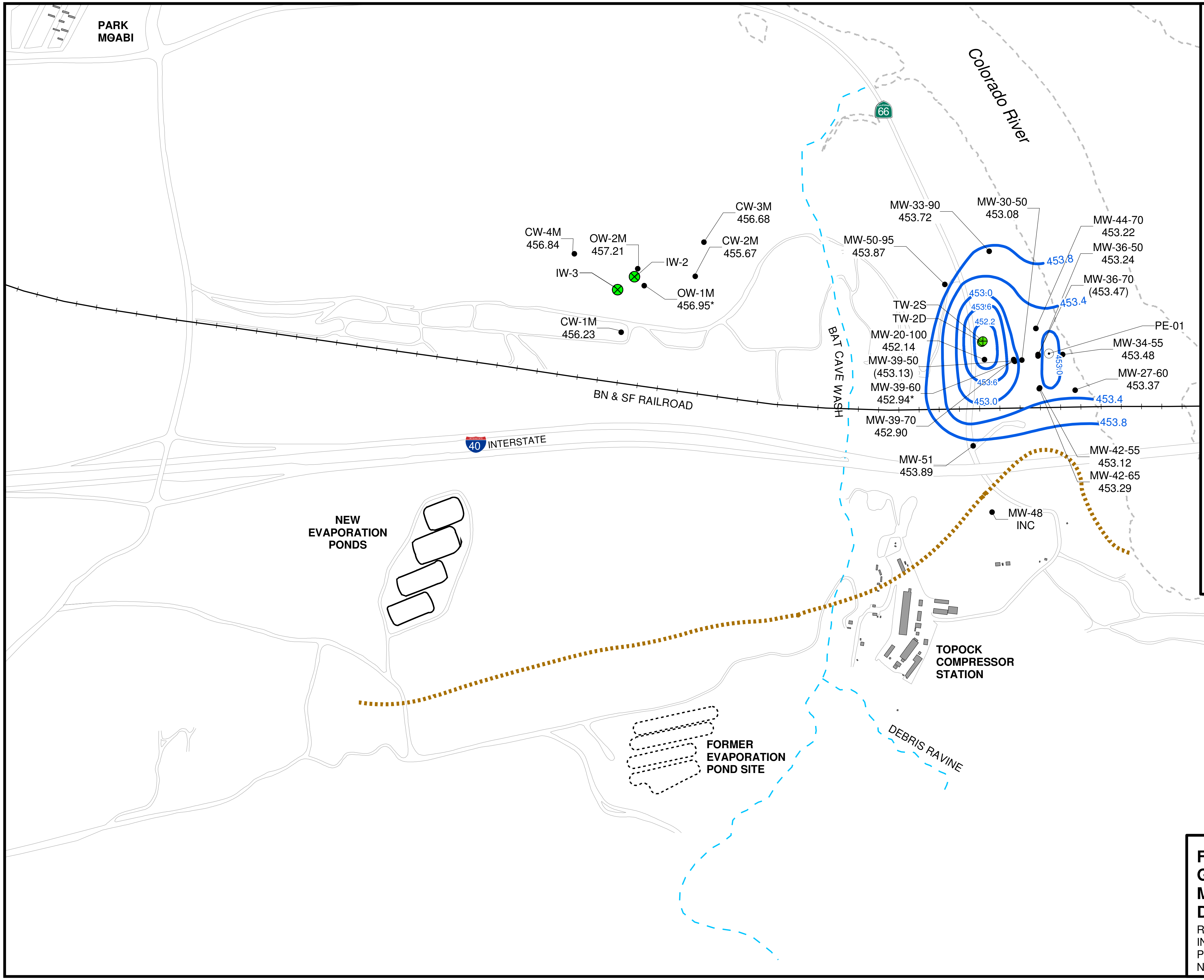
\\ZINFANDEL\PROJ\PACIFICGASELECTRICCO\TOPOCKPROGRAM\GIS\MAPFILES\2007\RFI\RFI_GWELEV_DEC06_UA.MXD FIG5-12A_RFI_GWELEV_DEC06_SZ 5/2/2008 15:15:30



N

0 700 1,400 Feet

LEGEND

⊕ Extraction well

⊗ Injection well

● Groundwater monitoring / observation well

MW-20-100 454.75 Well name with water level elevation (ft MSL)

MW-20-100 (454.75) Well name with water level elevation (ft MSL) not used in contouring

MW-20-100 454.75* Well name with water level elevation (ft MSL) Data available for ~2 weeks in December

Groundwater Elevation Contour 0.2 ft

Inferred or Approximate Groundwater Elevation Contour 0.2 ft

NA Data not available

Approximate bedrock / Alluvial Aquifer contact at elevation 425 ft MSL

Notes:

1. Posted groundwater elevations are average values measured with pressure transducers at 30 minute intervals during December 2006 monthly monitoring.

2. Extraction wells TW-3D and PE-1 were pumping, and IW-2 was injecting, in the lower interval of the Alluvial Aquifer during December 2006.

3. Groundwater elevation contours from December 2006 IM Performance Monitoring Report. See IM Compliance Monitoring Reports for groundwater gradient maps for IM No.3 injection area.

FIGURE 5-12b
GROUNDWATER ELEVATION MAP MID-DEPTH ZONE OF ALLUVIAL AQUIFER, DECEMBER 2006

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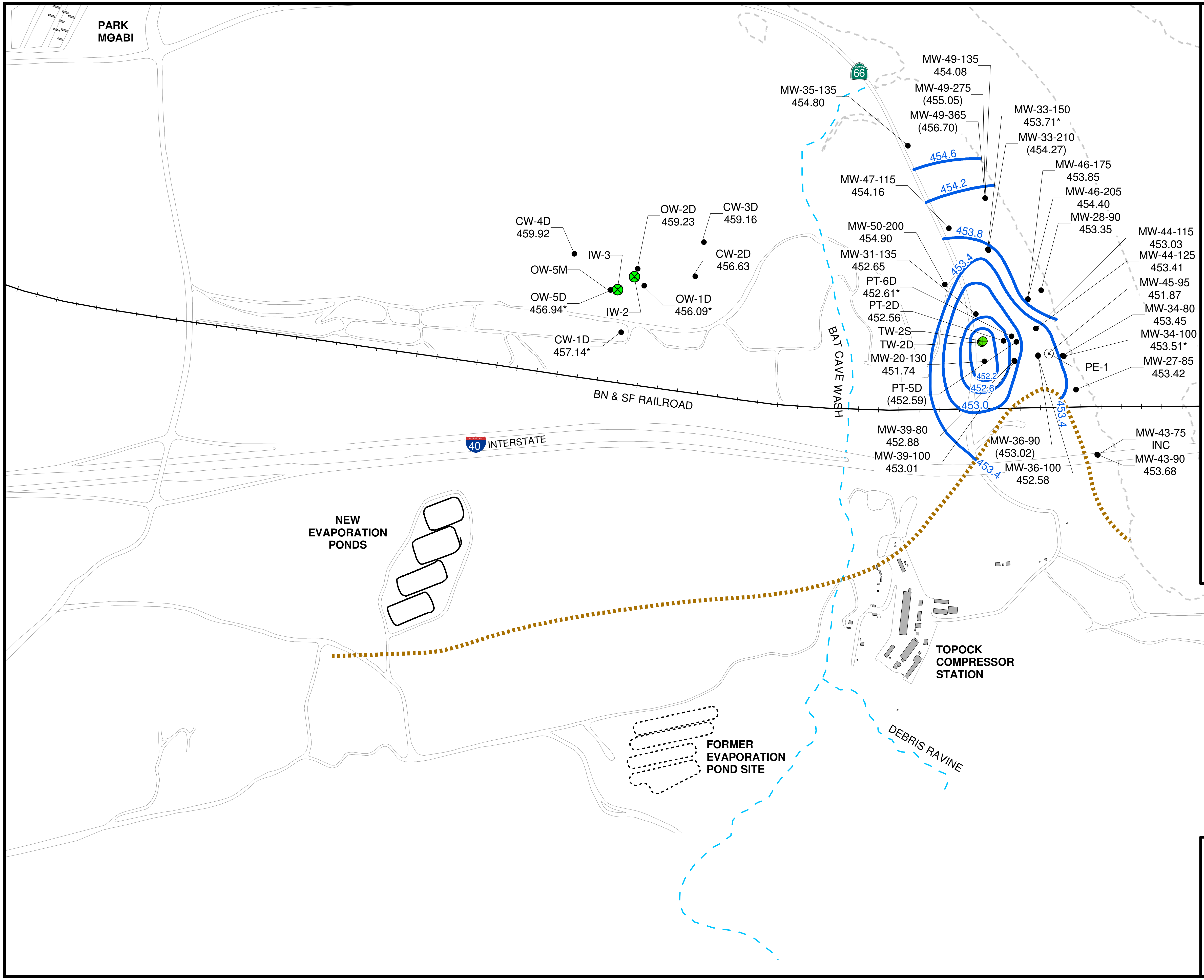
\\ZINFANDEL\PROJ\PACIFICGASELECTRICCO\TOPOCKPROGRAM\GIS\MAPFILES\2007\RFI\RFI_GWELEV_DEC06_MA.MXD FIGURE_5-12B_RFI_GWELEV_DEC06_MZ 5/2/2008 15:18:22



LEGEND

⊕	Extraction well
⊗	Injection well
●	Groundwater monitoring / observation well
MW-20-100 **454.75**	Well name with water level elevation (ft MSL)
MW-20-100 **(454.75)**	Well name with water level elevation (ft MSL) not used in contouring
MW-20-100 **454.75***	Well name with water level elevation (ft MSL) Data available for ~2 weeks in December
—	Groundwater Elevation Contour 0.2 ft
- -	Inferred or Approximate Groundwater Elevation Contour 0.2 ft
NA	Data not available
·····	Approximate bedrock / Alluvial Aquifer contact at elevation 395 ft MSL

Notes:

1. Posted groundwater elevations are average values measured with pressure transducers at 30 minute intervals during December 2006 monthly monitoring.

2. Extraction wells TW-3D and PE-1 were pumping, and IW-2 was injecting, in the lower interval of the Alluvial Aquifer during December 2006.

3. Groundwater elevation contours from December 2006 IM Performance Monitoring Report. See IM Compliance Monitoring Reports for groundwater gradient maps for IM No.3 injection area.

FIGURE 5-12c
GROUNDWATER ELEVATION MAP DEEP ZONE OF ALLUVIAL AQUIFER DECEMBER 2006

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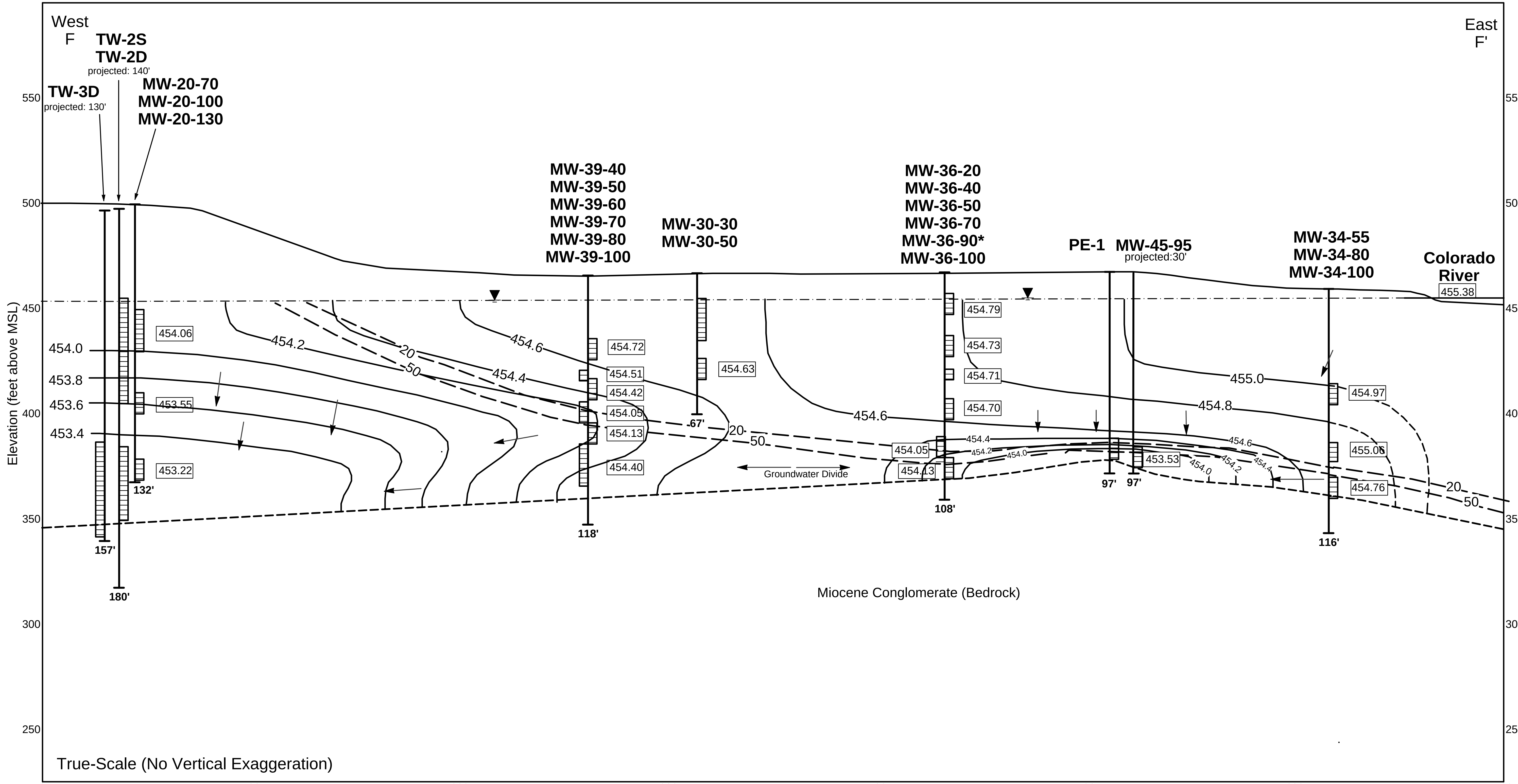
\\ZINFANDEL\PROJ\PACIFICGASELECTRICCO\TOPOCKPROGRAM\GIS\MAPFILES\2007\RFI\RFI_GWELEV_DEC06_LA.MXD FIGURE5-12C_RFI_GWELEV_DEC06LA 2/6/2008 17:05:33



Notes:
Results show average groundwater elevations for May 1 through July 31, 2007 measured with transducers at 30 minute intervals.

Groundwater elevations adjusted for salinity and temperature.
Well MW-36-90* is excluded from contouring.

See Figure 5-1 for location of cross-section F-F' and Figure 5-7 for additional hydrogeologic information.

Legend:

MW-30-50

Inferred water table ▼

well screen

103 boring depth (feet)

— — 20 — — Inferred hexavalent chromium contour (ppb) July 2007

453.66 Monthly average groundwater head (ft AMSL)

——— 453.5 ——— Groundwater head contour

— — — 453.5 — — — Inferred groundwater head contour

← Interpreted groundwater flow direction

FIGURE 5-13
AVERAGE GROUNDWATER ELEVATIONS FOR WELLS ON FLOODPLAIN CROSS-SECTION F-F'
OCTOBER 2007

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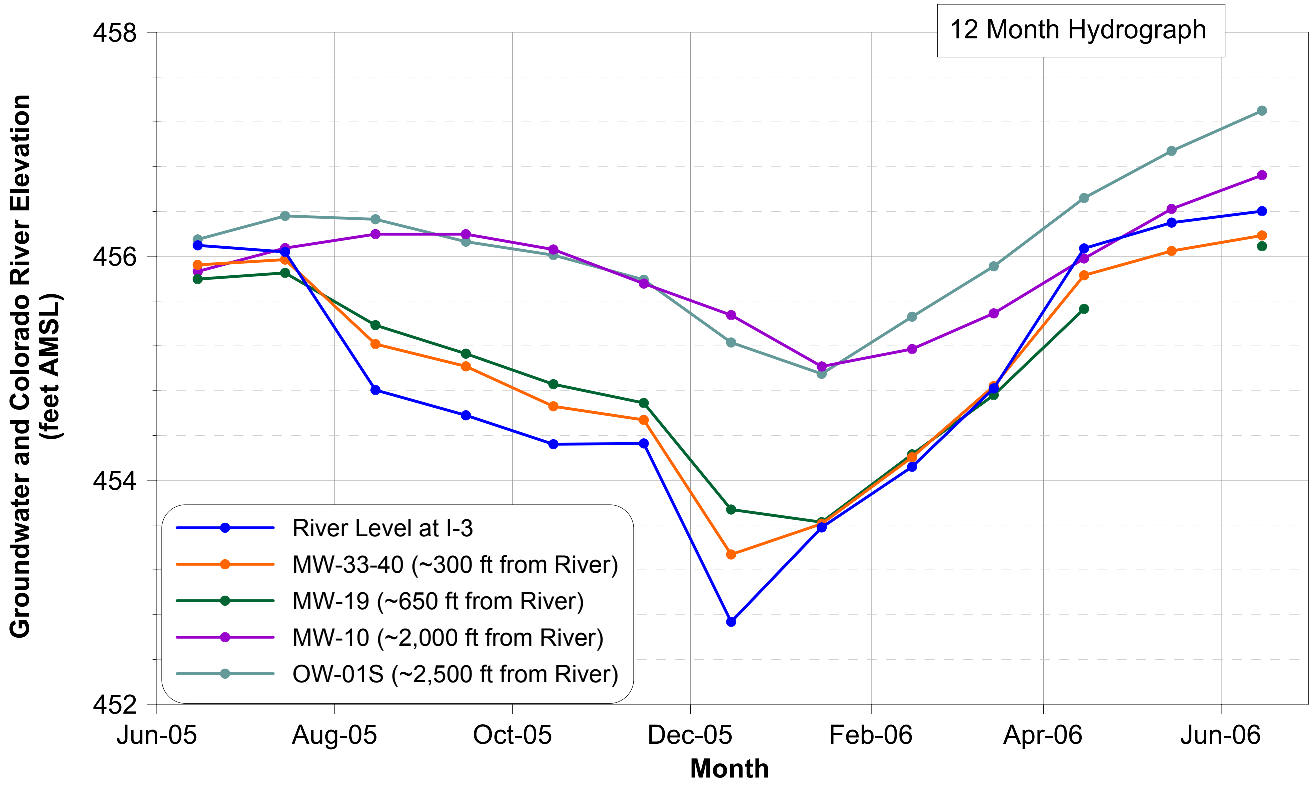
P:\INPUT\GINT_WORK_FILE_TYPES\GDW\X-SECTIONS\RFI_2007\12-2008_FINALREVISIONS\FIGURE5-13_XSECF_GW.GDW;



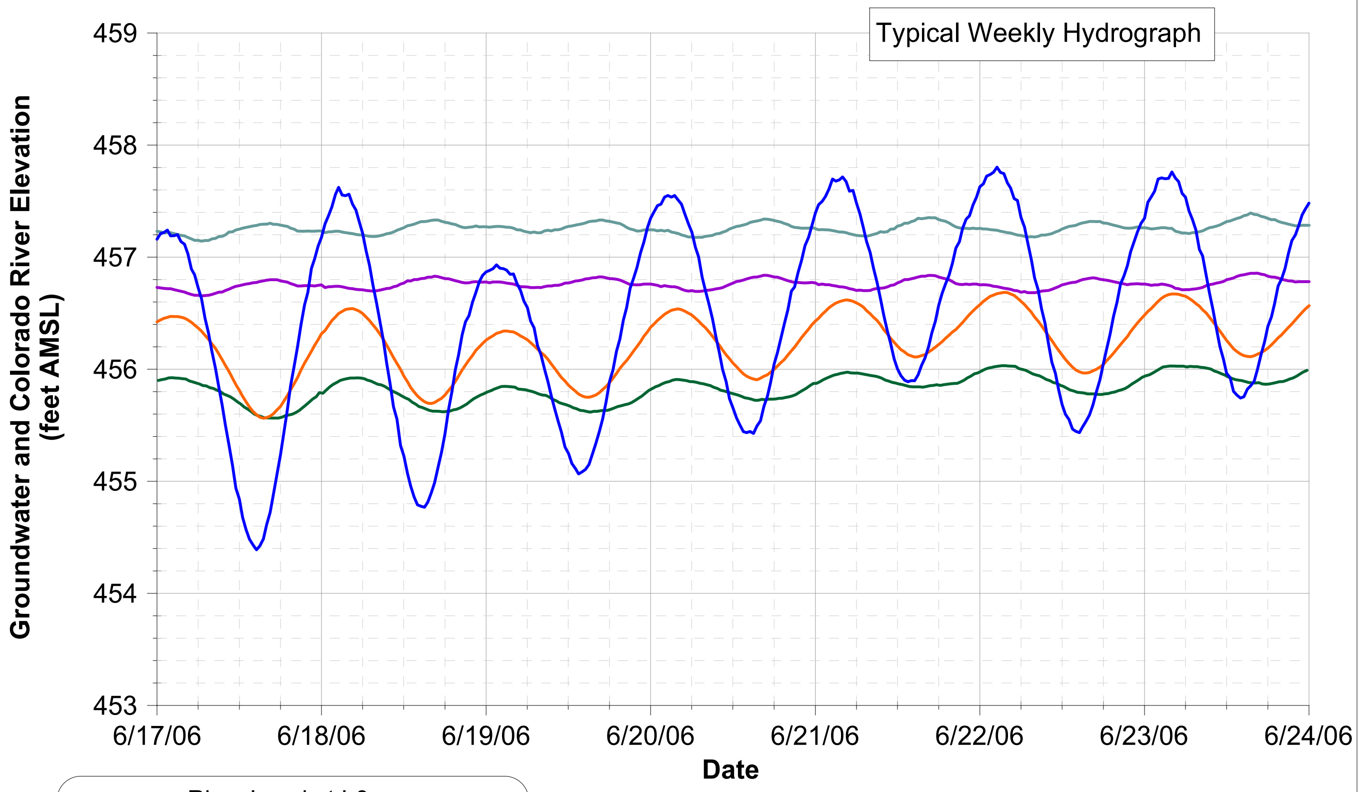


FIGURE 5-14
RIVER AND GROUNDWATER ELEVATIONS

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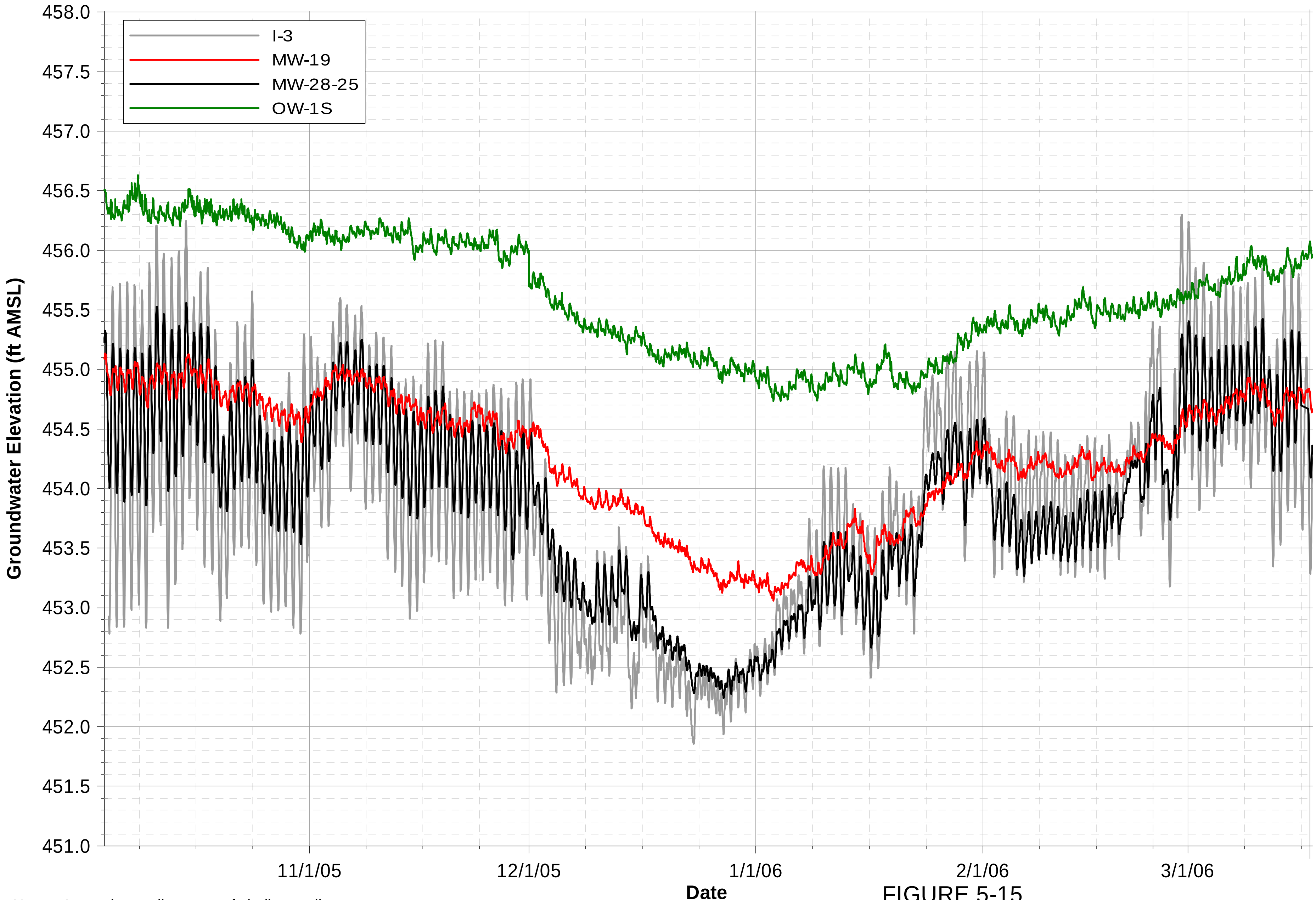

Notes: Approximate distances of shallow wells from Colorado River:
MW-28-25: 60 feet
MW-19: 675 feet
OW-1S: 2,500 feet

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\Section5_Hydrogeo&SCM\Sec5_Figs\Fig5-14_Seasonal_hydrographs

FIGURE 5-15
HYDROGRAPHS OF RIVER AND SELECTED SHALLOW WELLS, 2005-2006

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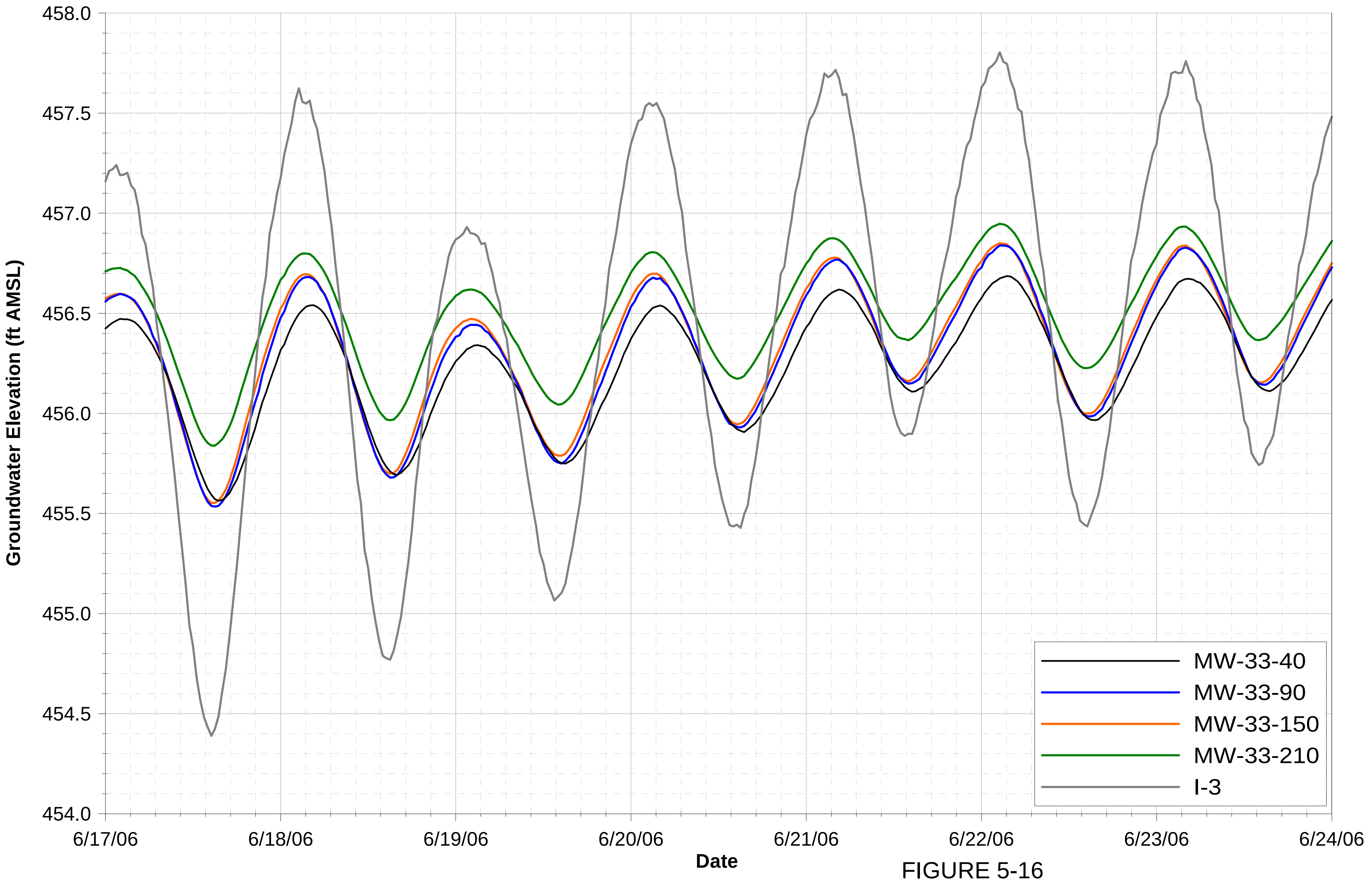

FIGURE 5-16
WEEKLY HYDROGRAPH OF RIVER AND FLOODPLAIN WELL CLUSTER MW-33

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Notes:
The MW-33 cluster wells range from 40 feet (MW-33-040) to 210 feet (MW-33-210) below ground surface.
Well cluster MW-33 is approximately 260 feet away from the Colorado River.

All Samples

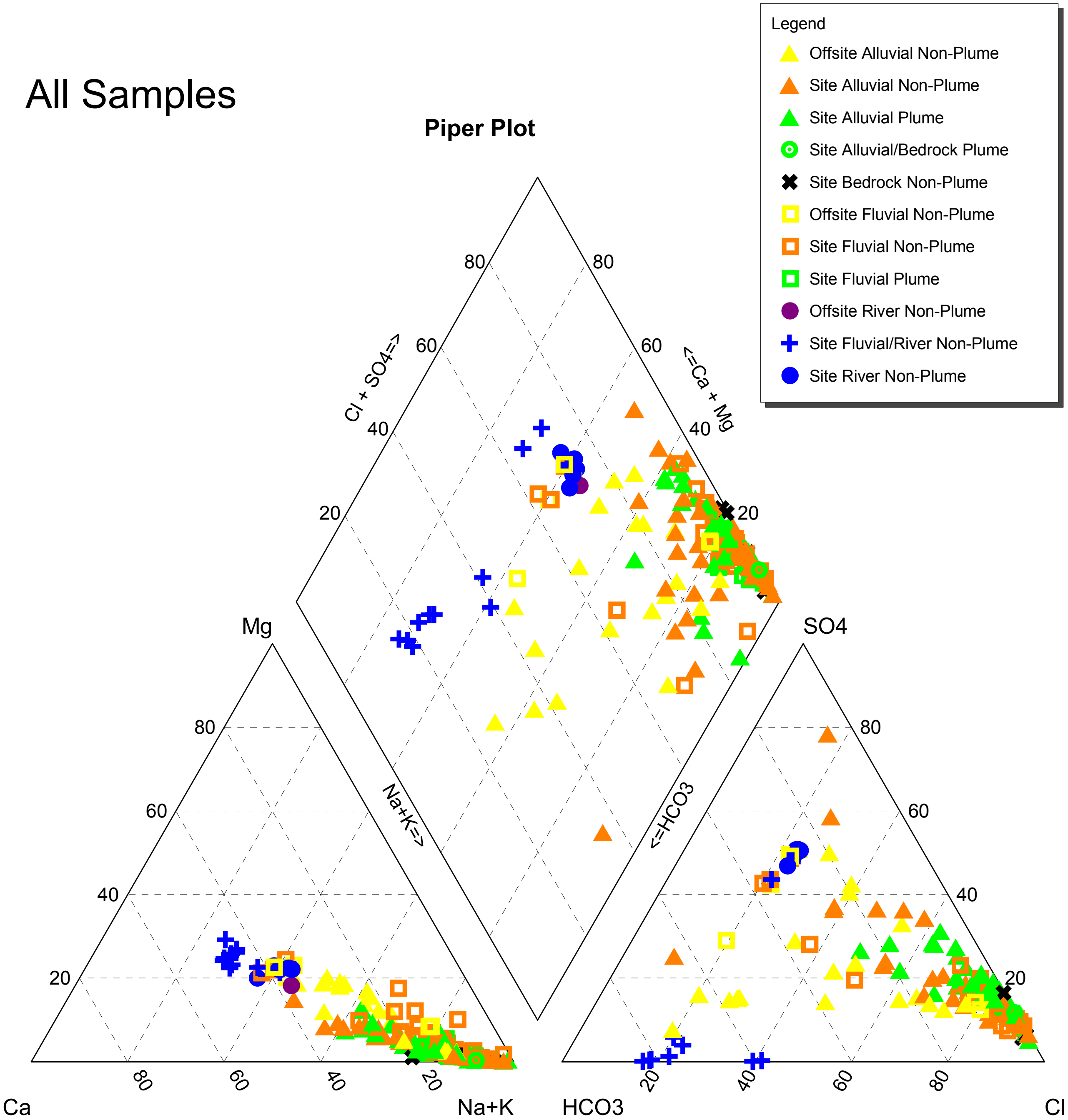

FIGURE 5-17a
PIPER CHEMICAL DIAGRAM OF GROUNDWATER AND SURFACE WATER SAMPLES

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Onsite Alluvial Samples

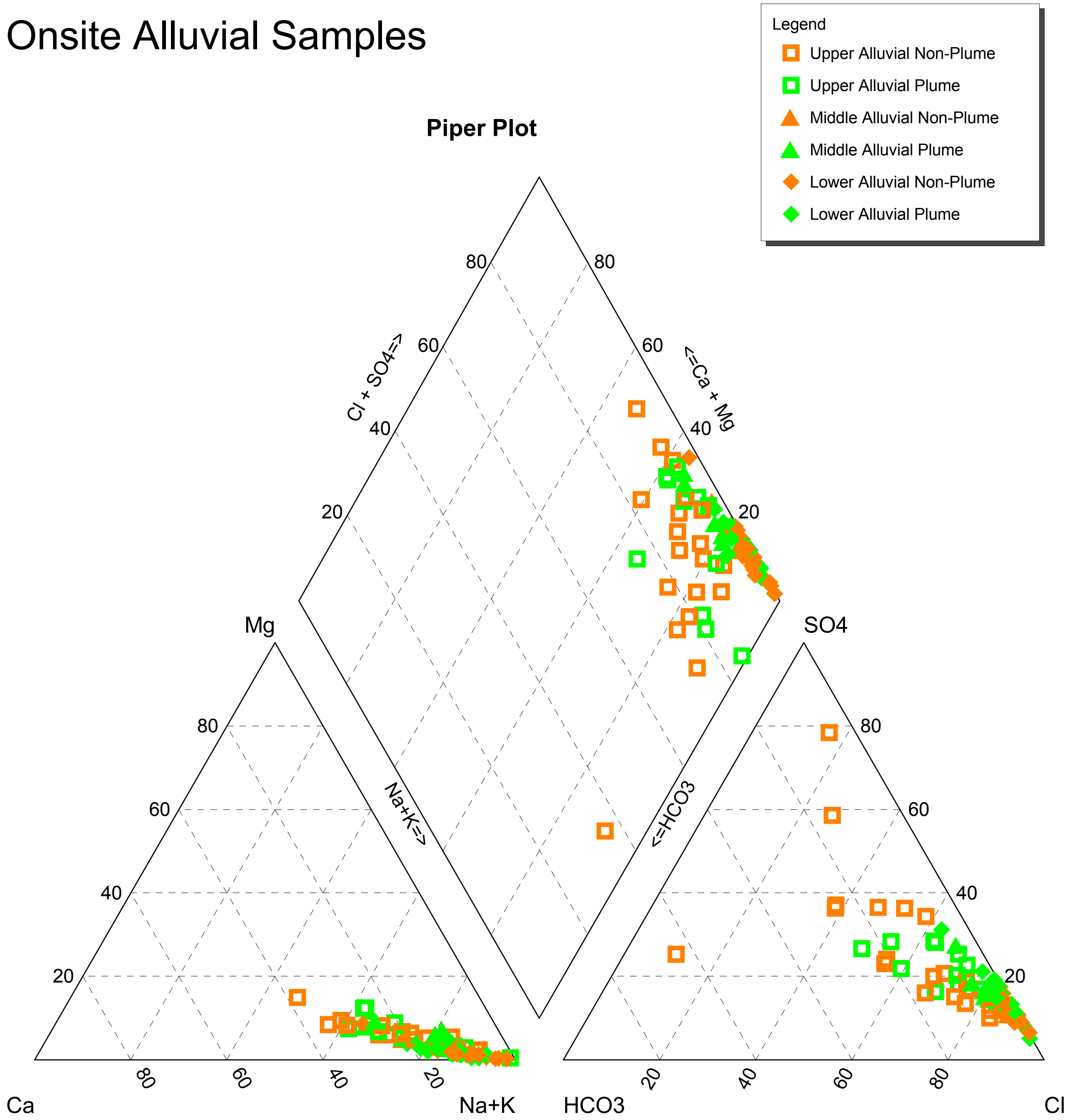

FIGURE 5-17b
PIPER CHEMICAL DIAGRAM OF ALLUVIAL GROUNDWATER DEPTH INTERVALS

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Onsite Fluvial Samples

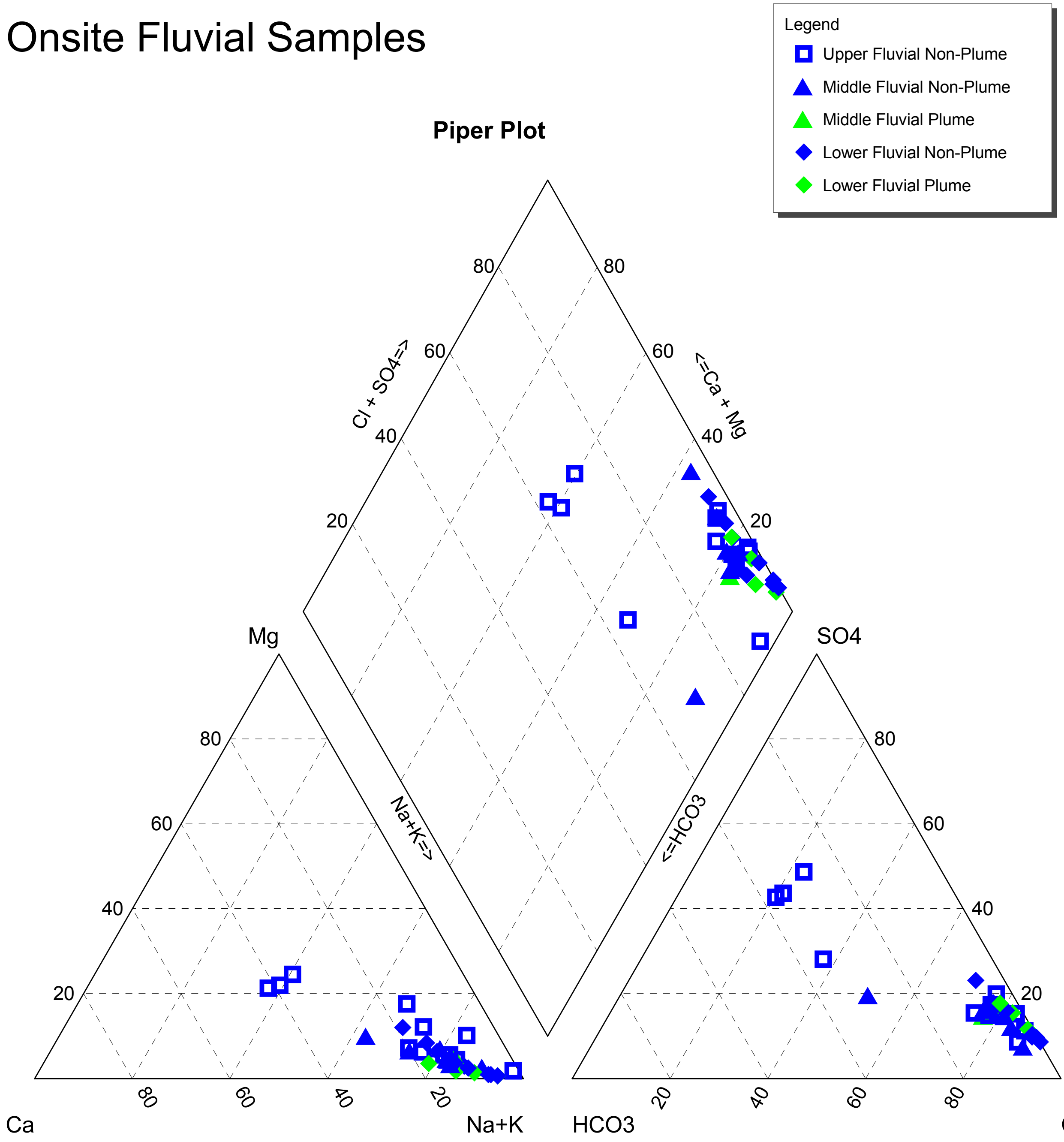

FIGURE 5-17c
PIPER CHEMICAL DIAGRAM OF FLUVIAL GROUNDWATER DEPTH INTERVALS

RCRA FACILITY INVESTIGATION/REMEDIAL
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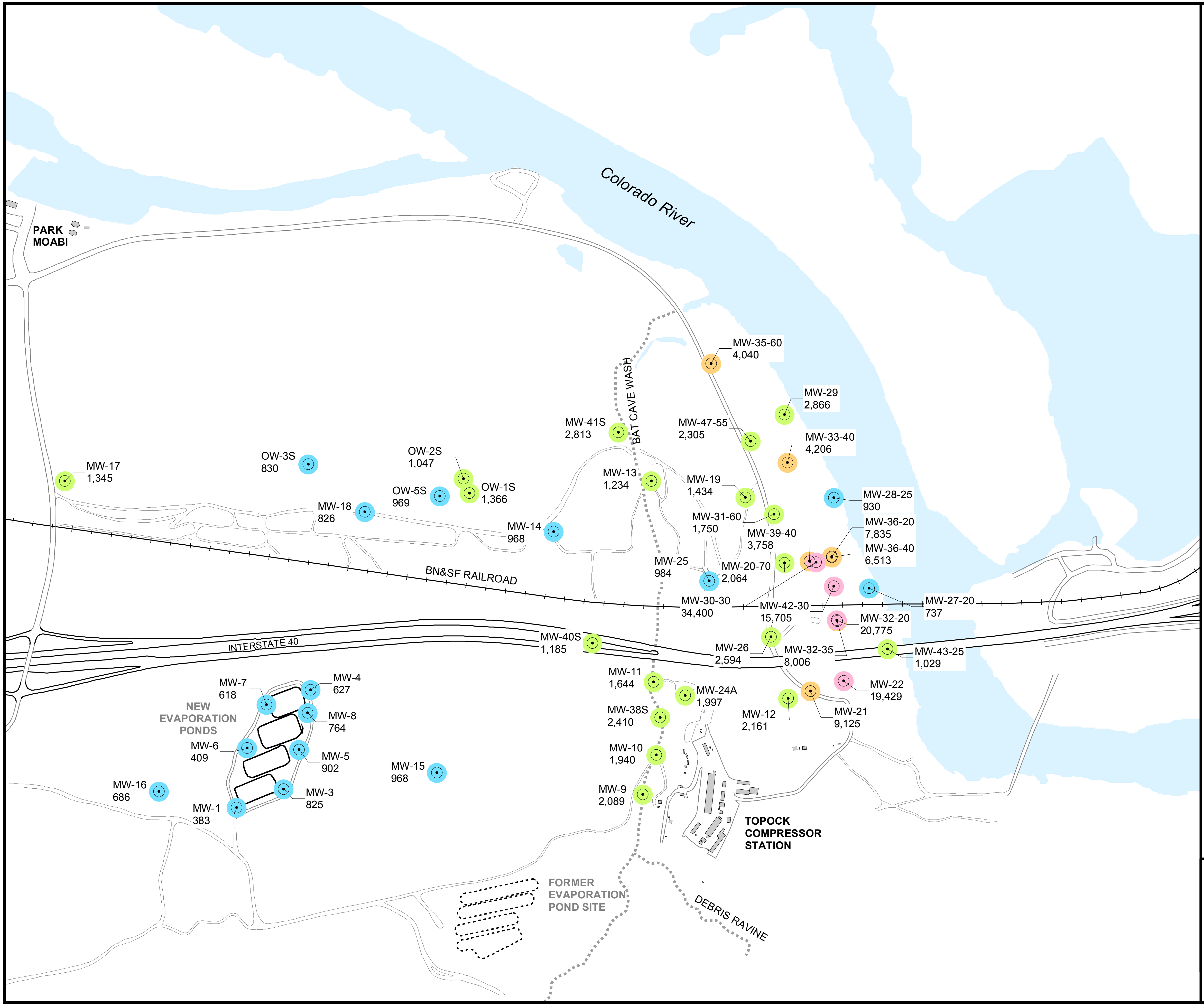
NEEDLES, CALIFORNIA



LEGEND

⊙ Monitoring, Test, or Supply Well

1,420 Average Total Dissolved Solids (TDS) concentration in miligrams per liter (mg/L)

Average TDS concentrations for wells completed in **Shallow Zone** of Alluvial Aquifer, from data collected between July 1997 and August 2007

Average TDS Concentrations

● <1,000 mg/L
● 1,000 to 3,000 mg/L
● 3,000 to 10,000 mg/L
● >10,000 mg/L

Note:
For comparison, the average TDS concentration for Colorado River surface water samples is 620 mg/L (7 sample locations, 1997-2007).

N

0 750 1,500
Feet

FIGURE 5-18a
AVERAGE TDS CONCENTRATIONS SHALLOW WELLS IN ALLUVIAL AQUIFER

RCRA FACILITY INVESTIGATION/REMEDIAL INVESTIGATION REPORT (VOLUME 2)
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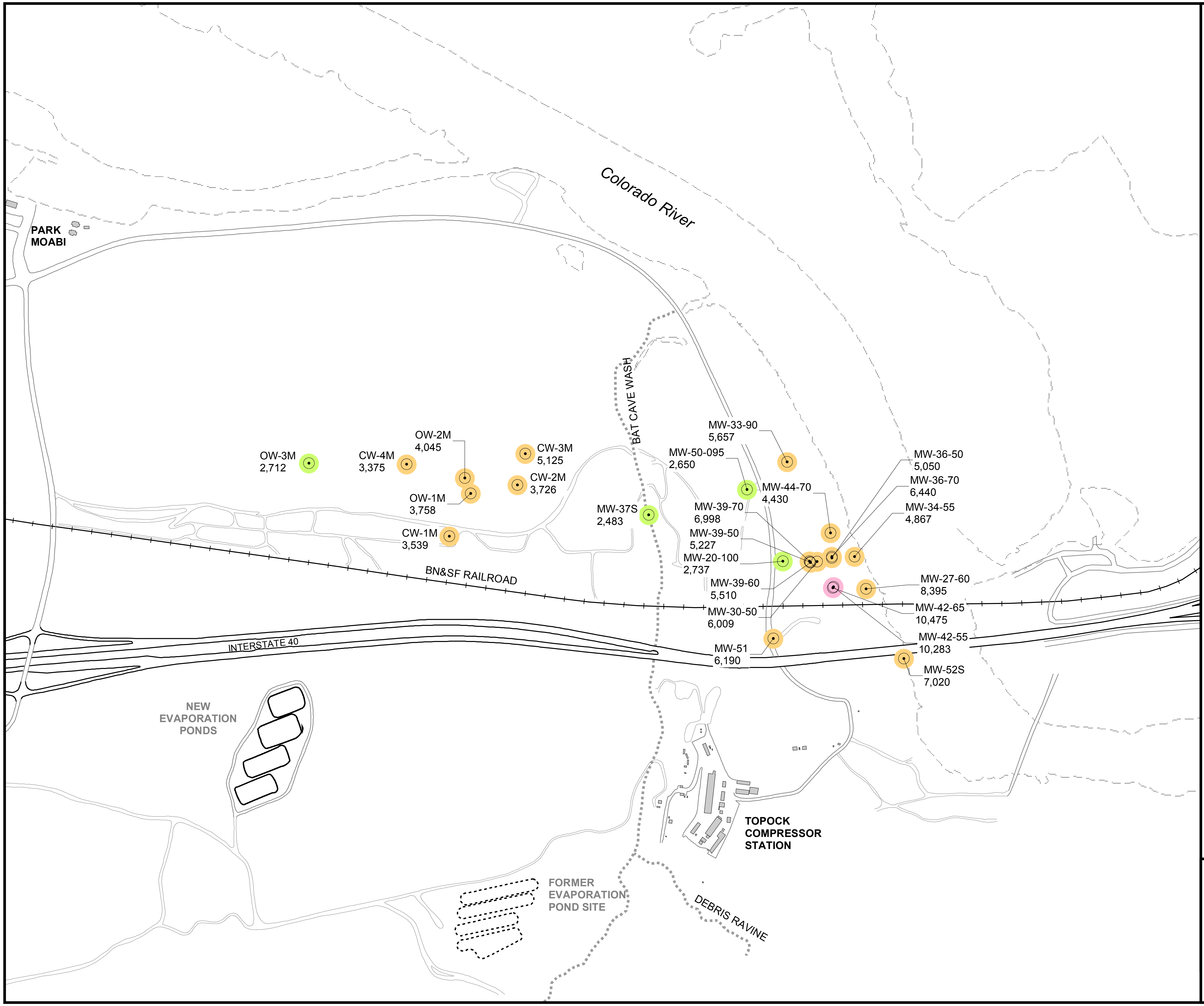
\\ZINFANDEL\PROJ\PACIFICGASELECTRICCO\TOPOCKPROGRAM\GIS\MAPFILES\2007\RFI\FIGURE5-17A_TDS2008_SZ.MXD FIGURE5-17A_TDS2008_SZ 5/1/2008 10:18:07



LEGEND

⊙ Monitoring, Test, or Supply Well

1,420 Average Total Dissolved Solids (TDS) concentration in miligrams per liter (mg/L)

Average TDS concentrations for wells completed in **Mid-Depth Zone** of Alluvial Aquifer, from data collected between July 1997 and August 2007

Average TDS Concentrations

🔵 <1,000 mg/L

🟢 1,000 to 3,000 mg/L

🟠 3,000 to 10,000 mg/L

● >10,000 mg/L

Note:
For comparison, the average TDS concentration for Colorado River surface water samples is 620 mg/L (7 sample locations, 1997-2007).

N

0 750 1,500 Feet

FIGURE 5-18b
AVERAGE TDS CONCENTRATIONS MID-DEPTH WELLS IN ALLUVIAL AQUIFER

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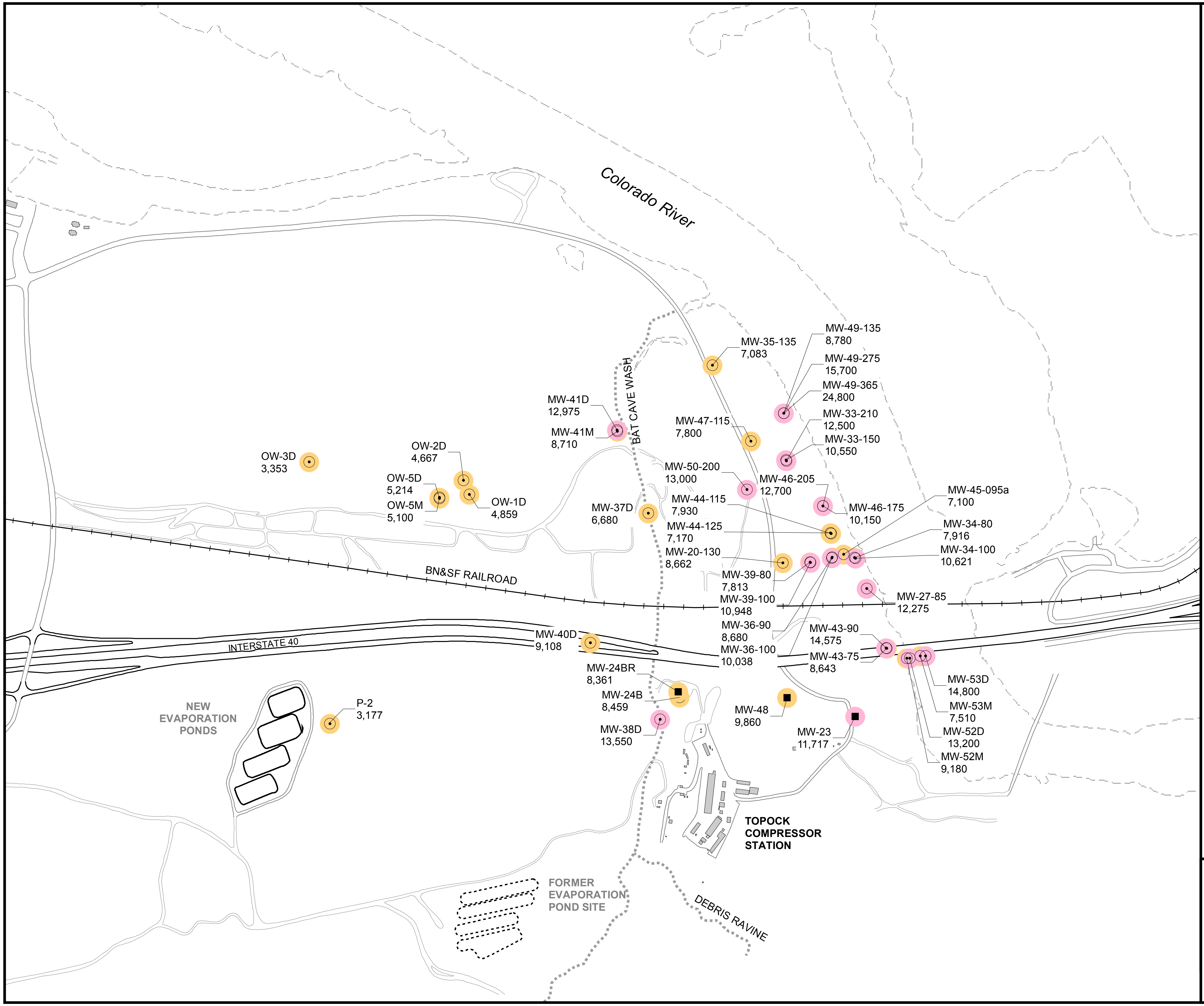
\\ZINFANDEL\PROJ\PACIFICGASELECTRICCO\TOPOCKPROGRAM\GIS\MAPFILES\2007\RFI\FIGURE5-17B_TDS2008_MZ.MXD FIGURE5-17B_TDS2008_MZ 5/1/2008 10:25:45



LEGEND

⊙ Monitoring, Test, or Supply Well

■ Bedrock Monitoring Well

1,420 Average Total Dissolved Solids (TDS) concentration in miligrams per liter (mg/L)

Average TDS concentrations for wells completed in **Deep Zone** of Alluvial Aquifer, from data collected between July 1997 and August 2007

Average TDS Concentrations

- ● <1,000 mg/L
- ● 1,000 to 3,000 mg/L
- ● 3,000 to 10,000 mg/L
- ● >10,000 mg/L

Note:
For comparison, the average TDS concentration for Colorado River surface water samples is 620 mg/L (7 sample locations, 1997-2007).

N

0 750 1,500 Feet

FIGURE 5-18c
AVERAGE TDS CONCENTRATIONS DEEP WELLS IN ALLUVIAL AQUIFER AND BEDROCK WELLS

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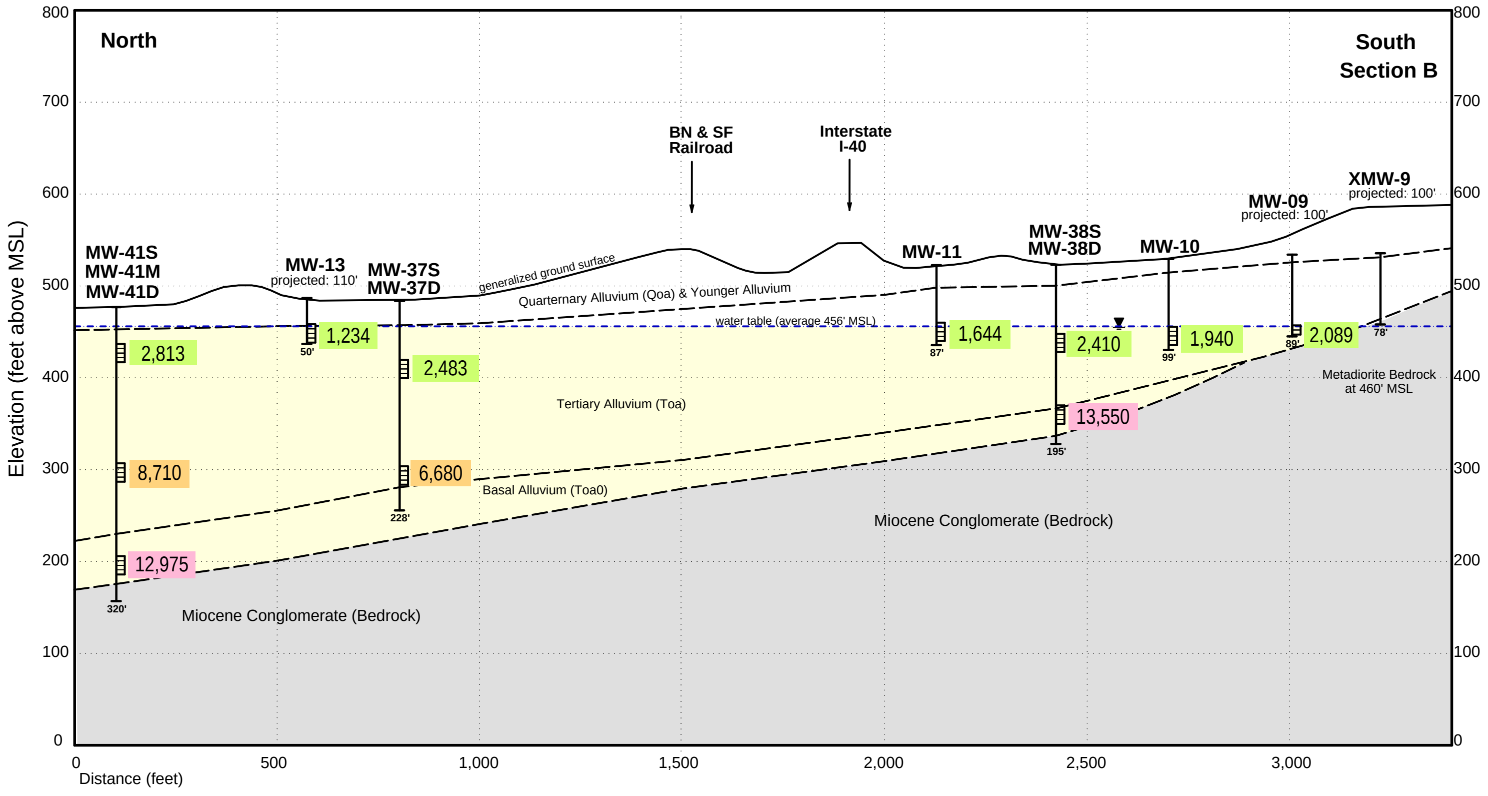
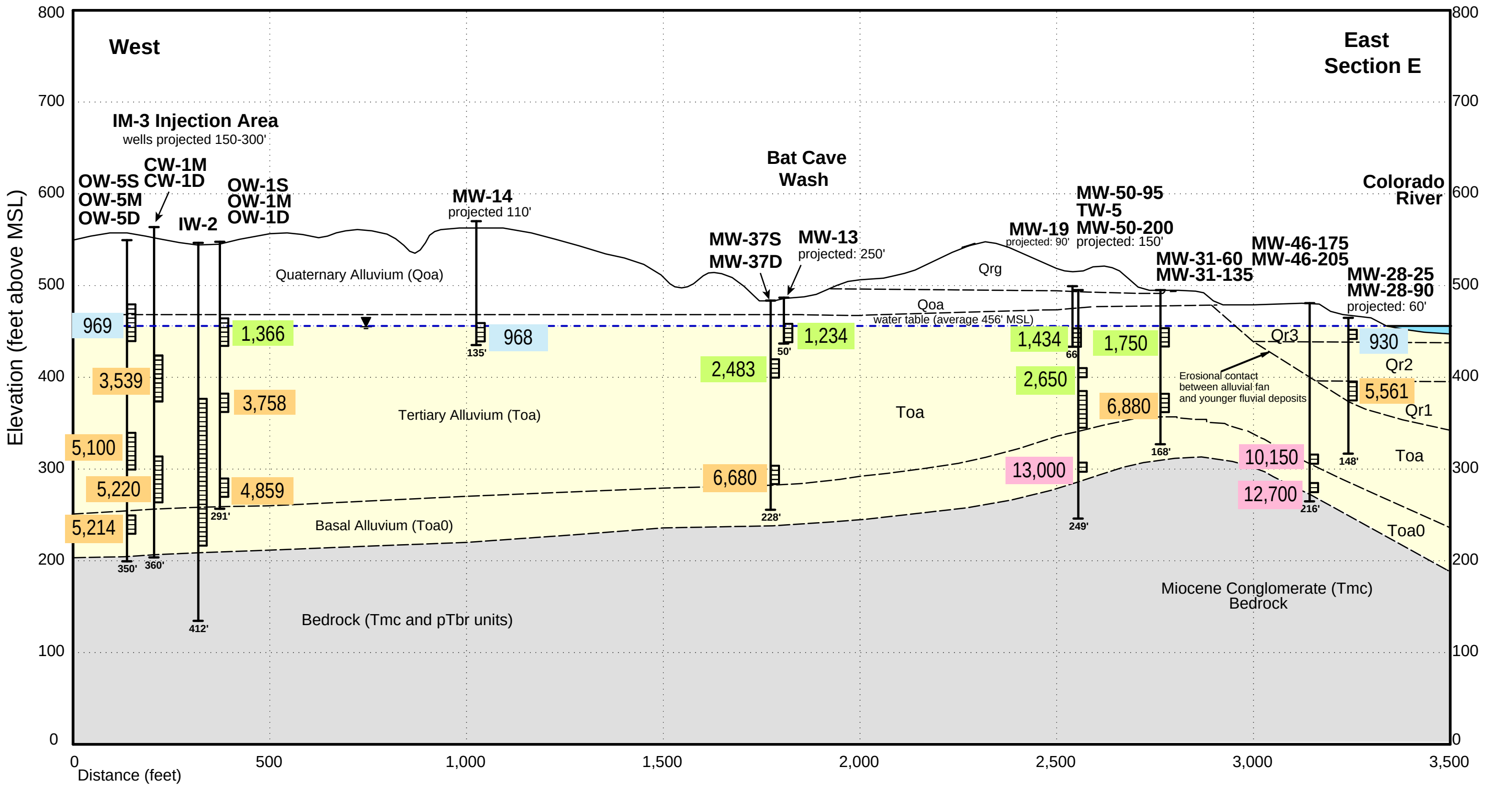
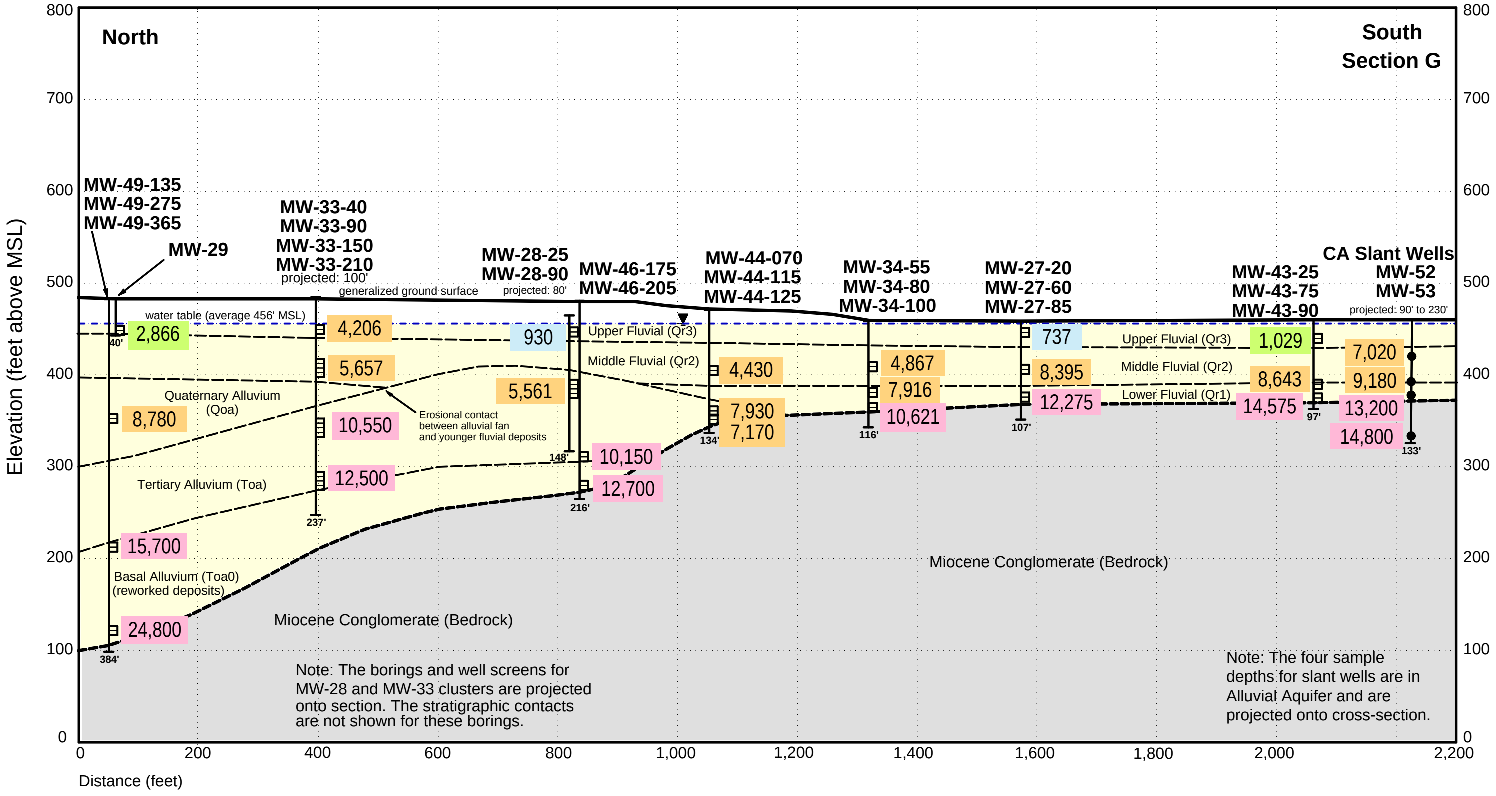
\\ZINFANDEL\PROJ\PACIFICGASELECTRICCO\TOPOCKPROGRAM\GIS\MAPFILES\2007\RFI\FIGURE5-17C_TDS2008_LZ.MXD FIGURE5-16C_TDS2008_LZ 5/1/2008 10:28:49





Note: Cross-sections displayed at Approximate 2.3 Vertical Exaggeration



Note: The borings and well screens for MW-28 and MW-33 clusters are projected onto section. The stratigraphic contacts are not shown for these borings.

Note: The four sample depths for slant wells are in Alluvial Aquifer and are projected onto cross-section.

LEGEND

water level ▼

Alluvial Aquifer

well screen 1,420 Average Total Dissolved Solids (TDS) concentration in milligrams per liter (mg/L)

boring depth (feet) 103

Average TDS Concentrations (1997-2007 Sampling)

700	< 1,000 mg/L
3,000	1,000 to 3,000 mg/L
7,000	3,000 to 10,000 mg/L
12,000	> 10,000 mg/L

Note: See Figure 5-1 for locations of cross-sections

FIGURE 5-19
TDS DISTRIBUTION IN ALLUVIAL AQUIFER, SELECTED CROSS-SECTIONS

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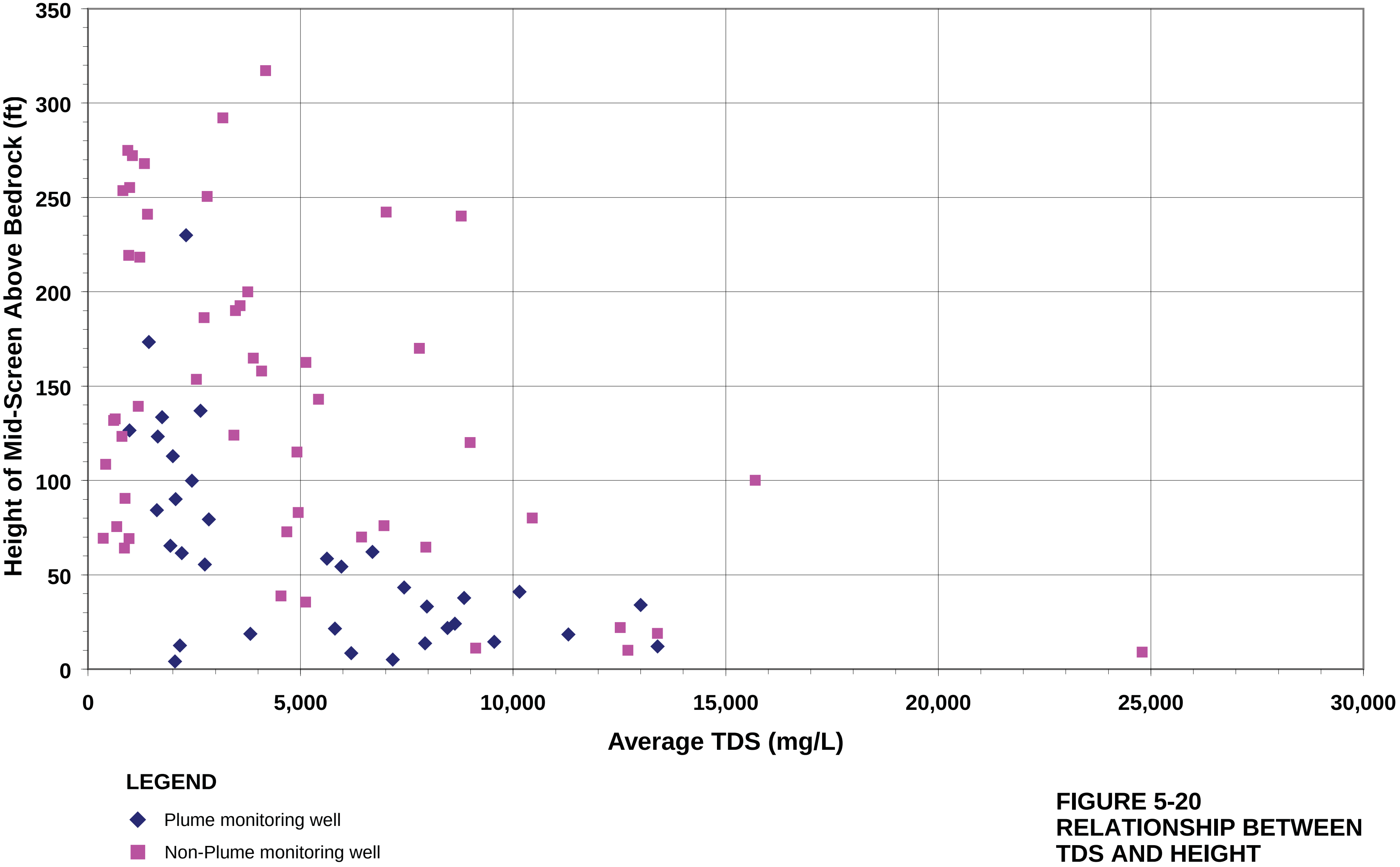

Note: Average TDS concentrations from 1997-2007 sampling events

FIGURE 5-20
RELATIONSHIP BETWEEN TDS AND HEIGHT ABOVE BEDROCK

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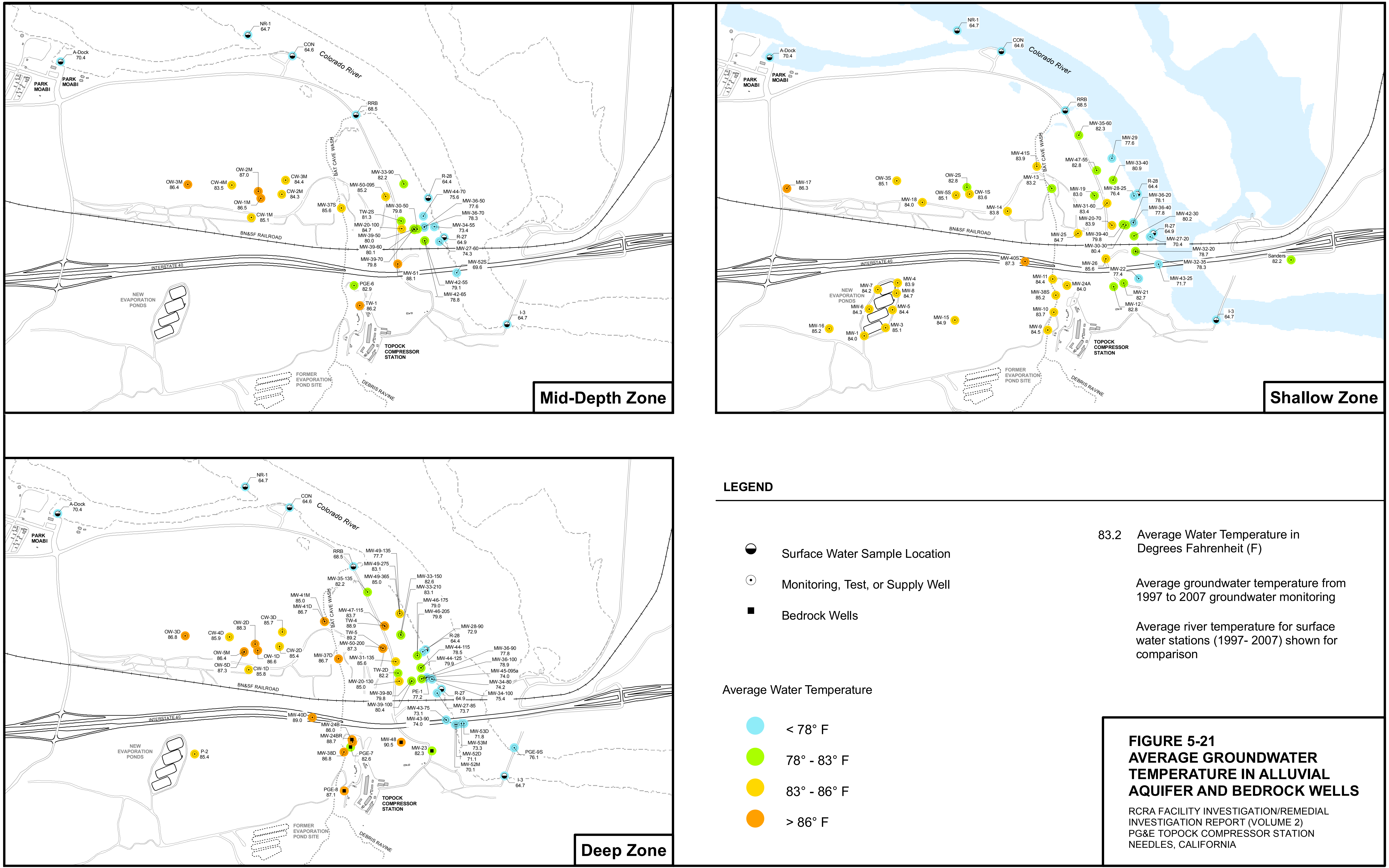

LEGEND

◒ Surface Water Sample Location

⊙ Monitoring, Test, or Supply Well

■ Bedrock Wells

83.2 Average Water Temperature in Degrees Fahrenheit (F)

Average groundwater temperature from 1997 to 2007 groundwater monitoring

Average river temperature for surface water stations (1997- 2007) shown for comparison

Average Water Temperature

● < 78° F

● 78° - 83° F

● 83° - 86° F

● > 86° F

FIGURE 5-21
AVERAGE GROUNDWATER TEMPERATURE IN ALLUVIAL AQUIFER AND BEDROCK WELLS

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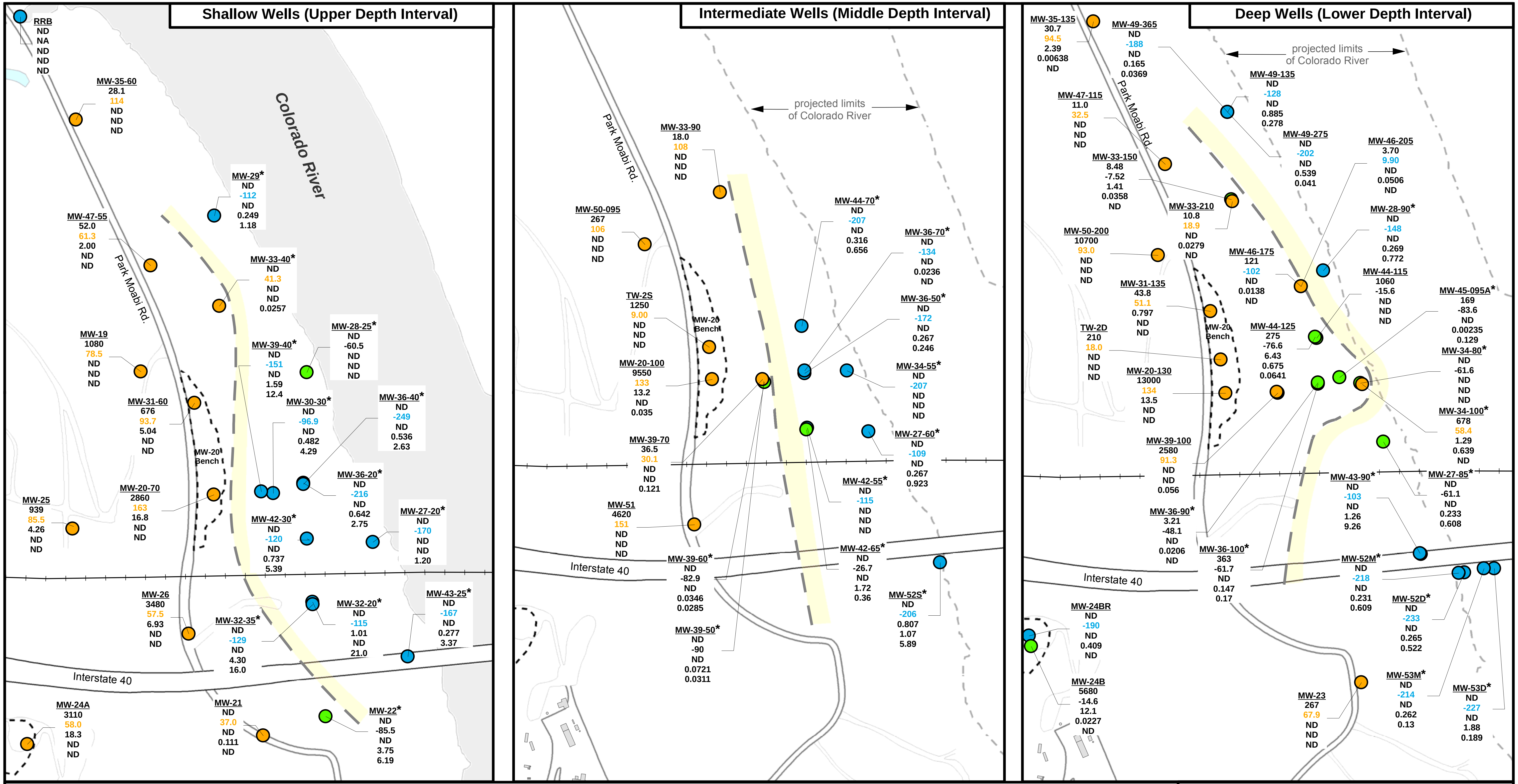
\\ZINFANDEL\PROJ\PACIFICGASELECTRICCO\TOPOCKPROGRAM\GIS\MAPFILES\2007\RFI\FIG5-21A_TEMP2008_ALL.MXD FIG5-19_TEMP2008_ALL.MXD 5/2/2008 10:05:24



LEGEND

- 🔵 Groundwater ORP < -90 mV
- 🟢 Groundwater ORP -90 mV to 1 mV
- 🟠 Groundwater ORP > 1 mV
- ▨ Approximate limit of reducing groundwater (ORP less than -90mV)

Average Groundwater Results From Nov. 2006 - Oct. 2007 Sampling

MW-26	Well ID
3,480	Hexavalent chromium, micrograms per liter (µg/L)
57.5	Oxidation reduction potential (ORP), millivolts (mV)
6.93	Nitrate as Nitrogen, milligrams per liter (mg/L)
0.25	Manganese, miligrams per liter (mg/L)
0.25	Iron, miligrams per liter (mg/L)

ORP values less than -90mV highlighted blue.
Positive ORP values highlighted green.

Notes:
ND = not detected
INC = not sampled during sample period
* wells screened in fluvial deposits

Several floodplain wells completed in fluvial deposits (MW-39-50, MW-39-60, MW-30-50) had detected Cr(VI) prior to the 2006-2007 sampling data posted. Well MW-30-50 was last sampled in Oct. 2006.

N

0 400 800 Feet
1 inch = 400 feet

FIGURE 5-22
DISTRIBUTION OF Cr(VI) AND GEOCHEMICAL INDICATOR PARAMETERS IN FLOODPLAIN

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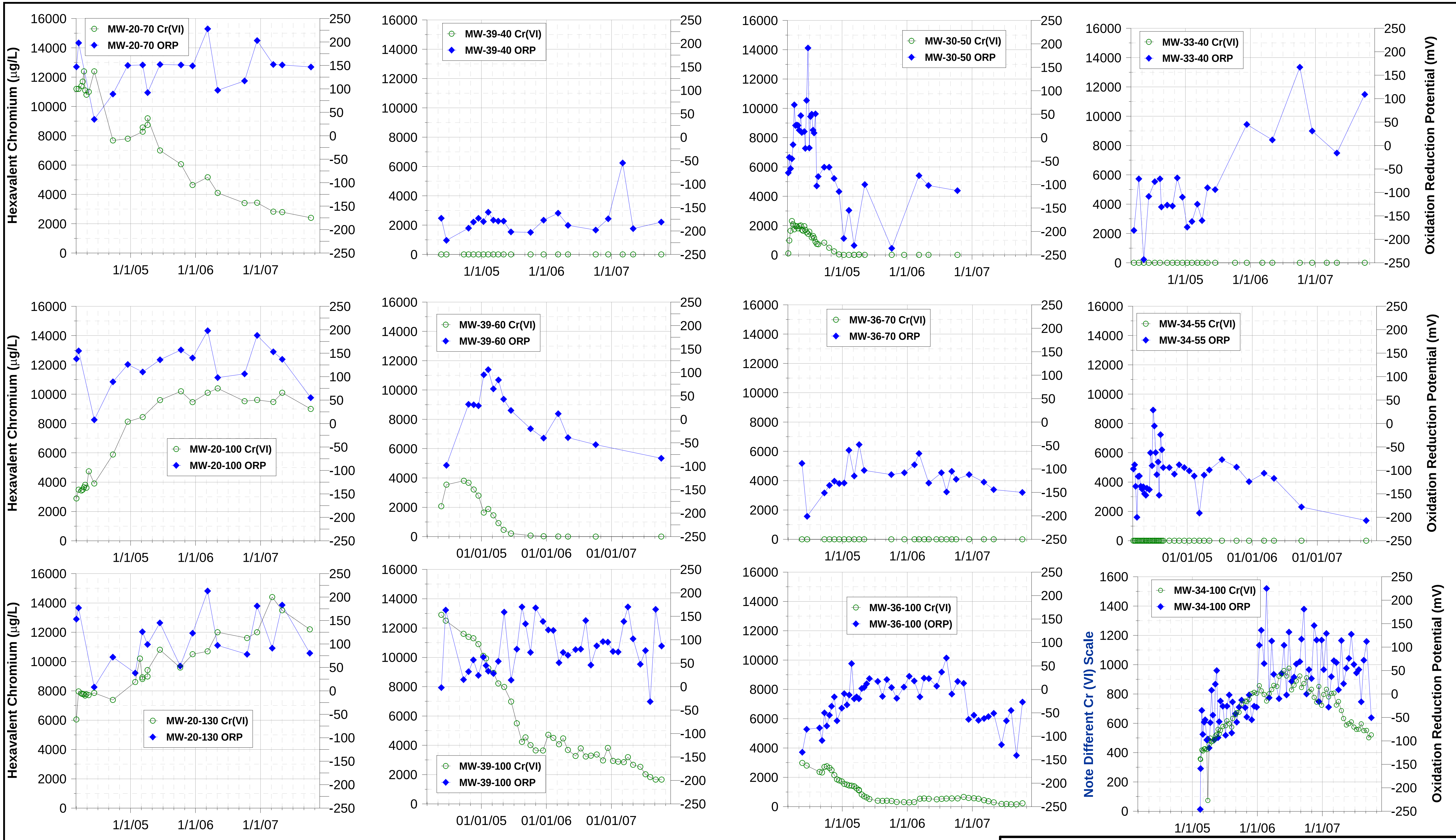
\\ZINFANDEL\PROJ\PACIFICGASELECTRICCO\TOPOCKPROGRAM\GIS\MAPFILES\2007\RFI\RFIGEOCHEMINFLOODPLAIN_20090205.MXD FIG5-22_RFIGEOCHEMINFLOODPLAIN_20090205 CARCHER 2/5/2009 14:26:51



See Figure 5-7 for hydrogeologic cross-section F-F'
and Figure 5-22 for locations of
the selected wells presented

FIGURE 5-23
GRAPHS OF Cr(VI) AND OXIDATION REDUCTION POTENTIAL FOR WELLS ALONG FLOODPLAIN CROSS SECTION F-F'

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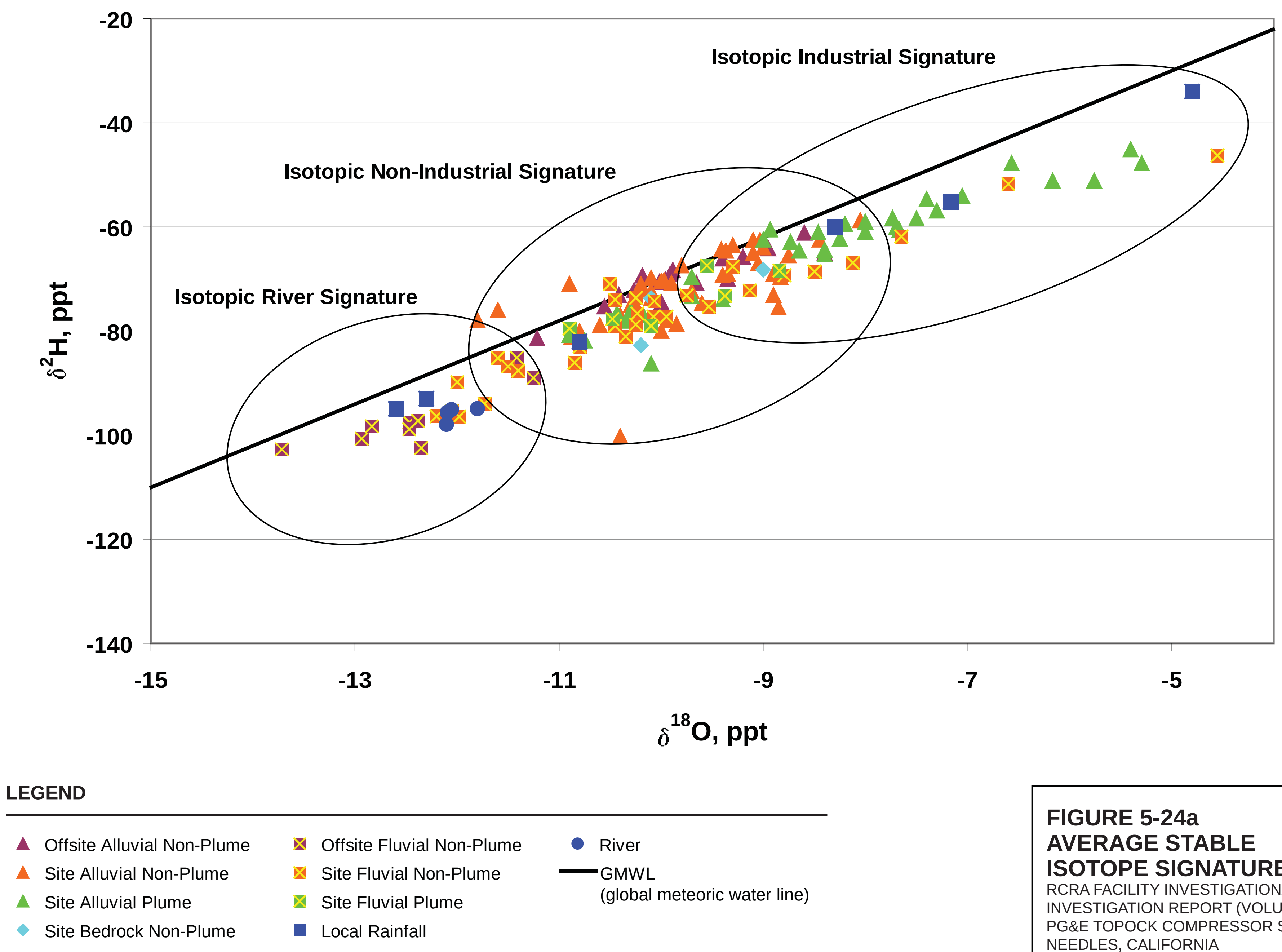

FIGURE 5-24a
AVERAGE STABLE
ISOTOPE SIGNATURES
RCRA FACILITY INVESTIGATION/REMEDIAL
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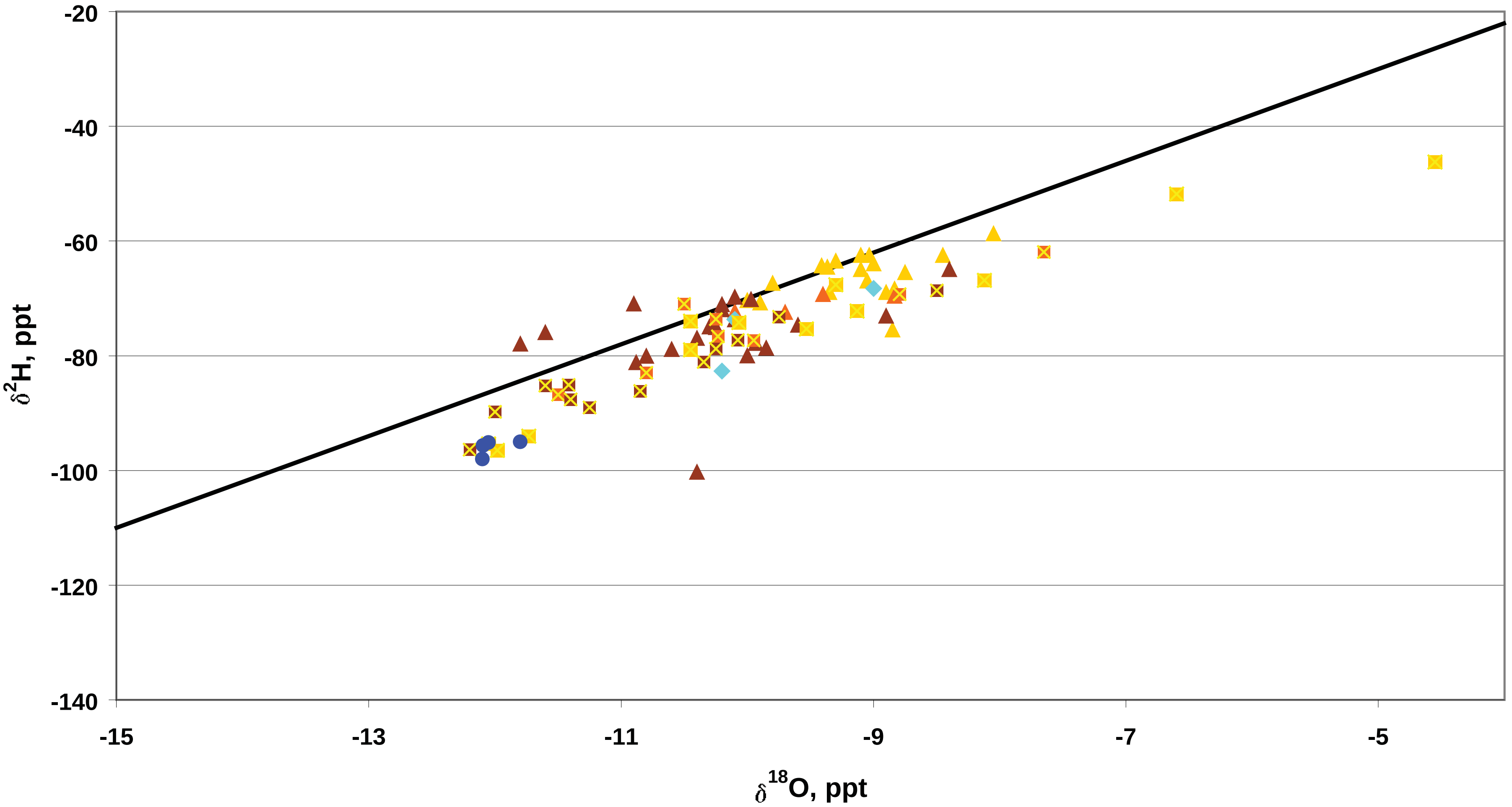

LEGEND

- ▲ Alluvial Non-Plume Upper
- ▲ Alluvial Non-Plume Middle
- ▲ Alluvial Non-Plume Lower
- ◆ Bedrock Non-Plume
- ☒ Fluvial Non-Plume Upper
- ☒ Fluvial Non-Plume Middle
- ☒ Fluvial Non-Plume Lower
- ● River
- ▬ GMWL (global meteoric water line)

FIGURE 5-24b
STABLE ISOTOPES BY DEPTH IN NON-PLUME WELLS

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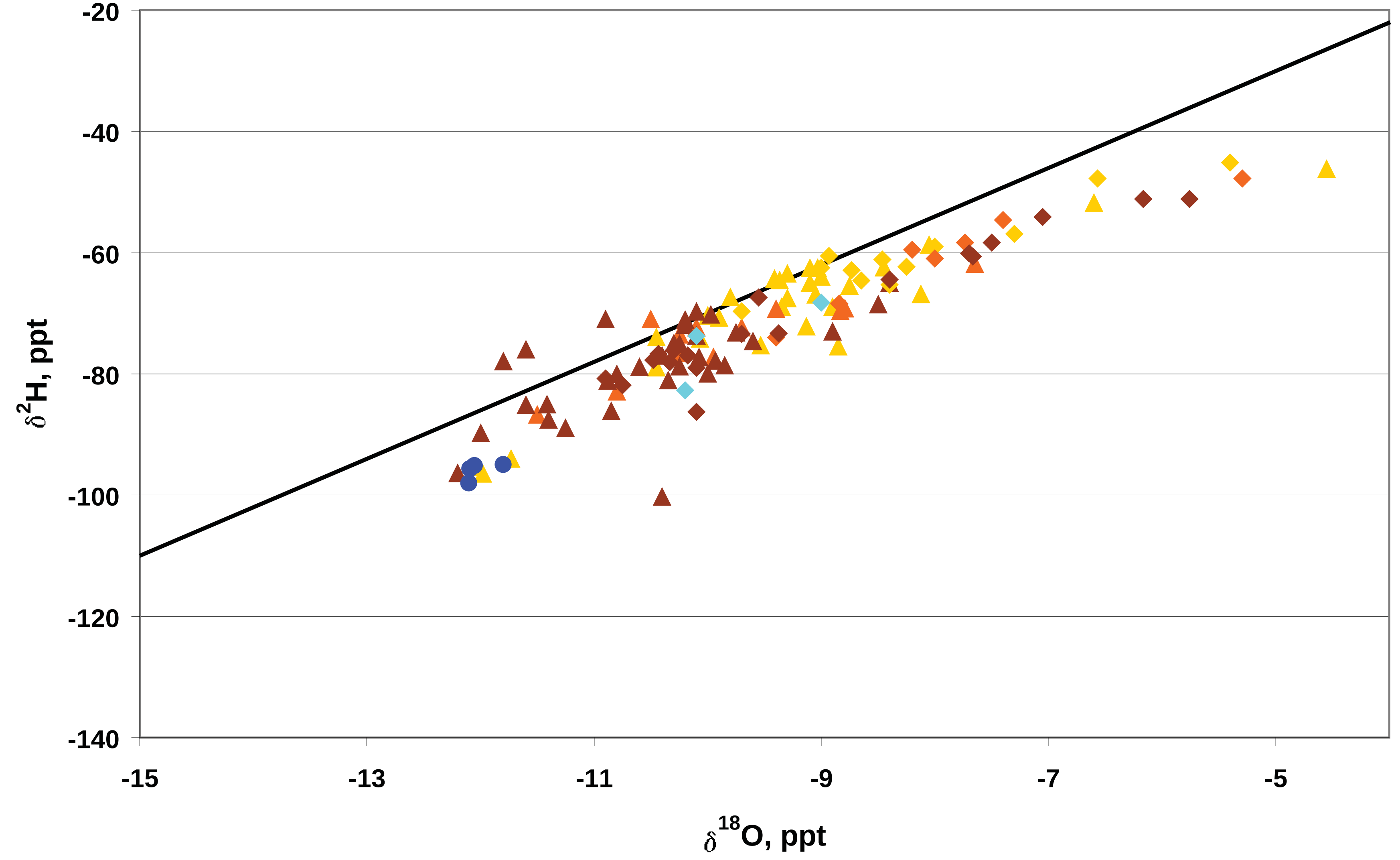
ES102007005BAO_Fig_5-22b_StableIsotope_Depth_Nonplume.ai_022908_lho



LEGEND

- ▲ Non-Plume Upper
- ▲ Non-Plume Middle
- ▲ Non-Plume Lower
- ◆ Plume Upper
- ◆ Plume Middle
- ◆ Plume Lower
- ◆ Bedrock Non-Plume
- ● River
- — GMWL (global meteoric water line)

FIGURE 5-24c
STABLE ISOTOPES BY DEPTH IN PLUME AND NON-PLUME WELLS

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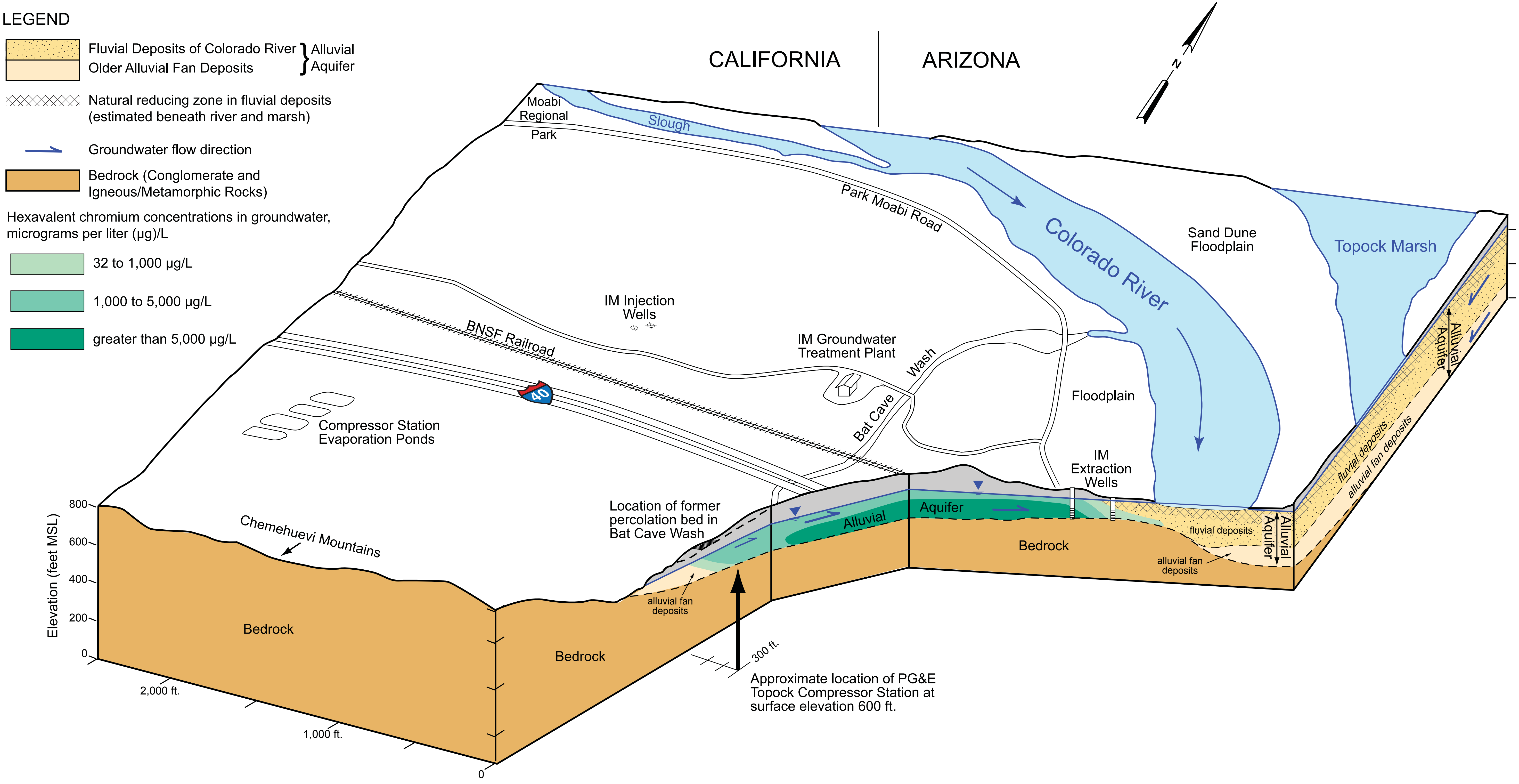

SCHEMATIC DIAGRAM

FIGURE 5-25
TOPOCK SITE
HYDROGEOLOGIC FEATURES
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6.0 Groundwater Characterization

This section presents the results and findings of the RFI/RI investigations to identify and characterize the nature, degree, and extent of COPCs in groundwater. The groundwater characterization presentation in this section additionally includes discussion of plume geochemistry, the conceptual model for chromium plume migration in groundwater, and chromium fate and transport processes.

6.1 Groundwater Data and Regulatory Standards

The current groundwater characterization is based on an extensive groundwater investigation, sampling, and monitoring data collected over a 10-year period (July 1997 through October 2007). To provide context for this presentation, the following sections summarize the chemical parameters, the analytical data sets, and regulatory standards applicable for the groundwater characterization. Additional trace metal data has been collected from select wells between December 2007 and September 2008 and is included in the RFI/RI Volume 2 Addendum Report.

6.1.1 Chemical Parameters and Data Sets for Characterization

The COPCs for SWMU 1/AOC 1 (Former Percolation Bed) and SWMU 2 (Inactive Injection Well – PGE-8) identified in the RFI/RI Volume 1 Report are:

- Cr(VI) and Cr(T).
- Electrical conductivity, and pH.
- Copper, nickel, zinc, and lead.
- TPH.

As described in Sections 4.2 and 5.3, additional COPCs and water quality analytes have been sampled during RFI/RI and site monitoring activities and include general chemistry parameters (including TDS, chloride, sulfate, nitrate, and other parameters), Title 22 trace metals, VOCs, SVOCs, PCBs, perchlorate, and radionuclides.

The groundwater wells at the site have been sampled quarterly, semiannually, and annually for some COPCs since 1997. Since 2004, more frequent groundwater sampling for the COPCs (including monthly, biweekly, and weekly sampling) has been conducted at selected wells. Field water quality parameter data (specific conductance, temperature, pH, oxidation-reduction potential, and dissolved oxygen) are also collected during the routine groundwater sampling and are stored in the project analytical database.

As summarized in Section 4.2.3, the cumulative groundwater sampling activities conducted for the RFI/RI and site monitoring programs have yielded an extensive chemical analytical data set for characterizing groundwater conditions. Table 6-1 summarizes the complete chemical analytical database by parameters analyzed, number of wells/samples, and specific sampling dates for the data sets. A database report listing of all the groundwater analytical results collected for the RFI/RI wells are included in Appendix H2.

6.1.2 Regulatory Standards for Groundwater

Table 6-2 lists the chemical-specific ARARs for the metals and other inorganic constituents in groundwater at the Topock site. These ARARs include the regulatory drinking water MCLs as defined in the California and federal Safe Drinking Water Acts. The drinking water standards listed on Table 6-2 include the primary California and federal MCLs, the secondary MCLs (consumer acceptance limits/ranges), and action levels, as applicable. Appendix G includes a complete listing and citation of the chemical-specific ARARs that apply to this site.

Background concentrations for trace metals in groundwater have been calculated for the Topock site, and are reported in PG&E's *Revised Groundwater Background Study, Steps 3 and 4: Report of* Results (CH2M HILL, 2008b). The site background metals concentrations are the 95-percent UTL of the elevated percentile that were calculated by statistical methods. Table 6-3 lists the calculated site background UTLs for 19 trace metals. As discussed in the cover letter for the Background Study report (CH2M HILL, 2008b), the data collected for this study may be interpreted to represent two or more populations based on geochemical or geological distinctions. For example, the river-influenced fluvial material produces a naturally more reducing environment compared to the less reducing material, which may be alluvial or fluvial. This is described in Section 5.3.1.6. Due to this and other geochemical distinctions, agencies have questioned whether the calculated UTLs are appropriate for all constituents in all portions of the site or at all depths.

6.2 Groundwater Characterization Results

The analytical results for the groundwater characterization are presented below, first for the COPCs and, then for other general chemistry parameters analyzed as part of the RFI/RI. More detailed presentation and evaluation of the groundwater results for Cr(VI) and Cr(T), the primary COPCs, are provided in Sections 6.3 and 6.4.

The analytical results and distribution of the COPCs and other constituents analyzed are discussed below for each of the COPCs or analyte groups. Evaluation and discussion of the groundwater characterization of the COPCs and other analyzed constituents are presented in Section 6.2.3.

Because Cr(VI) is relatively mobile and more abundant than other COPCs it would be expected that the distribution of any other COPCs released to SWMU 1/AOC 1 and SWMU 2 at the compressor station would lie within the boundaries of the Cr(VI) plume. For this reason, the question of whether other COPCs are related to site activity can in part be evaluated based on the distribution of the COPCs compared with the Cr(VI) plume.

6.2.1 Discussion of COPCs by Category

6.2.1.1 Hexavalent and Total Chromium

Table 6-4 presents the groundwater analytical results for Cr(VI) and Cr(T) (range of recent concentrations) for each of the wells in the RFI/RI network from sampling conducted October 2006 through October 2007. For the recent 2006 to 2007 monitoring period, the maximum Cr(VI) concentration of 15,700 µg/L was measured at ISPT monitoring well

PT-9D (initial baseline sampling), and the maximum Cr(T) concentration of 16,400 µg/L was measured at well MW-20-130. Discussion and presentation of October 2007 Cr(VI) sampling results is provided in Section 6.3.

A summary of the sampling results for Cr(VI) and Cr(T) for the full RFI/RI groundwater data set are presented in Table 6-6. This statistical summary lists the primary sampling parameters of the Cr(VI) and Cr(T) data sets and includes comparison with the calculated site background UTL and chemical-specific ARARs. The chromium sampling results summary in Table 6-6 is provided for background on the groundwater characterization; refer to Sections 6.2.3 and 6.3 for the discussion and evaluation of chromium distribution and comparison with the water quality criteria.

6.2.1.2 Specific Conductance and pH

Groundwater specific conductance and pH have been analyzed as routine COPCs as part of the RFI/RI and sitewide GMP sampling from 1997 to the present. Specific conductance is electrical conductivity normalized to a standard temperature (25°C) and is therefore essentially equivalent to electric conductivity, a designated COPC for the site. For the purposes of the RFI/RI groundwater (and surface water) characterization, this designated COPC will be referred to as specific conductance in text, tables, and figures.

Table 6-4 presents the specific conductance and pH groundwater results for the RFI/RI wells from October 2006 through October 2007. The groundwater specific conductance readings for this period range from approximately 1,100 microSiemens per centimeter (µS/cm) for shallow wells next to the Colorado River (e.g., MW-27-20) to values in the range of 40,000-65,000 µS/cm in shallow and deep wells that monitor brackish to saline groundwater zones (MW-30-30, MW-32-20, MW-49-365). Groundwater pH readings range from 6.79 to 8.98 for the 2006-2007 sampling period.

The results of specific conductance and pH analyses for the RFI/RI groundwater data set are summarized in Table 6-5. The range and average specific conductance and pH readings are presented separately for each of the Alluvial Aquifer depth zones and bedrock wells. The average concentrations for the depths show an overall increasing trend of specific conductance with depth (Table 6-5). A spatial depiction of average specific conductance in groundwater is illustrated in the groundwater TDS distribution maps described in Section 5.3.1 (Figures 5-18a, 5-18b, and 5-18c). The correlation between specific conductance and TDS is well established in the site data and in published studies. At the Topock site, TDS in mg/L is approximately 0.65 times the specific conductance in µS/cm. For samples above 20,000 µS/cm, the multiplier is closer to 0.80. Except for local isolated occurrences, the high TDS water (i.e., > 10,000 mg/L) occurs mainly within and is widely distributed in the deep zone of the Alluvial Aquifer and bedrock wells (Figure 5-18c).

Groundwater pH results for the RFI/RI dataset are summarized in Table 6-5 and the distribution for the site wells is shown on Figure 6-1. The average pH readings for the majority of the wells (all zones) fall within the pH range of 7.9 and 7.5. The average groundwater pH for the wells in the floodplain fall within the pH range of 7.5 to 7.0 (Figure 6-1). The average pH readings for the California slant wells MW-53D/M are notably higher (8.84 and 8.56 pH) than other floodplain wells, and this condition may be influenced by well construction of the slant well and borehole sealing. Due to their specialized construction techniques, slant wells are susceptible to grout leakage into the screened intervals. During construction, grout is injected into the collapsed borehole and may be able to travel down the borehole and into the screened interval. The shallow screened interval in well MW-53 was inadvertently completely plugged with grout during construction and does not produce sufficient water for sampling. It is very possible that grout may have affected although not completely plugged the other two screened intervals in this well where the elevated pH has been observed. Although only pure bentonite grout was used which should not strongly affect the pH, it is possible that some cement residue was present in the grout pump and hoses that could have produced an elevated pH in the grout resulting in the elevated pH observed in the wells. Well cluster MW-52, adjacent to the MW-53 cluster, has average pH around 8.0 at shallow, medium, and deep intervals over the same sampling period, which further suggests the elevated pH in MW-53 is artificial. In an increased pH environment, cationic trace metals such as copper, nickel, zinc, and lead would be even more prone to adsorption and precipitation reactions that would remove them from solution. Metals that form oxyanions (e.g. chromium, vanadium, arsenic, selenium, antimony) will tend to adsorb less at high pH and therefore be slightly more mobile.

6.2.1.3 Copper, Nickel, Zinc, and Lead

Copper, nickel, and zinc were identified as COPCs in the 1996 CACA and have been analyzed as part of routine groundwater sampling from 1997 through May 2004.[4] Beginning in September 2004, at DTSC direction, routine sampling for copper, nickel, and zinc in the RFI/RI wells was replaced with full-list, California Code of Regulations Title 22 trace metals sampling in nine selected groundwater wells (MW-10, MW-11, MW-12, MW-20-70, MW-20-130, MW-25, MW-34-55, MW-34-80, and MW-37D). Collection of Title 22 metals data in the nine wells selected in September 2004 has continued through October 2007 (the RFI/RI Volume 2 data cut-off date). Additional trace metals analytical data were collected at selected wells as part of the Groundwater Background Study and the IM-3 CMP sampling activity. Additional data for these and other trace metals have been collected from select wells between December 2007 and September 2008 and are presented in the RFI/RI Volume 2 Addendum Report.

Table 6-6 summarizes the sampling results for copper, lead, nickel, and zinc (COPCs) for the RFI/RI wells. This statistical summary lists the primary sampling parameters of the data sets for these metals and includes comparison with the calculated site background UTL and chemical-specific ARARs. The characterization results and distribution of each of the COPC metals is discussed below.

The detection frequencies in Table 6-6 for all metals except zinc and chromium are below 50%. In the case of chromium, the geochemical redox environment has a large influence on whether this metal will be detected, as discussed in Section 6.5. Copper, lead, and nickel are not affected by redox, and data from most wells consist of a collection of detections and non-detections.

It is common that suspended microparticles in groundwater, called colloids, pass through the 0.45 µm filters during sampling. These colloids are not assumed to emanate from the

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[4] Lead was added as a site COPC in groundwater at SWMU 1/AOC 1 and SWMU 2 in the 2005 RFI/RI (CH2M HILL 2005a).

historical discharge in Bat Cave Wash, but rather are likely derived from natural mineral and rock fragments in the aquifer matrix. Colloids can travel as suspended material in aquifers, however long distance colloid transport is more typical in fractured bedrock or clean sand and gravel aquifers and would not be expected in the mixed fine and coarse grained Alluvial Aquifer at Topock. The silt and clay that is present in the Alluvial Aquifer would be expected to act as an effective filter to attenuate colloids. The likely source of colloids in the Topock samples is groundwater in the neighborhood of the monitoring well itself, where colloids can, at times, be mobilized inadvertently into the sample by the force of purging the well during sampling. Consequently, monitor wells typically produce water higher in colloids than drinking water wells.

Trace metals that are either a component of or adsorbed to the colloids are then counted as part of the total "dissolved" metal analysis (Puls and Barcelona, 1996). Samples with highly variable concentrations and/or high percentages of non-detects are suggestive of colloidal presence in samples, since the amount and composition of colloids varies with each sample collected. Most of the Topock site data for trace metals follows this pattern. Samples that appear to be more consistent in concentration, suggesting truly dissolved metal presence, will be noted in the discussions below.

The metals results are presented on color-posted maps that list the average concentration of the metal, and the number of detections and number of RFI/RI samples at the well location (see Figure 6-2 for presentation format). Non-detect data were counted as one-half reporting limit in calculations of the average concentration at each well. The results are color-coded for concentration ranges to depict the spatial distribution of the metal in the three depth zones of the Alluvial Aquifer. The concentration ranges for color-coding were selected individually for each metal to incorporate the calculated site background UTL concentration for the metal (CH2M HILL, 2008b) and to optimally depict the observed data range. The outline of Cr(VI) in groundwater greater than or equal to 32 μg/L for the Alluvial Aquifer depth intervals are also shown for reference on the metals distribution maps.

Copper. The concentrations and distribution of dissolved copper in groundwater for the RFI/RI data set are shown on Figure 6-2. The well locations with the highest average copper results (>20 μg/L) include MW-21, MW-22, MW-30-30, and MW-33-90. However, the maximum average copper concentration (54.6 μg/L) is well below the chemical-specific ARAR of 1,000 μg/L, which is a secondary drinking water regulation. Well locations where copper exceeds the UTL of 10.5 μg/L occur in all depth zones, are located both inside and outside the plume outline, and show an overall discontinuous distribution across the site. Most of the well locations have less than 50% detection rate, suggesting that colloidal material may be accounting for the detected concentrations in those wells.

Lead. The concentrations and distribution of dissolved lead in groundwater are shown on Figure 6-3. The well locations with the highest average lead results (greater than the ARAR of 15 μg/L) are MW-22 and MW-30-30, although both have 50% detection rates. Well locations where lead exceeds the UTL of 1.91 μg/L occur primarily in the shallow depth zone, are located both inside and outside the plume outline, and show an overall discontinuous distribution. Concentrations are variable and most locations have less than 50% detections, suggesting colloidal influence in the reported concentrations. Lead is known to have a high affinity for adsorption to mineral surfaces compared to other trace metals, with essentially 100% adsorbed at pH 7 in laboratory studies (Sposito, 1984; Schindler, 1991). Given these properties, any lead that may have been disposed at SWMU 1 that was not adsorbed by vadose zone minerals would not be expected to travel far in groundwater beneath Bat Cave Wash. The fact that the highest concentrations of lead were found in wells far downgradient of SWMU 1 is in conflict with lead's low mobility.

Nickel. The concentrations and distribution of dissolved nickel in groundwater are shown on Figure 6-4. The well locations with the highest average nickel results (>20 µg/L) are MW-3, MW-20-130, MW-21, MW-22, MW-30-30, and PGE-7. Well locations where nickel exceeds the UTL of 10.6 µg/L occur primarily in the shallow zone (discontinuous distribution), are located both inside and outside the plume outline, and in isolated mid-depth and deep zone wells (MW-20-100/-130, MW-24B, and PGE-6). Like copper and lead, most of the samples have low detection rates and the higher concentrations tend to be driven by one or two anomalously high samples, both suggesting colloidal influence.

Zinc. The concentrations and distribution of dissolved zinc in groundwater are shown on Figure 6-5. The well locations with the highest average zinc results (> 150 µg/L) include MW-21, MW-32-35, PGE-9N, and PGE-9S. However, the maximum average zinc concentration (665 µg/L) is well below the chemical-specific ARAR of 5,000 µg/L. It is unlikely that the zinc concentrations in the PGE-9 wells represent natural occurrence. These wells have been idle with an installed pump for the last 9 years. It is likely that the standpipe, pump column, and the pump itself have some galvanized (i.e., zinc-coated) parts, and although zinc is rust-resistant, the high TDS water in this well could still corrode the galvanic layer, resulting in zinc in solution or attached to colloids. Well locations where zinc exceeds the UTL of 77.7 µg/L occur primarily in the shallow zone, are located both inside and outside the plume outline, and indicate an overall discontinuous distribution. Zinc concentrations above the UTL also occur in several mid-depth wells (Figure 6-5). Detection rate for zinc is significantly greater than that of copper, lead, and nickel, and concentrations are also more consistent in each well. These data suggest that measured zinc concentrations are more representative of dissolved forms in groundwater.

6.2.1.4 Total Petroleum Hydrocarbons

This section presents the results of TPH groundwater analyses and other constituents of interest that have been sampled for the RFI/RI characterization.

Total petroleum hydrocarbons were identified as an additional groundwater COPC based on waste water disposal records from SWMU 1 (Former Percolation Bed) and SWMU 2 (Inactive Injection Well PGE-8). Table 6-7 summarizes the groundwater analytical results for TPH and organic compounds sampling conducted in 2004 and 2007. Five shallow monitoring wells in the vicinity and downgradient of SMWUs 1 and 2 (MW-10, MW-11, MW-12, MW-24A, and MW-25) were sampled for TPH-gasoline, TPH-diesel, and TPH-motor-oil in May 2007. The TPH components were not detected at or above the analytical reporting limits in these samples.

6.2.1.5 Other Trace Metals

As noted in Section 6.2.1.3, additional trace metals have been sampled during the RFI/RI groundwater characterization. Table 6-1 presents the number of wells and the specific groundwater data sets for the other trace metals.

Table 6-8 summarizes the sampling results for the following trace metals that were reviewed for this characterization: aluminum, antimony, arsenic, barium, beryllium, cadmium, cobalt, mercury, molybdenum, selenium, silver, thallium, and vanadium. This statistical summary lists the primary sampling parameters of the data sets, detection frequency, and includes comparison with the calculated site background UTL and chemical-specific ARARs. The characterization results for the trace metals are discussed below.

Regarding comparison to background values (Tables 6-3 and 6-8), the trace metals that exceed the site UTL in > 5% of the data set include aluminum, arsenic, beryllium, molybdenum, selenium, and vanadium. Of these metals, only the average concentration of vanadium was not found to exceed the UTL in more than one well.

Regarding comparison to drinking water standards (Tables 6-2 and 6-8), the trace metals that exceed the ARARs in > 1% of the data set include antimony and arsenic. The average concentrations of both metals were found to exceed the ARAR in more than one well. On the basis of the criterion to exceed either UTL or ARAR in more than one well, metals distribution analysis was conducted for aluminum, antimony, arsenic, beryllium, molybdenum, and selenium.

Arsenic. The concentrations and distribution of dissolved arsenic in groundwater are shown on Figure 6-6. The only well location where arsenic exceeds the UTL of 24.3 µg/L is MW-12, with an average concentration of 97.3 µg/L. Several wells at the New Ponds site and in the floodplain ISPT area have average concentrations exceeding 10 µg/L (the Federal MCL and chemical-specific ARAR). The creation of reducing conditions during the ISPT areas has the effect of temporarily mobilizing naturally occurring arsenic from the aquifer materials. The reduced form of arsenic, As(III), is more mobile than the oxidized form, As(V), and reduction caused by *in-situ* pilot testing will release some of the adsorbed As(V) from the aquifer matrix. As the As(III) encounters less reducing conditions downgradient, it readily converts back to As(V) and readsorbs to mineral surfaces.

There are six other wells with at least one sample above the ARAR: MW-10 (2 of 13), MW-16 (1 of 6), OW-5M (1 of 14), PGE-9N (1 of 2), PGE-9S (6 of 6), and Sanders (6 of 6). Suspended colloidal material containing either adsorbed or coprecipitated arsenic may be causing the occasional elevated sample concentrations from wells that have highly variable concentrations (MW-10, MW-16, OW-5M, and PGE-9N). DTSC considers that colloids are not a significant factor related to arsenic detections in wells such as MW-10 and MW-16 as arsenic was always or routinely detected in these two wells (atypical of sporadic detections that might be related to colloidal affects).

As shown on Figure 6-6, the average concentrations of arsenic generally fall within the range of 2 to 8 µg/L. The analytical techniques used in arsenic analysis of site groundwater are susceptible to matrix interferences. This is due to the chemical properties of site groundwater, including high chloride concentrations and other constituents that may interfere with the analysis (Thomas, 2002). As a result, the uncertainty associated with arsenic concentrations of less than 10 µg/L are great enough that samples in this range may not be discernable from one another. The lowest two categories of color posts on Figure 6-6 should be viewed with this uncertainty in mind. DTSC considers the conclusions above regarding interpretation of arsenic data below 10 µg/L due to matrix effects somewhat tenuous as all arsenic data presented within the report are considered of acceptable quality and were not identified as estimates by the reporting laboratory. Additionally, DTSC considers that matrix effects, if significant, would in general apply equally across the alluvial aquifer and, therefore, allow for relative comparisons of concentrations.

Overall, the distribution of arsenic in groundwater is discontinuous. Arsenic concentration appears to be elevated significantly above background levels at well MW-12. The source of arsenic in the vicinity of MW-12 is unknown, but may be associated with herbicides commonly used during the time when that area was adjacent to railroad and highway right-of-way, or with refractory materials/debris that have been observed in the fill used to create the former railroad grade. Note that wells near these transportation corridors in Arizona (e.g., Sanders well) also show elevated levels of arsenic as shown on Figure 6-6. Whatever the actual source of arsenic in the vicinity of MW-12, it does not appear to be associated with a source in Bat Cave Wash. Outside of this area, the distribution of arsenic (shown in Figure 6-6) is inconsistent, and not suggestive of a plume distribution associated with the Bat Cave Wash discharge.

Since 1995 when documentation of spills at the station became more detailed and common, there have been several incidental releases of facility wastewater, a few of which have resulted in wastewater released to Bat Cave Wash. The spills have been described in Section 3.1.8 of the RFI/RI Volume 1 Report (CH2M HILL, 2007a), accompanied by all soil and wastewater analyses associated with the spills. The most significant spills in Bat Cave Wash involved wastewater dominated by cooling tower blowdown water on its way to the New Ponds. A single facility wastewater sample from 2005 showed arsenic below the reporting limit of 50 µg/L (CH2M HILL, 2007a). Any arsenic potentially dissolved in this water (below the reporting limit) would be expected to be in the As(V) state, as the water is exposed to air throughout the process cycle. This form of arsenic adsorbs readily to soil minerals, and would be expected to be attenuated in near-surface soil in the event of a spill of this type. Other spills to Bat Cave Wash documented in the RFI/RI Volume 1 Report (CH2M HILL, 2007a) have also identified slightly elevated arsenic in soil associated with the spills.

Average concentrations of arsenic in Bat Cave Wash wells in the vicinity of the spills (MW-10, MW-38S, MW-38D) are less than 10 µg/L, within the range observed in other monitoring wells around the site. Observed data do not support a significant contribution of arsenic to groundwater from spills in the compressor station area. Conversely, DTSC contends that arsenic concentrations between 5 to 10 µg/L (green symbols on Figure 6-6) are somewhat clustered around the SWMU 1/AOC 1 area and might be related to historic activities.

In well MW-10, concentrations of Cr(VI) and Cr(T) have fluctuated somewhat over time, and arsenic data from this well has followed a similar pattern (Appendix F3). Similar concentration fluctuations are observed for the COPCs molybdenum. These fluctuations are typical of monitoring well data, and may be caused by slight variations in groundwater level and/or direction, which may carry slightly higher or lower concentrations into the well's sampling radius. With respect to groundwater changes, random localized storm events in the nearby mountains may bring fresh water down Bat Cave Wash and into the shallow groundwater system, resulting in slight drops in concentration at some point in time following the storm event. This process should contribute to observed decreases in concentration. Conversely, groundwater level or flow direction perturbations that may be caused by the same storm event could carry higher natural arsenic concentration groundwater into the well area. Also, in the case of the two peak concentration events (October 3, 2005 and December 14, 2006), Cr(T) is greater than Cr(VI), especially in the second peak event. This suggests that colloidal material is making up the difference between the two, since Cr(III) is not stable in dissolved form above analytical reporting limits under site conditions (Brookins, 1988). The same colloids that add to the Cr(T) may also be supplying arsenic to the groundwater analysis.

There is no clear connection between the similar pattern of variation of arsenic and chromium in MW-10 with a potential common source of the two elements. Natural arsenic in groundwater may change with the same diluting events (such as fresh water influx) or concentrating effects (as may be brought with changing groundwater levels or direction) as those observed for chromium, without necessarily being sourced in the original SWMU 1 discharge.

In its evaluation of arsenic data in the vicinity of well MW-10, DTSC made different interpretations than PG&E. DTSC believes that a conceivable scenario for elevated arsenic in well MW-10 could arise from discharges emanating from SWMU 1/AOC 1 or one of the spills to Bat Cave Wash. This is based on the close relationship, pictured in Appendix F3, between arsenic, chromium, and molybdenum (two groundwater COPCs associated with SWMU 1/AOC 1 that will be dealt with further in the RCRA/CERCLA process) and the close proximity of well MW-10 to the former discharge ponds. DTSC also noted that the highest arsenic, chromium, and molybdenum concentrations occurred when specific conductance readings were lowest and groundwater levels were peaking (see figure in Appendix F3), suggesting that fresher water added contaminants to the groundwater system in the vicinity of the well. Despite the differences in interpretation between PG&E and DTSC, both conclude that arsenic is not recommended for consideration as a COPC in groundwater related to SWMU 1/AOC 1 as arsenic has dropped to below reporting limits in well MW-10.

Well MW-12, where arsenic concentrations are significantly higher, shows the opposite relationship between chromium and arsenic/molybdenum between 2005 and 2006 (Appendix F3). The different behavior of chromium compared to the other three elements suggests a different proportion of these elements that is introduced as a result of groundwater fluctuations, but does not suggest whether this source is natural or anthropogenic.

Molybdenum. The concentrations and distribution of dissolved molybdenum in groundwater are shown on Figure 6-7. The well locations with the highest average molybdenum results (> 70 µg/L) include MW-10 (average concentration 144 µg/L), MW-38D, MW-44-125, and MW-46-175. Well locations where molybdenum exceeds the UTL of 36.3 µg/L occur primarily in the deep zone and in scattered shallow zone wells. The distribution of molybdenum is discontinuous in the shallow wells, while the distribution in the deep wells extends to nearly all areas of the site (Figure 6-7). Time-series concentrations of molybdenum in well MW-10 are compared with those of Cr(VI) and Cr(T) in Appendix F3. Molybdenum has no California or federal MCL, and therefore no chemical-specific ARAR is listed in Table 6-2.

As discussed above in the arsenic section, several incidental spills have occurred at the facility, resulting in wastewater being temporarily released in Bat Cave Wash (CH2M HILL, 2007a). The molybdenum concentration in the only available wastewater sample was 6,700 µg/L (Table 3-14 in CH2M HILL, 2007a). Unlike arsenic, molybdenum is mobile under the geochemical conditions in the unsaturated zone, and would be expected to move with the water with relatively minimal attenuation. Although molybdenum concentrations in numerous non-plume wells also exceed the UTL (Figure 6-7), it cannot be eliminated as a COPC at this time. Additional molybdenum data will be collected as part of the RFI/RI Volume 2 Addendum and part of planned periodic monitoring.

Selenium. The concentrations and distribution of dissolved selenium in groundwater are shown on Figure 6-8. The maximum concentration of selenium is found at well TW-1 (155 µg/L). This is the only well location where the average selenium concentration exceeds the chemical-specific ARAR for selenium (50 µg/L, Table 6-2). Well locations where selenium exceeds the Background Study UTL of 10.3 µg/L were limited to MW-5, MW-17, MW-20-130, MW-21, MW-24B, and TW-1. Overall, the distribution of selenium in groundwater is discontinuous across the site and appears to be elevated significantly above background levels in one localized area (well TW-1). The possible source of the elevated selenium around well TW-1 is unknown. The only documented selenium concentration in facility wastewater was a non-detect below a relatively high reporting limit of 100 µg/L (Table 3-14 in CH2M HILL, 2007a). Additional data has been collected from selected wells for the RFI/RI Volume 2 Addendum Report and will be included in planned periodic monitoring.

Vanadium. Vanadium has no chemical-specific ARAR, and has a background study UTL of 59.9 µg/L. The only monitoring well with an average concentration that exceeds the UTL for vanadium is found in well MW-22, although 27 other wells have shown one or two samples that have exceeded UTL in the past. The distribution of average vanadium concentrations in groundwater is provided in Figure 6-9.

Of the 27 wells which have had at least one sample exceeding the vanadium UTL, 15 have been non-plume wells and 12 have been either plume or floodplain wells in the downgradient path of the plume. Only five of the 27 wells have had two samples exceeding UTL; the remainder of wells have had only one. Of the 14 samples in plume or plume flowpath wells that have exceeded UTL, ten were from a single sampling event in March 2005. Nine of these ten were reported as anomalous at the time (CH2M HILL, 2005x) and re-sampling in June 2005 showed vanadium values back in normal range (below UTL), suggesting that laboratory analytical issues were the source of the elevated concentrations. Overall, of the 32 groundwater samples that have exceeded vanadium UTL, 27 of them have occurred in just four sampling events, all in 2005. On the basis of the suspected laboratory issues and the fact that more exceedances occur outside the area influenced by SWMU 1 and SWMU 2, the vanadium distribution appears to reflect natural variation in site groundwater.

Antimony. Antimony has a chemical specific ARAR of 6 µg/L, and a Background Study UTL of 1.22 µg/L. The distribution of antimony in groundwater is provided in Figure 6-10. The only wells with average concentrations exceeding the antimony UTL are MW-20-100, TW-2S, and TW-2D, all located on the MW-20 bench. The averages in these three wells also exceed the chemical-specific ARAR. For each well, the average is driven by one sample; the other two samples from the TW-2 wells were below reporting limits, and MW-20-100 had only had one sample analyzed for antimony. The observation that the detected concentrations at the TW-2 wells (153 and 155 µg/L, collected on the same date) are so much higher than the other two samples from these wells (below reporting limits of 5 µg/L for one sample and 2 µg/L for the other), suggests that the detected concentrations were influenced by colloidal material passing through the filter, or perhaps an anomalous laboratory measurement. There were five other wells with one or two samples above the UTL: MW-10 (1), MW-12 (2), MW-20-70 (1), MW-34-55 (1), and OW-5M (1). All detections in these wells were also above the ARAR, with the exception of the sample from MW-10. Each of these wells had at least eight other samples that were analyzed for antimony, and all remaining samples were below reporting limit. Dissolved concentration of antimony in the redox and pH ranges of the Topock site are not thermodynamically favored to exceed the UTL of 1.22 µg/L (Brookins, 1988). Based on the infrequent, widely spaced detections it is concluded that the UTL/ARAR exceedances for antimony were the result of natural variation, lab error or colloidal breakthrough.

Beryllium. The Background Study UTL for beryllium is 0.663 µg/L, and the chemical-specific ARAR is 4 µg/L. The reporting limit for samples in the background data set was 1 µg/L. Many of the samples in the RFI/RI data set had a reporting limit of 3 µg/L. Samples with concentrations less than the reporting limit are assumed to contain half the reporting limit for the purposes of calculating averages. Using this half-reporting limit rule, there were 23 wells in the RFI/RI data set with average beryllium concentration above background UTL even though beryllium was not detected in any of these wells. Beryllium was detected in 13 wells in a total of 19 samples, with no more than two detections for any well. The typical concentration range was between 1.1 and 2.8 µg/L, except for one sample at 8.8 µg/L. All detections were in wells located in the IM-3 injection area (OW- and CW- well clusters, with the exception of OW-3), which is outside the area of the Cr(VI) plume. Because beryllium was first detected in these wells on widely varying distances during the same sampling event, it is not believed to represent breakthrough of treated groundwater from the IM-3 injection wells. Although beryllium was not analyzed in IM-3 effluent, there is no indication that it would be present in the treatment process. Eighteen of the 19 detections came in two sampling events (March and June 2006), with no detections in these wells before or since that time. Based on the limited detections and their location, beryllium is not believed to be associated with SWMU 1/AOC 1 or SWMU 2.

Aluminum. Aluminum has a Background Study UTL of 55.8 µg/L and an ARAR of 50 µg/L. It is not soluble in groundwater in the pH range (typically 7.0 - 8.5) of the Topock site (Brookins, 1988), so detections of aluminum in this environment would be expected to be the result of colloid-sized clay particles. In the Background Study, no well had detections of aluminum in more than 50% of the samples. Wells in the RFI/RI data showed the same maximum detection frequency. This is typical of colloid influence in samples, since the amount and size range of colloidal material varies with each sample. There were 12 wells with average aluminum above ARAR, and of these, ten were due to high reporting limits (i.e. average based on very high half-reporting limit caused exceedance of the ARAR). The two remaining wells, OW-5M and TW-2S, each had one anomalously high detection with all other samples below reporting limit. The locations of the wells where aluminum was detected and the inconsistent nature of the detections indicates that aluminum was not associated with SWMU 1/AOC 1 or SWMU 2.

Manganese. Manganese has an ARAR of 50 µg/L (a secondary drinking water standard). The UTL calculated from Background Study data is 1,320 µg/L. The manganese UTL was not calculated for the Background Study report, as that report was focused on trace metals, but is presented here because many site wells have average concentrations above the ARAR. As discussed in Section 5.3.1.6, dissolved manganese has increased solubility in groundwater under reducing conditions, and with other redox indicators provides for delineation of the zone of reduced groundwater in the floodplain. Although manganese may be found in non-reducing wells at the pH range (typically 7.0 - 8.5) of the Topock site, it has limited solubility in this environment (Brookins, 1988). As a result, the number of reducing zone fluvial wells with elevated manganese far outnumber the non-reducing alluvial wells. Ten wells have average manganese concentrations that are greater than the UTL: MW-22, MW-23, MW-32-35, MW-43-90, MW-49-135, MW-53D, PT-1M, PT-3M, PT-5S, and PT-6S. All of these wells are located in the floodplain area with the exception of bedrock well MW-23 (refer to Figure 5-22). Based on the locations of these wells, the distribution of elevated manganese concentrations is consistent with distribution of reducing conditions in groundwater and does not appear to be associated with SWMU 1/AOC 1 or SWMU 2. Elevated manganese would not have been soluble in the highly oxygenated water in the cooling towers.

6.2.1.6 Other Inorganic Constituents

Fluoride. Fluoride has a chemical-specific ARAR of 2 mg/L. The UTL calculated from Background Study data is 7.12 mg/L. The fluoride UTL was not calculated for the Background Study report, as that report was focused on trace metals, but is presented here because many site wells have average concentrations above the ARAR. The distribution of average fluoride values for site monitoring wells is provided in Figure 6-11.

The concentration of fluoride in well MW-10 (located near the site of the historical wastewater discharge) has been consistently above the UTL, in the range between 10 and 24.6 mg/L. However, the distribution of fluoride downgradient of this well is not consistent with what would be expected from historical large volume discharge. Concentrations of fluoride in all other plume wells are below the UTL. Well MW-33-40, just beyond the distal downgradient edge of the plume, has been above the UTL in all three of its samples. The lack of several wells with elevated fluoride concentrations between the potential source area and the MW-33-40 well strongly suggest that the presence of fluoride above the UTL is not related to transport from the historic large volume discharges at SWMU 1/AOC 1. The only other site well with fluoride above the UTL is MW-6, one of the New Ponds wells.

Because fluoride is geochemically conservative, its distribution would be expected to parallel that of Cr(VI) if its main source was the discharge to Bat Cave Wash. Although the highest concentrations are found at MW-10, the non-continuous nature of the fluoride distribution suggests either a natural variation in concentration or a small isolated release.

The elevated concentrations at the New Ponds and MW-33-40 support natural variation at the MW-10 area.

Fluoride concentrations over time in MW-10 are compared with those of chromium in Appendix F3. It is not clear whether fluoride concentrations correlate with chromium; there is a lack of fluoride data during the time when Cr(VI) was fluctuating the most.

6.2.1.7 Organic Compounds

Table 6-9 lists the results of groundwater analyses for organic constituents that were conducted in 2004, 2005, and 2007 to supplement the groundwater characterization. In June 2004, at the request of DTSC, nine selected groundwater wells (MW-10, MW-11, MW-12, MW-25, MW-34-55, MW-34-80, MW-37D, and TW-2S/2D) were sampled and were analyzed for VOCs, SVOCs, and PCBs. In 2005, at DTSC request, 10 observation/CMP monitoring wells in the IM-3 injection area were sampled for VOCs and SVOCs. In May 2007, seven selected wells (MW-10, MW-11, MW-12, MW-20 three-well cluster, and MW-25) were sampled and analyzed for VOCs and SVOCs. Except for trace concentrations of chloroform (a common laboratory contaminant) in five samples, VOCs were not detected in any of the groundwater samples collected in 2004, 2005, and 2007. SVOCs were not detected in any of the groundwater samples collected at the wells sampled (Table 6-9). PCBs were not detected in any of the groundwater samples collected at the six wells sampled for PCBs in 2004.

6.2.1.8 Perchlorate

In June 2003, at the request of DTSC, PG&E sampled eight monitoring wells for perchlorate. The well locations sampled are listed in Table 6-10. Perchlorate was never used or stored at the PG&E site; however, perchlorate from sources near Las Vegas has been detected in water samples from the Colorado River and Lake Havasu. DTSC was interested in determining whether perchlorate from these upstream sources had impacted groundwater at the Topock site.

In June and July 2004, at DTSC request, seven selected wells, including the new IM groundwater extraction wells TW-2D and TW-2S, were sampled for perchlorate. In both the 2003 and 2004 sampling, perchlorate was not detected in any of the groundwater samples collected at the selected wells (Table 6-10).

In May and July 2005, perchlorate samples were additionally collected at selected wells at the site as part water quality characterization for PG&E's groundwater background study (CH2M HILL, 2005y). In addition to the 10 selected monitoring wells (listed on Table 6-5), active water supply wells Park Moabi-3 and the Sanders private well and the inactive supply wells PGE-9S/9N were sampled for perchlorate. Perchlorate was not detected in the groundwater samples from the four supply wells and the eight monitoring wells (Table 6-5). Perchlorate was reported in groundwater samples at two of the monitoring wells at the New Ponds site (MW-3 and MW-5) at concentrations ranging from 2.43 to 3.77 μg/L (below the MCL of 6 μg/L). Based on site history and the distance of these wells from the Colorado River (see Figure 4-5 for well locations), the 2005 perchlorate detections are considered anomalous and potentially false-positive analytical results. In reviewing the results from the background study and the earlier 2003 to 2004 sampling, DTSC did not request verification or additional characterization sampling for perchlorate.

6.2.1.9 Radionuclides

In July 2004, in response to a request from MWD, groundwater samples from three selected wells (MW-13, MW-18, and TW-2D) and the IM treatment effluent were analyzed for radionuclides (gross alpha, gross beta, and total uranium). The analyses of the one-time radionuclide sampling show results within background ranges, and no additional sampling was conducted. The July 2004 radionuclide results are included in the RFI/RI chemical data listing (Appendix H2).

6.2.2 Evaluation of Groundwater Characterization Findings

6.2.2.1 Hexavalent and Total Chromium

The groundwater RFI/RI has characterized the nature, concentration, and distribution of chromium in groundwater at the site. In the Alluvial Aquifer at and downgradient of SWMU 1, Cr(VI) and Cr(T) occur at concentrations that exceed the calculated background values for the Topock site, and Cr(T) exceeds the California and federal MCLs. Based on the completed characterization, Cr(VI) and Cr(T) are considered the primary COPCs proceeding forward in the RCRA/CERCLA process. More detailed presentation and evaluation of the chromium characterization data is provided in Section 6.3.

6.2.2.2 Specific Conductance and pH

The majority of the wells sampled in the groundwater background study were selected to be water supply wells and, as such, were deliberately screened in low-specific-conductance intervals. Wells PGE-9S, located across the river from the compressor station, and P-2, a deep well adjacent to the New Evaporation Ponds, were the only two wells with elevated specific conductance (averaging 15,400 and 5,400 µS/cm, respectively). There are numerous non-plume wells at the Topock site with average specific conductance values above 15,000 µS/cm, and these values are believed to represent natural groundwater conditions. Many of these wells display specific conductance values that are well above those of most plume wells and do not show chemical similarity to plume water (examples include the MW-49 cluster and CW-4D). Elevated specific conductance is interpreted to be a natural property of the deep alluvial and bedrock groundwater and is also found in some shallow fluvial zones. Wells screened close to the alluvial-bedrock interface tend to have the highest specific conductance, as these are the oldest portions of the aquifer. The southern plume wells, due to their location in a relatively thin part of the aquifer, tend to be screened closer to the bedrock surface more commonly than non-plume wells, and the generally higher values of specific conductance in these wells reflect this bias. Although limited records exist of specific conductance and TDS of the historical discharge at SWMU 1, indications are that discharge of water with specific conductance elevated above that of local groundwater was limited to the earlier years of facility operation. It is therefore recommended that specific conductance not be considered as a COPC in groundwater related to SWMU 1/AOC 1.

Like specific conductance, natural variation of pH in groundwater is not well-represented by the background study data because of the bias towards high-quality water zones. The vast majority of samples from plume and non-plume wells, have pH values within the Secondary MCL range of 6.5 to 8.5 (Table 6-2). The few average pH values outside of this range are from two non-plume monitoring locations (MW-53M and MW-53D). Average pH values for these wells are between 8.5 and 9.0, and are likely influenced by grout emplaced near the screen during well construction. The few slightly elevated pH values do not appear to be associated with the groundwater plume or any site activity; therefore, pH should not be considered as a COPC in groundwater related to SWMU 1/AOC 1.

At the request of DTSC, an analysis of specific conductance and Cr(VI) over time in site alluvial wells will be conducted and later appended as part of the RFI/RI Volume 2 Addendum.

6.2.2.3 Copper, Nickel, Zinc, and Lead

For the RFI/RI sampling, copper, nickel, and zinc have been detected at concentrations slightly above background levels in about half of the wells sampled; however, the distribution does not suggest an identifiable source. Dissolved lead has been detected infrequently (13 percent during sampling period) at generally low concentrations.

Elevated concentrations of copper, lead, and nickel were not found consistently in wells where average concentrations exceeded background. As discussed in Section 6.2.1.3, colloidal material is a likely influence on concentrations of these three metals, given the highly variable concentrations and frequent non-detects. Inclusion of colloids in samples tends to skew the concentrations above what is truly dissolved in groundwater. This is unavoidable in practice, yet the effect on the data should be taken into account.

The pattern of concentrations of all four metals does not match that of the chromium plume, nor do they suggest other clearly definable facility sources. The distribution is discontinuous in space, suggesting a combination of natural variation and of sampling artifacts from colloid influences, as discussed above.

Copper and lead are not typically found in the mid-pH environment of the Alluvial Aquifer. Unless complexing agents (such as organic acids or surfactants) are present, dissolved concentrations are normally well below ARARs in this environment. There is no evidence of natural or synthetic complexing agents in groundwater at the site, so the few samples with concentrations of these metals above ARARs (Table 6-6) are considered to be most likely from colloidal material. By contrast, zinc and nickel may be expected to be dissolved over part of the pH range of site groundwater. Zinc concentrations are all below ARARs, and only 10 out of over 1,000 samples exceeded the nickel ARARs (Table 6-6). The nickel exceedances were not found consistently at any of the wells, suggesting incidental colloidal presence rather than truly elevated dissolved concentrations.

On the basis of these observations, none of the four metals are recommended as COPCs in groundwater related to SWMU 1/AOC 1.

6.2.2.4 TPH and other Organic Compounds

TPH was not detected in groundwater samples at the site, and is therefore not recommended for consideration as a COPC in groundwater related to SWMU 1/AOC 1. The RFI/RI sampling results for VOCs, SVOCs, and PCBs indicate no impacts to groundwater by organic compounds.

6.2.2.5 Other Trace Metals

As presented in Section 6.1.2.5, aluminum, arsenic, beryllium, molybdenum, selenium, and vanadium are present in groundwater above the site background UTL concentrations and arsenic is found in several locations at concentrations exceeding ARARs. In addition, antimony has been found above the chemical-specific ARARs in a few samples. The conclusions regarding the occurrence and distribution of these trace metals in groundwater are presented below.

Arsenic. The background UTL for arsenic in the area is 24.3 µg/L, which exceeds the Primary MCL of 10 µg/L. As such, site groundwater arsenic concentrations exceeding ARARs are to be expected and do occur in various wells. There is little evidence that correlates these wells with SWMU 1/AOC 1. Only one site well, MW-12, exceeds the UTL. There is no current indication that the facility used arsenic in the MW-12 area. However, arsenic was commonly used as a weed killer around railroad tracks and highways up until the 1970s, and the original railroad line and later Route 66 followed the path of present-day Park Moabi Road. Well MW-12 is located in a depression adjacent to Park Moabi Road, and it is reasonable that the arsenic that may have been applied to the railroad track area (and later Route 66) was leached to groundwater in this depression, which forms a pond following storm events. There are no known records to verify this, however.

Average concentrations of arsenic in other site monitoring wells are below 10 µg/L, with the exception of some of the New Ponds wells and *in-situ* pilot study wells affected by temporarily altered geochemical conditions. Fluctuation of arsenic concentration over time in well MW-10 generally parallels that of Cr(VI), but the latest arsenic data has dropped to below detection limits and thus the UTL and ARAR.

Whatever the source of arsenic above the UTL in groundwater, it is not believed to be associated with facility operations or the chromium plume. It is therefore not recommended for consideration as a COPC in groundwater related to SWMU 1/AOC 1.

Molybdenum. Molybdenum is elevated above UTL in 20 site wells. There is no ARAR associated with molybdenum. As shown on Figure 6-7, there are elevated concentrations in the Bat Cave Wash area where the original chromium discharge occurred, and there are more wells with molybdenum above background within the plume (13) than outside the plume (7). Because of this apparent grouping, PG&E further evaluated whether the molybdenum distribution in groundwater may be related to site activity.

The use of molybdenum at the facility, its detection in more recent wastewater samples, and its presence above the UTL in a number of site wells suggest that it may merit further assessment. While the elevated molybdenum distribution within the plume area is inconsistent, with very low levels in wells down the wash from SWMU 1, there are enough plume wells with elevated molybdenum to suggest that the potential for facility contribution to groundwater cannot be ruled out at this time. Molybdenum is therefore recommended to remain a COPC in groundwater related to SWMU 1/AOC 1.

Selenium. Selenium is found at concentrations slightly exceeding UTL at six wells around the site, half within the plume and half outside the plume. The pattern of concentrations is scattered and does not suggest a clear source. The frequency of selenium UTL exceedances in site wells is 8.8% (Table 6-8), only slightly greater than the expected 5%. Well TW-1 is the only well that is clearly above the UTL, although only one sample has been analyzed from this well for the RFI/RI data set. There is no documented use of selenium at the facility nor any detections of selenium in wastewater.

Based on the lack of clear source and only one sample out of 400 that has exceeded ARARs, PG&E concluded that selenium should not be considered a COPC in groundwater related to SWMU 1/AOC 1. However, DTSC has directed that selenium should be considered a COPC based on additional selenium data for well TW-1 that will be presented in the Addendum to RFI/RI Volume 2.

Vanadium. Average vanadium concentrations are below the UTL of 59.9 µg/L in all monitoring wells except well MW-22 in the southern floodplain. The elevated average in this well was driven by one anomalous sample result. In addition, 26 other wells have had one or two samples above UTL in the past. Most of these samples have occurred in a small number of sampling events, suggesting laboratory error and/or sample matrix issues during analysis (see CH2M HILL, 2005x, for an example). Due to laboratory issues, the inconsistent nature of elevated vanadium occurrence, and the distribution of wells with elevated samples, the distribution of elevated vanadium is concluded to be due to natural variation and in some cases from analytical issues. Vanadium is therefore not considered a COPC in groundwater related to SWMU 1/AOC 1.

Antimony. The UTL and ARAR for antimony were exceeded in only three wells (MW-20-100, TW-2S, and TW-2D), and these exceedances were driven by a single sample from each well. Five other wells had one or two samples above the chemical-specific ARAR, but the remainder of samples from these wells were below reporting limit. On the basis of the infrequent UTL exceedances, and the lack of a clear source, antimony is not considered a COPC in groundwater related to SWMU 1/AOC 1.

Beryllium. The UTL for beryllium was exceeded in 12 wells, all located outside the plume area. All but one of the detections occurred during two sampling events in 2006. Only one well average exceeds the ARAR for beryllium, but solely due to one non-detect sample with a high reporting limit. On the basis of the infrequent UTL exceedances, and the locations far from the plume area, beryllium is not considered a COPC in groundwater related to SWMU 1/AOC 1.

Aluminum. There were 12 wells with average aluminum above the ARAR of 50 µg/L, and of these, ten were due to high reporting limits (i.e. averaging non-detect samples at half-reporting limit values caused exceedance of the ARAR). The two remaining wells, OW-5M and TW-2S, each had one anomalously high detection with all other samples below reporting limit. The locations of the wells where aluminum was detected and the inconsistent nature of the detections indicates that aluminum was not associated with SWMU 1 or SWMU 2. Therefore, aluminum is not considered a COPC in groundwater related to SWMU 1/AOC 1.

Manganese. Ten wells have average manganese concentrations that are greater than the UTL of 1,320 µg/L: MW-22, MW-23, MW-32-35, MW-43-90, MW-49-135, MW-53D, PT-1M, PT-3M, PT-5S, and PT-6S. All of these wells are located in the floodplain area with the exception of bedrock well MW-23 (refer to Figure 5-22). Based on the locations of these wells, the distribution of elevated manganese concentrations is consistent with distribution of reducing conditions in groundwater and does not appear to be associated with SWMU 1 or SWMU 2. Therefore, manganese is not considered a COPC in groundwater related to SWMU 1/AOC 1.

6.2.2.6 Other Inorganic Constituents

Fluoride. Due to the lack of continuous distribution of fluoride across the site, there does not appear to be a large plume associated with fluoride originating in SWMU 1. Even though well MW-10 has elevated concentrations, the geochemically conservative nature of fluoride would be expected to extend to a similar area as that of Cr(VI), but this is not the case. The occasional fluoride concentrations elevated above UTL (MW-10, MW-33-40, MW-6) appear to be reflective of natural variation. Therefore, fluoride is not considered a COPC in groundwater related to SWMU 1/AOC 1.

6.3 Present Distribution of Chromium in Groundwater

This section focuses on the present distribution of chromium in groundwater associated with releases from SWMU 1/AOC 1 and AOC 2. Figure 4-5 shows the location and identifications of the wells sampled for the RFI/RI groundwater investigation and defining the extent of chromium in groundwater. This section presents and discusses the chromium sampling results for the October 2007 comprehensive sitewide groundwater monitoring event. For this sampling event, 118 groundwater wells were sampled for Cr(VI) and Cr(T), as well as for other chemical parameters.

For reference, Table 6-4 lists the Cr(VI) and Cr(T) groundwater results for the RFI/RI wells for the period October 2006 through October 2007. Table 6-4 also indicates the monitoring zone well designations for the RFI/RI wells (criteria described in Section 4.2.2). Appendix H2 includes a complete listing of RFI/RI groundwater chromium analytical data collected July 1997 through October 2007.

6.3.1 Lateral Chromium Distribution in Alluvial Aquifer

For the RFI/RI characterization, the results and distribution of chromium from a comprehensive sitewide GMP monitoring event conducted in October 2007 are used. As described in Section 4.2.1, the RFI/RI groundwater data are presented in separate displays based on relative depth and position within the Alluvial Aquifer and bedrock lithology. The sampling results and the distribution of chromium in groundwater for October 2007 are shown on three separate figures:

- Shallow zone wells of the Alluvial Aquifer (Figure 6-12a)
- Mid-depth zone wells of the Alluvial Aquifer (Figure 6-12b)
- Deep zone wells of the Alluvial Aquifer (Figure 6-12c)

Figure 6-12a presents October 2007 Cr(VI) results from the shallow wells. There are 40 groundwater wells in the RFI/RI well network that provide samples from the shallow zone of the Alluvial Aquifer. The range of Cr(VI) results from July 2007 for three discrete shallow monitoring wells in the upland ISPT area (baseline sampling) are also shown on the shallow results map and the sampling results for individual wells are presented in

Table 6-4. The maximum Cr(VI) concentration detected in the shallow zone wells during October 2007 sampling was 3,510 µg/L at well MW-26.

Figure 6-12b presents October 2007 Cr(VI) results from the mid-depth wells. There are 25 groundwater wells in the RFI/RI well network that provide samples from the mid-depth zone of the Alluvial Aquifer. The range of Cr(VI) results from July 2007 for three discrete mid-depth monitoring wells in the upland ISPT area (baseline sampling) are also shown on the mid-depth results map and the sampling results for individual wells are presented in Table 6-4. The maximum Cr(VI) concentration detected in the mid-depth wells during October 2007 sampling was 9,000 µg/L at well MW-20-100.

Figure 6-12c presents October 2007 Cr(VI) results from the deep wells. There are 53 groundwater wells in the RFI/RI well network that provide samples from the deep zone of the Alluvial Aquifer. The range of Cr(VI) results from July 2007 for three discrete deep monitoring wells in the upland ISPT area (baseline sampling) are also shown on the Figure 6-12c and the sampling results for individual wells are presented in Table 6-4. The maximum Cr(VI) concentration detected in the deep wells during October 2007 sampling was 12,000 µg/L at well MW-20-130. In the July 2007 ISPT sampling, the maximum Cr(VI) concentration detected in the deep zone monitoring wells was 15,700 µg/L (well PT-9D, see Figure 4-3 and Table 6-4).

Figures 6-12a, 6-12b, and 6-12c also show the inferred Cr(VI) isoconcentration contours (including the chromium plume delineation value of 32 µg/L) in each of the three Alluvial Aquifer monitoring zones. The positions of the Cr(VI) isoconcentration contours on these figures are based on the maximum concentrations measured during October 2007 within each monitoring interval. The lateral and vertical delineation and characteristics of the groundwater Cr(VI) plume are discussed further below.

6.3.2 Vertical Chromium Distribution in Alluvial Aquifer

The chromium results from October 2007 sampling are presented on selected hydrogeologic cross-sections of the Alluvial Aquifer. The locations of the four site cross sections selected for results presentation are shown Figure 5-1. The RFI/RI sampling results that illustrate the vertical chromium distribution in groundwater are summarized below.

Results Cross-Section A-A′ (Figure 6-13) presents the Cr(VI) results for wells and well clusters along a cross section extending from upper Bat Cave Wash to the floodplain and shoreline of the Colorado River. This cross section illustrates the depths and elevations of the shallow, mid-depth, and deep monitoring wells, and summarizes the Cr(VI) results from the October 2007 sampling. The cross-section view shows that Cr(VI) concentrations vary laterally and vertically for the sampling locations and depths within the Alluvial Aquifer. The higher Cr(VI) concentrations in the Alluvial Aquifer occur in the deepest wells at the MW-20, MW-24, and MW-39 monitoring clusters. Figure 6-13 also shows the well screen intervals and sampling results for the MW-24BR and PGE-8 bedrock wells.

Results Cross-Section B-B′ (Figure 6-14) presents the Cr(VI) results for wells and well clusters located within and adjacent to Bat Cave Wash. The Cr(VI) concentrations for this cross-section of the Alluvial Aquifer range from 1,010 µg/L at shallow well MW-10, near the former percolation bed (chromium plume source area) to less than 20 µg/L in the shallow, mid-depth, and deep zone wells at the downstream, northern end of Bat Cave Wash (see Figure 5-1 for cross-section location).

Results Cross-Section D-D′ (Figure 6-15) presents the Cr(VI) results for wells and well clusters on a cross section paralleling Park Moabi Road. This cross section illustrates the depths and October 2007 sampling results for the shallow, mid-depth, and deep monitoring wells in the areas north and south of well TW-3D, the IM primary pumping location on the MW-20 bench (see Figure 5-1 for cross-section location). The higher Cr(VI) concentrations in this cross-section of the Alluvial Aquifer are found in wells MW-20-130 (12,200 µg/L), MW-50-200 (9,430 µg/L), MW-20-100 (9,000 µg/L), and MW-51 (4,500 µg/L). Figure 6-15 also shows the well screen intervals and October 2007 sampling result for the shallow bedrock well MW-23 (south-end of cross-section D-D’).

Results Cross-Section G-G′ (Figure 6-16) presents the Cr(VI) results for the monitoring well clusters along a floodplain cross section, oriented parallel to the Colorado River, extending northward from the MW-52/53 cluster to MW-49 cluster. In October 2007 sampling, the higher Cr(VI) concentrations were measured in the deep wells MW-44-115 (783 µg/L) and MW-34-100 (521 µg/L). Cr(VI) was non-detect in the groundwater samples from all of the shallow monitoring wells and all mid-depth and deep wells north of MW-33 cluster and south of MW-34 cluster, consistent with prior 2006 and 2007 sampling (Table 6-4).

6.3.2.1 Vertical Chromium Distribution at Well Clusters

The RFI/RI well network includes 25 monitoring well clusters which provide data to further assess the vertical distribution of chromium in the Alluvial Aquifer. The well clusters and individual monitoring well are listed in Table 4-2. An additional nine vertical well clusters have been installed for monitoring the ISPT tests (Figure 4-3). Table 6-4 presents the Cr(VI) and Cr(T) results for the July 2007 baseline sampling of the three well clusters installed in the upland ISPT area. The Cr(VI) and Cr(T) results for the 2006 baseline sampling of the six monitoring well clusters installed in the floodplain ISPT are included in the complete RFI/RI groundwater analytical dataset (Appendix H3).

The sampling data for the vertical well clusters at the site show a wide range in concentrations and no uniform trend of Cr(VI) concentration with depth in the Alluvial Aquifer. In some locations, the higher chromium concentrations are found in the shallow portion of the aquifer, and in other locations, the higher concentrations are found in the deeper intervals of the aquifer. In the IM-3 injection well field area, low level chromium concentrations are noted to decrease to below reporting limits with depth. Observations on the October 2007 vertical chromium distribution for selected monitoring well clusters are summarized below:

- An overall increasing chromium concentration trend with depth exists at the MW-20 and MW-24 well clusters (see hydrogeologic cross-section A-A′ Figure 6-13). A similar increasing concentration with depth trend is evident in floodplain well clusters MW-34, MW-36, and MW-39 (Figure 6-13). However, the current vertical distribution of Cr(VI) in the floodplain wells has been strongly influenced by IM pumping since 2004 (CH2M HILL, 2007g-h).
- As shown on cross-section B-B′ along Bat Cave Wash (Figure 6-14), Cr(VI) concentrations are higher in the shallow wells relative to the deeper wells at the MW-38

and MW-41 clusters. At the MW-37/MW-13 cluster (lower Bat Cave Wash area, Figure 6-14), Cr(VI) concentrations are higher in the deep well and concentrations are significantly lower (< 25 µg/L) in the shallower wells MW-37S and MW-13.

- As shown on cross-section D-D′ (Park Moabi Road alignment, Figure 6-15), the Cr(VI) concentrations observed at the MW-47/TW-4 and MW-50/MW-19 well clusters do not show a consistent vertical trend, either increasing or decreasing with depth. At the MW-31 cluster, the higher concentration is observed in the shallower monitoring well, which is in contrast to the increasing with depth trend at nearby well cluster MW-20 (Figure 6-15).

The variability in the vertical distribution and trends for chromium within the Alluvial Aquifer is believed to result from the combined effects of: (1) proximity to the source area, (2) density contrast between groundwater and the untreated cooling tower blowdown water (initial discharges to Bat Cave Wash), (3) heterogeneity and permeability variations (vertical and lateral) of the aquifer media, (4) long-term groundwater gradients within the aquifer (natural and pumping-induced), and (5) site-specific geochemical conditions affecting the stability of Cr(VI). The hydraulic conditions, discharge history, and modeled simulation for the distribution of chromium over time are discussed in Section 6.6 and the Cr(VI) fate and transport mechanisms are discussed in Section 6.7.

As described in Section 1.2.2, since 2004-2005, interim remedial measures have been implemented at the site, which have included groundwater extraction from the Alluvial Aquifer adjacent to the floodplain area and injection of treated groundwater to the Alluvial Aquifer on PG&E property north of the compressor station. Refer to the Figure 4-2 and Figures 5-2 and 5-6 (site cross-sections) for the locations and depths of the IM extraction and injection wells that have been operated during the RFI/RI. In addition to the hydraulic effects on natural groundwater gradients, chromium and other water quality changes have also been observed in groundwater wells at the extraction and injection areas and are described in detail in the IM performance and compliance monitoring reports (CH2M HILL 2007h, 2008k).

6.3.3 Chromium Plume Delineation

The chromium plume at the Topock site can be viewed as that part of the Alluvial Aquifer where Cr(VI) concentrations exceed natural background levels, following the subsurface flowpath along which the original industrial discharge passed. An addition to this definition is that the concentration also exceeds the chemical-specific ARARs established for chromium in groundwater. The groundwater Background Study utilized 25 wells in the southern Mohave Valley to estimate natural background concentrations for trace metals in groundwater (CH2M HILL, 2008b). Each well was sampled six times over the course of a year. Mean values of Cr(VI) concentrations ranged from less than 0.2 to 31.8 µg/L. The statistical UTL of natural background levels for Cr(VI) in groundwater is 31.8 µg/L (CH2M HILL, 2008b). Except as noted below, the existing network of groundwater monitoring wells is sufficient to delineate the lateral and vertical extent of the 32 µg/L Cr(VI) concentration limit in the Alluvial Aquifer. For practical presentation purposes, the Cr(VI) concentration value of 32 µg/L (the Cr[VI] UTL rounded to whole unit) is used for delineating the groundwater chromium plume at the site. Dissolved total chromium (Cr[T]) is not specifically used for plume delineation because essentially all of the dissolved chromium species measured in groundwater at the Topock site by the Cr(T) analysis method is Cr(VI). For the Topock site dataset as a whole, there is no statistically significant difference between Cr(VI) and dissolved Cr(T) concentrations, as illustrated in graphical cross-plots of the RFI/RI chromium groundwater data (Appendix F4).

In each of the aquifer monitoring zones (Figure 6-12a, 6-12b, and 6-12c), the location of Cr(VI) concentrations for groundwater greater than or equal to 32 µg/L follows Bat Cave Wash northward approximately 2,000 feet from the compressor station. For shallow and mid-depth wells, the 32 µg/L concentration limit extends eastward from Bat Cave Wash into the western portion of the floodplain. In the deep zone of the Alluvial Aquifer, the 32 µg/L concentration limit is also located eastward from Bat Cave Wash and extends further eastward into the floodplain, especially in the area between wells MW-27 and MW-28 (Figure 6-12c). Non-reducing conditions are still prevalent in deep fluvial wells within the plume flowpath at this location, and Cr(VI) concentrations are correspondingly elevated.

To support the groundwater characterization, additional data for plume delineation east of the existing RFI/RI monitoring well network was collected subsequent to the Volume 2 data cutoff date of October 2007. A supplemental groundwater investigation conducted in March-April 2008 included installation of additional monitoring wells (including a slant monitoring well) in locations along the east shoreline of the Colorado River in Arizona as described in the *Installation Report for Wells on the Arizona Shore of the Colorado River at Topock Arizona* (CH2M HILL, 2008h). The locations of the drilling sites in Arizona are shown on Figure 6-17. The results of this groundwater investigation and sampling will be reported in the RFI/RI Report Volume 2 Addendum.

6.3.4 Chromium Sampling Results for Bedrock Units

The groundwater wells completed in bedrock formations include MW-23 (Miocene Conglomerate), MW-24BR (pre-Tertiary metamorphic bedrock), MW-48 (Miocene Conglomerate), the former injection well PGE-8 (metamorphic bedrock), and PGE-7BR (pre-Tertiary metamorphic bedrock). Figure 4-5 shows the locations of the bedrock wells.

Table 6-11 presents the Cr(VI) and Cr(T) results for groundwater sampling of bedrock wells during March 2001 through October 2007. Dissolved Cr(T) typically has been non-detectable or detected at trace to low concentrations (typical range 2 to 10 µg/L) in groundwater samples from the bedrock wells. The complete listing of the chromium analyses for MW-23, MW-24BR, and PGE-8 (1997 through 2000) is included in Appendix H3. In the 2001-2007 sampling, Cr(VI) has not been detected in any of the groundwater samples from four out of the five bedrock wells (MW-24BR, MW-48, PGE-8, and PGE-7BR [first sampling December 2007]).

Beginning in March 2004, Cr(VI) has been detected in groundwater samples at MW-23 (shallow monitoring well completed in Miocene Conglomerate bedrock; see Figure 6-12). The Cr(VI) concentrations observed in the March 2004 through October 2006 sampling of MW-23 ranged from 1.1 to 16.8 µg/L (Table 6-11). The Cr(VI) concentration for one sample in a duplicate sample pair at MW-23 in December 2006 was reported to be 1,920 µg/L. The other sample in the pair had a Cr(VI) concentration of 14.4 µg/L. In conformance with data quality procedures in the Topock Quality Assurance Project Plan, the sample result was flagged as "R" due to the large difference between the duplicate samples. The March 2007 sample showed a similar anomalously-elevated Cr(VI) concentration (1,020 µg/L).

In June and July 2007, at DTSC request, a special sampling activity was conducted at well MW-23 to try to replicate the anomalous Cr(VI) results and to better assess how the sampling results may be affected by different purging rates at this low-recharging bedrock well. The results and sampling activities are described in the Second Quarter 2007 GMP monitoring report (CH2M HILL, 2007i). The anomalous Cr(VI) concentrations and pumping conditions observed in December 2006 and March 2007 were not reproducible in the sampling test. Subsequent MW-23 samples in May and October 2007 were at concentrations of 13 and 19.2 µg/L, consistent with the 2005 to 2006 results (Table 6-11).

In October 2007, a bedrock monitoring well, designated PGE-7BR, was constructed within the open-hole interval in well PGE-7, as part of the recent bedrock hydraulic testing activity (CH2M HILL, 2008b). The new monitoring well PGE-7BR is completed in the pre-Tertiary crystalline bedrock and exhibits very slow recharge. The initial sampling of PGE-7BR was conducted in December 2007, and Cr(VI) and Cr(T) were not detected (Table 6-11).

With the exception of MW-23, Cr(VI) has consistently not been detected in the groundwater samples from bedrock wells at the site. It should be noted that MW-23 is a shallow bedrock well located within 500 feet of the Alluvial Aquifer where Cr(VI) concentrations are in excess of 2,500 µg/L (MW-12, Figure 6-12a and MW-26, Figure 6-15). The presence of Cr(VI) and the positive or only slightly negative ORP in MW-23 suggest that the bedrock at this location is impacted and possibly in hydraulic communication with the nearby alluvial aquifer, likely through localized fractures.

Shallow bedrock well MW-23 is located immediately north of East Ravine (Figures 5-1 and 6-17). Based on the available hydrogeologic mapping information (discussed in Section 5.1), bedrock occurs at very shallow depth and above the site water table in the East Ravine area. To confirm and characterize hydrogeologic conditions in the East Ravine area, a focused groundwater investigation will be conducted in this area (CH2M HILL, 2008f). Figure 6-17 shows the proposed primary investigation drilling sites for characterizing groundwater conditions in the bedrock and at the alluvium/bedrock contact in East Ravine. The conceptual site model and groundwater conditions in the East Ravine area are discussed in Section 6.7.2.

6.4 Chromium Concentrations Over Time

A comprehensive sampling data set is available for several RFI/RI monitoring well locations to assess long-term concentration trends in the groundwater chromium plume. Figure 6-18 presents a graph of Cr(VI) concentrations in well cluster MW-20 from groundwater monitoring 1998 through October 2007. This three-well monitoring cluster, located on the MW-20 bench near the floodplain (Figure 4-5), is within 150 feet of the IM groundwater extraction wells TW-2S/2D and TW-3D. The well screens and recent Cr(VI) sampling results for the MW-20 cluster and TW-2S, TW-3D are shown in cross-section view on Figure 6-15.

In the sampling data that predate the March 2004 startup of IM groundwater extraction, Cr(VI) concentrations were generally stable in the deep zone well (MW-20-130), whereas a seasonally-fluctuating trend is observed in the shallow zone well (MW-20-70). From March 8 to May 13, 2004, the MW-20 cluster wells were pumped for the initial IM groundwater extraction as part of the IM No. 2 activity. Groundwater extraction on the MW-20 bench has been continuous since May 2004, using primarily well TW-2D (through January 2006) and well TW-3D (December 2005 to present). During full-time groundwater extraction, the Cr(VI) concentrations in the MW-20 wells show pronounced increasing concentrations in the mid-depth and deep wells and declining concentrations in the shallow water-table monitoring well MW-20-70. These trends reflect the pumping influence of the IM extraction system.

Figure 6-19 presents a graph of Cr(VI) concentrations (October 1997 to October 2007) in wells MW-10, MW-24A, and MW-24B, which are located near the compressor station and upper Bat Cave Wash (Figure 4-5). The well screens and recent Cr(VI) sampling results for the MW-24 cluster and MW-10 are shown in cross-section view on Figure 6-13. At shallow well MW-10, located near the SWMU 1 discharge area, Cr(VI) concentrations have been generally stable (averaging approximately 1,900 µg/L) but have shown higher concentrations in certain sampling events. Cr(VI) concentrations have remained stable overall in shallow zone well MW-24A over the 10-year period. The sampling data from the deep-zone well MW-24B shows a slowly increasing concentration trend since 1998 (Figure 6-19). The increasing trend may reflect natural groundwater flow in this area and interval of the Alluvial Aquifer.

Figure 6-20 presents graphs of Cr(VI) concentration results (2004 through October 2007), for eight selected groundwater monitoring wells in the floodplain area. Refer to the October 2007 chromium distribution maps (Figures 6-12b and 6-12c) for the locations of the eight monitoring wells. The concentration graphs for monitoring locations near the pumping wells (MW-39, MW-30, and MW-36) show pronounced decline trends reflecting the pumping influence of the IM extraction system. The sampling data since July 2006 (CH2M HILL, 2007i) show gradual declining concentration trends for MW-34-100 and MW-44-115 (deep-zone wells in the eastern edge of the floodplain, Figure 6-12c).

Chemical concentration graphs for RFI/RI monitoring wells with consistent detections of Cr(VI) are included in Appendix I.

6.5 Plume Geochemistry

The chromium plume is defined in the simplest sense as the part of the Alluvial Aquifer where Cr(VI) concentrations exceed natural background levels and where the subsurface flowpath of the original industrial discharge passes, according to the site conceptual model. The statistical UTL of background Cr(VI) in groundwater is 31.8 µg/L (CH2M HILL, 2008b). The concentration value of 32 µg/L (the Cr[VI] UTL rounded to whole unit) is used for delineating the groundwater chromium plume at the site. As discussed in the cover letter for the Background Study report (CH2M HILL, 2008b), the data collected for this study may be interpreted to represent two or more populations based on geochemical or geological distinctions. For example, the river-influenced fluvial material produces a naturally more reducing environment compared to the non-reducing material, which may be alluvial or fluvial. This is described in Section 5.3.1.6. Due to this and other geochemical distinctions, the calculated UTLs may not be appropriate for all constituents in all portions of the site or at all depths. The issue will be taken into consideration in the risk assessment and CMS/FS.

This section will describe the geochemical characteristics of the plume and will discuss the geochemical factors that influence Cr(VI) mobility and fate. A discussion of the groundwater flowpath originating from the original discharge is provided in Section 6.6.

6.5.1 General Chemistry

Hexavalent chromium is stable only in a chemically non-reducing environment, as defined in Section 5.3.1.6. This may be characterized by observing key redox-sensitive parameters in groundwater samples: ORP, nitrate, ammonia, manganese, and iron are the most useful at the Topock site. As discussed in Section 5.3.1.6, a non-reducing groundwater is one with ORP generally above -90 mV (i.e. less negative or positive values of ORP). The majority of plume samples have average ORP between 0 and +100 mV. As it is measured in the field with an electrode that can be sensitive to many geochemical and operational variables, ORP is considered a general index of redox conditions. Nitrate is the oxidized form of nitrogen in water and is therefore expected to be present where Cr(VI) is stable. Groundwater data verify that nitrate is present in nearly all plume groundwater samples.

Given these general indicators of non-reducing conditions, there are believed to be small quantities of reducing material present in all alluvial aquifers of this type, as natural materials would be expected to have small pockets of fine material where localized reducing conditions may exist. Materials that can directly reduce Cr(VI) to insoluble Cr(III) include solid and dissolved forms of ferrous iron and organic carbon (Richard and Bourg, 1991). Reduction of Cr(VI) by microorganisms has been demonstrated in both reducing and non-reducing environments (Cooke et al., 1995; Gopalan and Veeramani, 1994; Turick et al., 1996). As a result, a portion of natural Cr(VI) present in an alluvial aquifer becomes reduced, as will be discussed in Section 6.5.2. In a high-concentration Cr(VI) area such as the plume, however, the natural reducing material could have been used up by the overabundance of anthropogenic Cr(VI). Previous core testing results showed that the total organic carbon measurements in aerobic core samples in the plume flowpath have been consistently below reporting limits (CH2M HILL, 2005d and 2008a), and ferrous iron has been near or below reporting limit (CH2M HILL, 2008a).

The other redox indicators—ammonia, manganese, and iron—are found in more reduced waters in which Cr(VI) would not be expected. Correspondingly, these three constituents are found in many of the fluvial wells in the floodplain area, where organic carbon is more abundant (see discussion in Section 5.3.1.6 and Figures 5-22 and 5-23). The reducing conditions indicated by samples from shallow and medium-depth fluvial wells act to rapidly reduce Cr(VI) to Cr(III), which is highly insoluble in water (Eary and Rai, 1988; Hering and Harmon, 2004). As a result, groundwater samples from these wells do not contain detectable chromium. Similar reducing conditions were observed in 63 of 64 river pore water samples collected a few feet below the river bottom (CH2M HILL, 2006j). The extent of reducing material is not precisely known, but these data suggest that reducing conditions are prevalent not only in the floodplain area but also beneath the river as well, consistent with the river-based depositional environment.

Non-reducing conditions are present in several mid-level and deep fluvial wells (MW-33-90, MW-34-100, MW-36-090, MW-36-100, and MW-45-95a e.g., MW-36-100, MW-34-100, as shown on Figures 5-22 and 5-23). Prior to IM-3 extraction, which acted to spread more reducing shallow groundwater deeper and to the west, several other fluvial wells showed non-reducing conditions (MW-30-50, MW-34-80, MW-39-50, and MW-39-60). Because these wells are within the plume flowpath, Cr(VI) concentrations are correspondingly elevated. The reason for these non-reducing conditions is believed to be a combination of original depositional environment and age of the deep fluvial deposits. In the early stage of the Colorado River when these sediments were deposited, the young river was actively eroding and flowing at high energy. This early stage of river development is not as conducive to biological habitat development as in later stages, resulting in fluvial deposits that are relatively low in organic carbon. In addition, because these deposits are old compared to the more recent shallow deposits, there has been more time for the original organic carbon to be used up by reaction with naturally-aerobic alluvial groundwater over recent geologic time. The overall result is a carbon-poor, non-reducing environment similar to that observed in the alluvial material. This geochemical condition is not present in all deep fluvial wells. The southern end of the floodplain has more dense vegetation, and may have supported this environment as long as the river has been in this eastward-bending orientation. Fluvial well clusters in this area (MW-43, MW-52, MW-53) display reducing conditions in all depth intervals. In addition, well MW-28-90, a deep fluvial well in the northern floodplain, also shows consistently reducing conditions. Data from these wells demonstrate that there is natural variation in the distribution of reducing material in deep fluvial deposits.

TDS concentrations in plume well samples are highly variable. The same tendency toward higher TDS at depth observed in non-plume wells (Section 5.3.1.4) is observed in plume wells. Although historical records of the composition of cooling tower blowdown water are sparse, it appears that cooling water was kept in circulation much longer in the early 1950s than in later decades. This would result in a larger degree of evaporation before the water was discharged, resulting in higher TDS. General chemistry analyses of two “tower recirculating water” samples from 1952 were used to calculate TDS, resulting in values of 22,000 and 29,000 mg/L made up of naturally present, but concentrated salts. The circulation cycles were reduced over the course of operations and, in 1969, the blowdown water TDS was 8,900 mg/L. By 1986, blowdown TDS had been further reduced to 6,610 mg/L. At first review, it was observed that the TDS of alluvial plume wells tends to be greater than that of non-plume alluvial wells. However, upon more detailed analysis, it is apparent the explanation for the apparent higher TDS in plume well data set relates to the proximity of their screened intervals to the bedrock surface. As shown in Figure 5-20, most plume wells are screened close to the bedrock surface. Wells screened closer to the bedrock surface tend to have higher TDS, regardless of whether the well is associated with the plume or not. The alluvial material at the base of the aquifer represents the oldest in the depositional sequence, which would be expected to have been segregated from the hydrologic cycle the longest and has accumulated the most dissolved solids. Many of the plume wells were constructed with screens closer to bedrock and may therefore biased toward higher TDS compared to non-plume wells. A two-tailed student t-test was run between plume wells and non-plume wells, and the range of screen heights above bedrock for non-plume wells was significantly different (i.e. higher) than that of plume wells at the 95% confidence level. Once this bias was removed from the data set, there is no statistically significant difference between the average TDS of plume wells and non-plume wells (95% level).

In fluvial wells, the TDS distinction is not apparent, as plume and non-plume groundwater have similar TDS.

Other groundwater data, including major ions and trace metals, were examined in an effort to further distinguish plume groundwater from non-plume groundwater. The results were inconsistent compared to the constituents discussed above. Where there may be a few isolated elevated concentrations of a given constituent in plume water, there are many more plume samples with low or non-detect concentrations of the same constituent. Stable isotopes proved more useful in this regard and are discussed below.

The variability in Cr(VI) concentration within the plume does not follow a consistent pattern. In some areas, the highest Cr(VI) concentrations were found in the shallow zone (e.g., MW-20 and MW-31 clusters [pre-IM-3 extraction data] and the MW-38 cluster). In other areas, the opposite is true (e.g., MW-37, MW-40). There is no apparent geochemical mechanism for this variation. As stated above, reducing material in the alluvium is not present in significant enough quantity to reduce Cr(VI) by hundreds of μg/L. One of the more likely explanations is the natural variation in hydraulic properties of the Alluvial Aquifer. These geologic materials would be expected to vary in hydraulic conductivity over several orders of magnitude, thereby creating a mixture of non-continuous preferred pathways separated by relatively low-conductivity zones. This would act to disperse the Cr(VI), creating variable concentrations in randomly-placed monitoring wells. In addition, the Cr(VI) concentration of the original discharge to Bat Cave Wash was variable throughout its history. Although limited data are available to document these variations, it is generally known that Cr(VI) concentrations in blowdown water were initially higher due to both high usage concentrations and longer residence time in the towers, thereby producing greater evaporative concentration of Cr(VI). Due to the way the cooling towers were operated at the time, the density of the blowdown water in the early years of compressor station operations was likely significantly greater than natural groundwater. During this time the discharge would have tended to sink downward as it migrated through the aquifer. In addition, extraction from the original facility supply wells PGE-1 and PGE-2, located about 800 feet downgradient, would be expected to spread the Cr(VI) concentration both laterally and vertically by pumping over a large perforated interval. With time, both Cr(VI) concentration and circulation time were reduced. This, coupled with changing discharge and extraction conditions over time (see Section 6.6), would also be expected to contribute to a variable distribution of Cr(VI) in the Alluvial Aquifer.

6.5.2 Stable Isotopes

As discussed in Section 5.0, the stable isotope parameters $\delta^{18}O$ and $\delta^{2}H$ are used to help determine the source of a groundwater sample. At least three sources are evident on the basis of stable isotope data: (1) Colorado River water or river-influenced groundwater, (2) local recharge, or “non-industrial water” and (3) discharge from the Topock facility, or “industrial water.” The estimated range of each source is shown on Figure 5-24a. Groundwater influenced by the oldest plume water from the 1950s, where significant evaporation was allowed before discharging, contains the heaviest isotopic signature. These samples tend to follow a line with a smaller slope than the Global Meteoric Water Line

(Figure 5-24a), also typical of partially-evaporated water. Identifying industrial-source water is complicated by two factors: (1) variation in discharge water quality and (2) mixing with other sources. Facility blowdown water was only highly evaporated in the 1950s; analyses of blowdown water from the 1960s and 1980s show TDS values similar to medium- and deeper-alluvial groundwater. As a result, the isotopic signature of the later blowdown water would be expected to be similar to non-industrial local groundwater. As can be seen on Figure 5-24a, there is significant overlap between the non-industrial and industrial water groups; therefore, mixing at the alluvial edges of the plume on the west and north tend to cloud the distinction of plume water. Also, the mixing that occurs in the floodplain area between alluvial and river-influenced fluvial groundwater tends to produce isotopic signatures falling between the river and industrial water groups, and these mixtures directly overlap with the non-industrial group (note the plume symbols in the middle group on Figure 5-24a). Further distinguishing industrial and non-industrial samples by depth does not make separation more clear, as evidenced in Figure 5-24c (Figure 5-24b is useful to view non-industrial waters only and compare with Figure 5-24c). It is impossible to distinguish plume samples that represent a mixture of two or more waters and those that fall within the industrial water isotopic range. The groupings on Figure 5-24a are estimates based on plume configuration and mixing inferences.

The recent interim measures extraction activity has provided an illustration of mixing effects on isotopic signature. End-member δ^2H values for river water and industrial water were estimated by calculating average δ^2H for historical river samples and for historical monitoring well samples with greater than 3,000 μg/L Cr(VI). To ensure each represented an end-member, one standard deviation was subtracted from the river sample average, making the value lighter than the average (-100.3 ‰), and one standard deviation was added to the industrial water average, producing an isotopically-heavy end-member (-46.7‰). Based on these assumptions, "100% river water" would correspond to a δ^2H value of -100.3‰, and "0% river water" would be -46.7‰. Figure 6-21 shows the trends for selected wells that have been under the influence of IM-3 extraction, which has acted to pull river-influenced groundwater westward and downward over the course of the IM -3 program (2004 to present). This figure shows how plume water can develop a lighter isotopic signature by mixing with river-influenced water in the floodplain.

In 2006 and 2007, selected samples were collected from site and regional wells and were analyzed for the stable chromium isotope, ^{53}Cr. This is a relatively recent tool that has been developed to help understand reactions of chromium in the environment and as an aid in distinguishing natural Cr(VI) from anthropogenic sources (Ellis et al., 2002 and 2004). Both sources of Cr(VI) start out with a δ^{53}Cr value of around 0.0‰. As natural groundwater moves along its flowpath, it encounters materials that act to partially reduce the Cr(VI) to Cr(III). The Cr(VI) that remains is slightly enriched in the heavy isotope ^{53}Cr, so the δ^{53}Cr value for the groundwater will increase (Ellis et al., 2002). In the case of anthropogenic sources, the groundwater flowpath and timescale of transport are expected to be much shorter than with natural sources, and so the δ^{53}Cr value is expected to remain fairly close to zero. If any Cr(VI) remained following the blowdown water treatment from 1964 onward, the δ^{53}Cr would be expected to be elevated due to the reduction reaction in the treatment process. However, due to the effectiveness of the reduction reaction, the amount of Cr(VI) remaining in treated blowdown water during this period is assumed to be very small and would therefore not be expected to influence overall isotopic signature of the plume. Results of δ^{53}Cr from the chromium isotope study are shown in Figures 6-22a (regional) and 6-22b (Topock site area). As expected, most plume samples had δ^{53}Cr values around 0.0 ‰, and known background wells ranged between +2.0 and +3.0‰. Some samples with Cr(VI) concentrations below the background UTL of 31.8 µg/L but geographically close to the edge of the plume had δ^{53}Cr values between +3.5 and +4.0. Samples from these wells (MW-13, MW-33-90, MW-33-210, and MW-40S) may have contributions from plume water but have been mixed with local alluvial groundwater and the Cr(VI) partly reduced to produce the elevated δ^{53}Cr values (Chromium Isotope Study Report to be produced in Spring 2008). The chromium isotope tool has served to help better define the extent of the plume.

6.6 Site Conceptual Model of Chromium Plume Migration in Groundwater

The evolution of the Alluvial Aquifer chromium plume may be considered three stages:

1. 1951 to 1960: Untreated blowdown water was discharged into Bat Cave Wash unponded. Historical photos indicate the surface flow traveled as far as the culvert beneath the railroad tracks. During this period, wells PGE-1 and PGE-2 were the primary source of water for the facility and are assumed to have been pumped at rates comparable to those of Topock-2 and Topock-3 today.

2. 1960 to 1970: Wells PGE-1 and PGE-2 were switched to backup status in 1960 and subsequently were removed for construction of I-40 in 1964. Discharge to Bat Cave Wash continued but was confined to a bermed area in the upper end of the wash near the facility. Beginning in the mid-1960s, the blowdown water was treated prior to discharge.

3. 1970 to 2004: Discharge of treated blowdown water was discontinued in Bat Cave Wash in 1970. Between 1970 and early 1974, treated water was injected into PGE-8. Discharge was gradually redirected to the Old Evaporation Ponds beginning in 1972, and these lined ponds were the sole recipient of treated discharge from 1974 to 1985, when the use of chromium was discontinued. During this final phase and up to the initiation of IM pumping, plume groundwater flowed under ambient conditions.

The most recent calibrated version of the groundwater flow model (CH2M HILL, 2005b) was used to simulate the first two stages in order to estimate the general plume orientation during phases for which no data are available. Stage 1 discharge to Bat Cave Wash was simulated by applying aquifer recharge of 8 million gallons per year to between the wash area from well MW-10 and the railroad tracks. Estimates of discharge during this period vary between 4 and over 10 million gallons. A portion of the discharge would be expected to evaporate before recharging the groundwater. Simulation of extraction from wells PGE-1 and PGE-2 was set at 60 gpm (split between the two wells). The average extraction rate from current wells Topock-2A and Topock-3 was about 45 gpm in 2004; 60 gpm was chosen for the 1950s under the assumption of less-efficient water use during this period. Particle transport was simulated under these conditions for a 9-year travel time. Particles were started from all nodes in the designated discharge area, starting from the top of the aquifer. The effective porosity was assumed to be 0.12, a value estimated from IM-3 injection breakthrough data and from ISPT data. The estimated plume configuration in 1960 is shown in the Stage I panel of Figure 6-23. Simulated gradient during this stage was amplified between SWMU 1 and the former supply wells, i.e., nearly due north beneath Bat Cave Wash. The simulation produced a downward gradient at SWMU 1 in response to the discharge volume, and the vertical gradient became smaller to the north as the supply wells extracted from the top two layers (based on documented well perforations and estimated aquifer thickness in this area).

For simulation of Stage 2, extraction from PGE-1 and PGE-2 was removed, and the 8 million gallons per year of discharge were concentrated into a smaller area corresponding to the bermed discharge area, described in Volume 1 of the RFI/RI. Simulation of particle flow for a 10-year period, starting from all nodes and all model layers within the simulated 1960 plume, resulted in the outline of estimated 1970 plume flowlines shown in the Stage 2 panel of Figure 6-23. Simulated extraction at Topock-2A and Topock-3 was maintained throughout Stage 2. Simulated gradient remained downward at SWMU 1, and in fact was greater than during Stage 1 due to the smaller area containing the discharge. Without the onsite supply wells, the horizontal gradient was in the natural direction towards the floodplain, but with greater magnitude due to the SWMU 1 discharge being much greater than natural mountain front recharge.

Stage 3 conditions have produced the area enclosed by the present-day 32 μg/L Cr(VI) contour in the third panel of Figure 6-23. The natural groundwater flow under ambient gradient is driven by regional flow from the north and a by local recharge from the surrounding mountains on the west and south, as discussed in Section 5.0. According to model simulations, groundwater from the Stage 2 plume moves towards the floodplain around a bedrock high in the southern part of the site.

Each simulated “plume” in Figure 6-23 depicts the outline of simulated flowlines from the first two stages of the plume and, as such, does not represent any particular concentration of Cr(VI). Actual plume flowlines would be expected to contain relatively high concentrations of chromium on the order of several thousand μg/L. Lower concentrations would be expected to surround the simulated “plume” as a result of dispersion processes. Wells with concentrations between 32 and a few thousand μg/L would be expected within a few hundred feet of the orange shaded areas of Figure 6-23. Flowlines entering the floodplain sediments would be expected to have a significant portion of the Cr(VI) removed in the chemically reducing environment, except in a portion of the deep zone.

As discussed previously, available historical data indicate that the water discharged initially into Bat Cave Wash in the early 1950s was highly brackish to saline, with a TDS between 20,000 and 30,000 mg/L. This high TDS water would have greater density than native groundwater. This density, combined with the elevated hydraulic head from the discharge, helped to drive the discharged water downward through the unsaturated zone and through most of the aquifer. During this time, wells PGE-1 and PGE-2 were extracting groundwater adjacent to Bat Cave Wash, in the area now occupied by the I-40 right-of-way. The brackish water was drawn northward to these wells. The long perforated intervals of the two extraction wells effectively spread the Cr(VI) over the vertical interval of the alluvial aquifer, while keeping the water largely confined laterally to the zone beneath Bat Cave Wash. Some dispersion would be expected in a heterogeneous system, and the present-day concentrations in MW-40D (around 100 μg/L) likely reflect the edge of the dispersive front.

Because TDS was reduced over time in the discharge water, it is not likely that density-driven flow has been important in the subsequent development of the plume. The natural TDS of alluvial groundwater ranges up to 10,000 to 15,000 mg/L in deeper zones, and blowdown water was at or below this TDS level for most of the period of discharge.

Between 1970 and early 1974, treated wastewater was injected into well PGE-8 and discharge to Bat Cave Wash was ceased. By 1972, the first of the former evaporation ponds was constructed, and a portion of the treated water was directed to that pond. It is not precisely known how much treated water was injected in PGE-8, and the concentration of Cr(VI) in that water is also not documented, though it is believed to have been very low given the effectiveness of the two-step treatment process employed at the time (CH2M HILL, 2007a). Recent testing of PGE-8, discussed in Section 5.1.4.2, has demonstrated a clear hydraulic connection between bedrock and the Alluvial Aquifer in this area, and the conceptual model of the site indicates that the majority of the injected water flowed through bedrock fractures into the Alluvial Aquifer during the injection period. Due to high uncertainty in flow quantities, direction of flow from bedrock to alluvium, and assumed low Cr(VI) concentration, this discharge was not included in the simulations described above.

6.7 Fate and Transport of Chromium

6.7.1 Mobility of Chromium

Hexavalent chromium is relatively stable and conservative under the non-reducing conditions of the alluvial portion of the aquifer beneath the Topock site. It is in the form of the chromate anion, CrO_4^{2-}, in the pH range of site groundwater. This is a relatively mobile ion that does not form insoluble precipitates, nor does it adsorb strongly to mineral surfaces (Hering and Harmon, 2004). This stability is evidenced by the persistence of Cr(VI) from the original discharge area in Bat Cave Wash throughout the predicted flowpaths in the non-reducing alluvial material (Section 6.6).

As described in Section 5.3.1.6, reducing conditions are present in the vast majority of shallow and mid-depth fluvial wells, along with pore water and slant well samples beneath the river bottom. The fluvial wells where non-reducing conditions have been observed are listed in Section 6.5.1, but they constitute a minority. Once Cr(VI) encounters a sufficiently reducing environment, it is quickly reduced to Cr(III). Trivalent chromium is essentially immobile except either under highly acidic pH conditions or in the presence of strong complexing agents, neither of which is present at the Topock site. Once reduced to Cr(III), chromium will precipitate as either an oxide, hydroxide, or a coprecipitate with iron where iron is present (Eary and Rai, 1988). Even at trace concentrations, the Cr^{3+} cation will strongly adsorb to mineral surface (unlike the chromate anion), further reducing its concentration in solution, typically to levels at or below analytical reporting limits. Solubility of chromium oxide, Cr_2O_3, is low enough to maintain Cr^{3+} concentration below the reporting limit of 0.1 µg/L (Brookins, 1988). Once reduced, Cr(III) does not readily become reoxidized to Cr(VI). The only naturally-occurring oxidant that can accomplish this is solid manganese dioxide, MnO_2 (Fendorf, 1995). If this solid is present, the Cr^{3+} ion can adsorb to the MnO_2 surface, where a redox reaction can take place with Cr oxidized and Mn reduced. However, under the reducing conditions present in the fluvial materials, MnO_2 is not stable, and manganese tends to exist as the dissolved cation Mn^{2+}, as shown by the detectable manganese concentrations in these wells (Figure 5-22. In summary, dissolved chromium is removed from groundwater as the groundwater encounters reducing fluvial material present in the floodplain. As long as the natural reducing capacity of the fluvial material is present, chromium is not expected to be mobile within this area.

The capacity of the reducing fluvial material to reduce Cr(VI) has been investigated by conducting two phases of the anaerobic core study (CH2M HILL, 2005d; Stage 2 report to be released Spring 2008). The most recent (2007) samples were collected in slant borings for the MW-52 and MW-53 clusters and were transferred immediately from the sample core barrel to a nitrogen glove box adjacent to the drilling site. This was to avoid the rapid oxidation that occurs upon exposure of anaerobic soil to the atmosphere. Laboratory analysis has confirmed that fluvial material in reducing groundwater zones demonstrates a strong capacity to reduce Cr(VI) when exposed to alluvial, non-reducing plume groundwater. Calculation and review of this capacity are currently in progress, and the estimated range of natural reducing capacity will be used in the CMS/FS.

6.7.2 Fate and Mobility in East Ravine

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. This is based on the large contrast in permeability between the bedrock and alluvial aquifer, and the observed upward hydraulic gradient between the bedrock and the overlying alluvial aquifer. It is also noted that chromium is absent in the limited number of samples obtained from bedrock monitoring wells, with a few exceptions. The geologic map presented in Figure 3-5 shows the surface outcropping of the Miocene Conglomerate in the south and southeast of the site, and the cross-section presented in Figure 5-5 shows the limits on the Alluvial Aquifer to the south of the site. Within the framework of the RFI/RI site conceptual model, the presence of bedrock at the surface (i.e., the absence of saturated alluvial material) to the south and southeast of the compressor station precluded the installation of Alluvial Aquifer wells in this region. Due to the absence of the Alluvial Aquifer, movement of the groundwater chromium plume associated with the Bat Cave Wash discharge through this area is considered improbable.

Treated blowdown water was injected into the bedrock at well PGE-8 for a period of about 3 years in the early 1970s at an average rate of about 22 gpm. Very low levels of Cr(VI) were present in the treated water that was injected. Hexavalent chromium has not been detected in samples from PGE-8. The injection zone in PGE-8 was below a depth of 405 feet. It is possible that this well intercepted the Chemehuevi detachment fault, which is mapped as outcropping along the mountain front south of the compressor station. Recent hydraulic testing at PGE-8 indicated that the bedrock is of very low permeability laterally but is clearly hydraulically connected to the overlying alluvial aquifer. A review of published scientific literature showed that faults in adjacent basins often formed barriers to groundwater flow rather than conduits to flow. It is also not known whether the water injected into PGE-8 traveled along the detachment fault or emerged through vertical or high-angle fractures to the alluvial aquifer. An investigation is currently being planned to install bedrock wells in the East Ravine. These wells may provide additional information on the location and characteristics of the detachment fault and the potential for chromium migration through bedrock from PGE-8.

A review of aerial photographs has shown impoundments in the East Ravine. Depending on the source of the water, it may have contained Cr(VI). Historical soil sampling data indicate elevated chromium concentrations have been detected in the drainage depressions in the East Ravine (CH2M HILL, 2007a). It is likely that the top of the bedrock underlying much of the East Ravine is at an elevation above the groundwater table. In other words, there is not likely to be any saturated alluvial material underlying the East Ravine.

Anomalous elevated concentrations (>1,000 ppb) of Cr(VI) have recently been observed sporadically in well MW-23 (detailed in Section 6.3.4). MW-23 is a shallow bedrock well located immediately north of the mouth of East Ravine. As discussed in Section 6.3.4, the origin of the sporadic and anomalously-elevated Cr(VI) concentrations in MW-23 is unknown. Concentrations of Cr(VI) similar to the sporadically-elevated concentrations found in MW-23 are found in the alluvial aquifer near well MW-12, approximately 500 feet from MW-23. The sporadically-elevated Cr(VI) concentrations in MW-23 may be related to intermittent groundwater flow through localized fractures that connect to the nearby alluvial aquifer. Because elevated Cr(VI) has not been detected in other bedrock wells or in the former injection well PGE-8, it is considered less likely that the sporadically-elevated Cr(VI) concentrations in MW-23 are related to flow through the bedrock from PGE-8. In contrast to other bedrock wells, MW-23 typically contains detectable Cr(VI) concentrations and often has a positive or only slightly negative ORP. This may be a further indication of a fracture connection between MW-23 and the alluvial aquifer. Currently, an additional groundwater investigation is planned to characterize the groundwater conditions of bedrock formations in the East Ravine and MW-23 area. Figure 6-17 shows the general locations of the proposed drilling sites for the East Ravine groundwater investigation. The anticipated schedule and reporting of the East Ravine groundwater investigation is presented in Table 4-6.

6.7.3 Density-driven Flow

6.7.3.1 Salinity

In addition to movement caused by advective flow or pressure gradients, groundwater movement can also be influenced by the presence of density gradients. Groundwater of variable density will stratify as gravity moves denser waters downward and lighter waters upward. A common cause of density gradients is variation in groundwater salinity. Salinity variation within the groundwater monitoring network was previously discussed in Section 5.3.1 as average TDS concentrations. Average TDS concentrations obtained from monitoring well samples at the Topock site generally increase with depth and appear to be loosely stratified. Figure 5-19 presents two north-south and one east-west cross-sectional view illustrating TDS variation with depth. The highest average TDS concentrations are found at the base of the alluvium and within the bedrock. The range of average TDS concentrations varies from a low of 737 to a high of 24,800 mg/L across the monitoring well network. In qualitative terms, this range of TDS concentration varies from fresh to brackish water.

Density-driven flow and mixing is commonly applied to brine disposal areas or in petroleum exploration where deep natural brines are common. Flowers and Hunt (2007) examined solution mixing between fresh water and brines, citing environmental examples with brine TDS of 45,000 mg/L and higher. In these cases, the density contrast between the brines and fresh water were much greater than those between historical blowdown water and native groundwater at the Topock site. In addition to density contrasts, conditions under which brine may flow as a separate phase include viscosity contrast with native groundwater (Flowers and Hunt, 2007). Because both the blowdown water and groundwater were both sodium-chloride waters, the viscosity differences are negligible at the Topock site. For these reasons, the criteria described in the work of Flowers and Hunt (2007) were not applied to the RFI/RI dataset. The discussion below is used instead.

The change in the density of water with respect to TDS concentration is not a linear relationship but varies as a function of the dissolved analytes and concentration level. Governing equations for density to TDS concentration relationships of water are typically empirically derived for individual analytes and concentrations. At Topock, the major component of TDS is sodium chloride, where density can be approximated using the following equation (de Marsily, 1986):

$$\rho = \left(6.87 \times 10^{-4} C_{TDS}\right) + 998.4575 \tag{1}$$

where:

ρ = density of water in kilograms per cubic meter (kg/m^3).
C_{TDS} = TDS concentration in mg/L.

Using 737 and 24,800 mg/L, the range of densities that can be attributed solely to average TDS concentration differences are 999.0 and 1,015.5 kg/m^3, respectively. The density of pure water, without any TDS at all, is approximately 998.2 kg/m3 at 20°C (de Marsily, 1986). The effect of increasing TDS would be to increase the density of water, with higher TDS water being denser. The density difference between the freshest and most brackish groundwater at the site is 16.5 kg/m^3, or approximately 1.6 percent.

This range of low and high ends of the TDS concentration present bounding conditions for the site in general and do not occur next to each other in the field, so the density difference presented above is not representative of any localized conditions. A more realistic occurrence of density gradients would be found in the clustered wells screened in multiple intervals. An example would be wells MW-41S, MW-41M, and MW-41D, which have average TDS concentrations of 2,813, 8,710, and 12,975 mg/L, respectively. The range of densities that can be attributed solely to average TDS concentration differences in these wells would be 1000.4, 1004.4, and 1007.4 kg/m^3, respectively. The density differences between intervals are 4.0 and 3.0 kg/m^3 (0.4 percent and 0.3 percent, respectively), with density increasing downward. Because the column density increases with depth at this clustered well, density differences do not result in groundwater movement. This area is in equilibrium, as is the majority of the site, as presented on Figure 5-19.

To assess the current potential for density-driven flow, it is necessary to find an area where observed density values do not appear to be in equilibrium (i.e., the density decreases with increasing depth). Wells MW-27-85, MW-34-100, and MW-44-125, all lower zone wells, are located within a space of several hundred feet (Figure 5-19), with screened intervals placed immediately above a northerly-dipping bedrock slope. The average TDS concentrations in these wells are 12,275, 10,621, and 7,170 mg/L, respectively, decreasing with increasing screened interval depth. Using the previously presented empirical equation, the density for these wells is 1006.9, 1005.8, and 1003.4 kg/m^3, which results in density differences between wells of 1.1 and 2.4 kg/m^3 (0.1 percent and 0.2 percent). Density differences of this magnitude are small, and the resultant density-driven flow would not be significant when compared to advective gradients and advective flow. In addition, while this example displays an apparent disequilibrium within fluid density, surrounding wells such MW-46-175 and MW-46-205 have increased TDS concentrations, indicating that any density disequilibrium is isolated to a discrete location and of limited extent. As discussed earlier, the current density distribution across the site is stratified, with density generally increasing with depth. This is the opposite trend to the example above, and therefore the more common density distribution at the site favors a stable, advection-driven flow system (as opposed to density-driven flow).

Past conditions and practices at the site that have the potential for transport of constituents by density-driven flow should be addressed within the above framework. Blowdown water used in the cooling towers increased in ambient TDS concentration as water was re-circulated in the cooling process. An additional increase in TDS concentration occurred when discarded water was held in detention ponds. Only limited information exists on the concentration of fluids released to Bat Cave Wash, but this information indicates that the TDS concentration was brackish, or approximately 15,000 mg/L TDS. Since the original source of this water was local groundwater, the majority of TDS concentration would be attributed to sodium chloride. Release of blowdown water with a TDS concentration of 15,000 mg/L into the density-stratified alluvium would place this water initially on top of water similar in composition to that found in shallow wells. Figure 5-18a and Figure 5-19 present the average TDS concentration for shallow wells. Contrasting blowdown water of 15,000 mg/L TDS with groundwater from wells MW-9 (TDS 2,089 mg/L), MW-10 (2,410 mg/L) or MW-11 (1,640 mg/L) yields a density difference of approximately 9 kg/m^3 (0.9 percent). This difference is large enough that blowdown water would displace shallow groundwater, moving downward.

Moving downward, density-driven flow would place blowdown waters in contact with groundwater of composition found in mid-depth wells. Figure 5-18b and Figure 5-19 present the average TDS concentration for mid-depth wells. Contrasting blowdown water of 15,000 mg/L with groundwater from wells MW-51 (6,190 mg/L), MW-39-60 (5,510 mg/L) or MW-33-90 (5,657 mg/L) yields a density difference of approximately 6 kg/m^3 (0.6 percent). This difference is most likely large enough that blowdown water would eventually displace mid-depth groundwater as it was pulled downward by gravity.

With time, density-driven flow would place blowdown waters in contact with groundwater of composition found in deep wells. Figure 5-18c and Figure 5-19 present the average TDS concentration for deep wells. Contrasting blowdown water of 15,000 mg/L with groundwater from wells MW-38D (13,550 mg/L), MW-39-100 (10,948 mg/L), MW-50-200 (13,000 mg/L) or MW-41D (12,975 mg/L) yields a density difference of approximately 1 kg/m^3 (0.1 percent). This difference in density is small, and the resultant density-driven flow would not be significant when compared to advective gradients and advective flow. Density-driven flow would not be a significant process for transporting TDS concentrations within groundwater of this character. Blowdown water of brackish composition would not be transported by density gradients any deeper than the interval of the mid-depth wells.

Figure 5-18a-c and Figure 5-19 present a reasonably complete horizontal and vertical characterization of the current average TDS concentrations found at the Topock site. The characterization of groundwater with respect to salinity varies at the site from fresh to brackish, but in no case is the water quality near the concentration level of a brine. It is important to note the distinctions between brackish water and brine when discussing density-driven flow. Brines are defined as having a TDS concentration greater than 50,000 mg/L, which would yield a density of approximately 1,035 kg/m^3 for a sodium chloride brine. This is roughly an order-of-magnitude greater density difference over freshwater than the average TDS concentration for brackish waters found at Topock.

6.7.3.2 Temperature

Variations in groundwater temperature can also contribute to density gradients and density-driven flow. Temperature variation within the groundwater monitoring network was previously discussed in Section 5.3.3, where groundwater close to the Colorado River displayed a lower temperature response than groundwater farther away. The range of average groundwater temperatures measured in the field varied from approximately 70°F (21°C) to 89°F (32°C) across the monitoring well network (Figure 5-21).

The change in water's density with changing temperature is a complex relationship but can be simplified in the range of temperatures typically found at Topock. The governing equation for the density to temperature relationship of water can be approximated by (Bos, 1994):

$$\rho = 1000 - \frac{(T-4)^2}{150} \tag{2}$$

where:

ρ = density of water in kg/m^3.
T = temperature of water in degrees Celsius.

Using 21°C and 32°C, the range of densities that can be attributed solely to average groundwater temperature differences are 998.1 and 994.8 kg/m^3, respectively. The effect of temperature would be to decrease the density of water, with higher-temperature water being less dense. The density difference between the coldest and warmest groundwater at the site is 4.7 kg/m^3, or approximately 0.3 percent.

As small of a difference as this is, it represents the difference between the low and high end of the range and does not actually occur in the field. A more realistic occurrence of density differences due to variable temperature would be clustered wells screened in multiple intervals. An example would be wells MW-33-40, and MW-33-210, which have average groundwater temperatures of 80.9 and 83.1°F (27.2 and 28.4°C), respectively. Using 27.2°C and 28.4°C, the range of densities that can be attributed solely to average groundwater temperature differences in these wells would be 996.4 and 996.0 kg/m^3, respectively. The density difference between these two intervals is 0.4 kg/m^3 or less than 0.05 percent.

Temperature differences have the potential to result in relatively small density differences within groundwater at the Topock site. Field-observed temperatures have the potential to create density differences as high as 4.7 kg/m^3 but are more likely to be significantly less than this. Temperature generally increases with depth at the Topock site which, considering only temperature, results in lighter density water with depth. Density-driven flow related to temperature differences will generally be relatively small and in an upward direction.

TABLE 6-1
Summary of RFI/RI Groundwater Characterization Data, July 1997 - October 2007
RCRA Facility Investigation/Remedial Investigation Report (Volume 2)
PG&E Topock Compressor Station, Needles, California

Parameter	**Groundwater COPC assigned in RFI/RI Volume 1**	**Number of Wells Sampled**	**Number of Primary Samples**	**First Sampling Date**	**Last Sampling Date[1]**
Dissolved Metals					
Hexavalent chromium	x	167	2,924	07/01/1997	10/18/2007
Chromium (total)	x	166	2,944	07/01/1997	10/18/2007
Copper	x	89	1,133	07/01/1997	10/18/2007
Nickel	x	89	1,133	07/01/1997	10/18/2007
Lead	x	85	488	07/01/1997	10/18/2007
Zinc	x	89	1,133	07/01/1997	10/18/2007
Aluminum		72	339	02/17/2004	10/18/2007
Antimony		66	387	06/08/2004	10/18/2007
Arsenic		109	464	06/08/2004	10/18/2007
Barium		111	578	07/01/1997	10/18/2007
Beryllium		66	377	06/08/2004	10/18/2007
Cadmium		66	377	06/08/2004	10/18/2007
Cobalt		66	377	06/08/2004	10/18/2007
Mercury		67	383	06/08/2004	10/18/2007
Molybdenum		85	577	07/01/1997	10/18/2007
Selenium		74	400	06/08/2004	10/18/2007
Silver		66	377	06/08/2004	10/18/2007
Strontium		14	14	06/13/2005	12/22/2005
Thallium		66	377	06/08/2004	10/18/2007
Vanadium		85	475	07/01/1997	10/18/2007
General Chemistry					
pH	x	133	1,909	07/01/1997	10/18/2007
Specific conductance	x	133	1,966	07/01/1997	10/18/2007
Boron		121	637	03/03/2004	10/18/2007
Calcium		165	968	07/01/1997	10/18/2007
Iron		163	752	07/01/1997	10/18/2007
Magnesium		154	964	07/01/1997	10/18/2007
Manganese		165	848	07/01/1997	10/18/2007
Potassium		164	884	07/01/1997	10/18/2007
Sodium		165	963	07/01/1997	10/18/2007
Alkalinity hydroxide		63	104	03/03/2004	10/11/2007
Alkalinity, as carbonate		164	836	07/01/1997	10/18/2007
Alkalinity, bicarb as CaCO3		164	836	07/01/1997	10/18/2007
Alkalinity, total as CaCO3		163	814	06/10/2003	10/18/2007
Ammonia		32	96	07/01/1997	11/30/2001
Ammonia as nitrogen		128	531	06/10/2003	10/18/2007
Bicarbonate		79	82	03/07/2005	10/11/2007
Carbonate		79	83	03/07/2005	10/11/2007
Deuterium		118	450	03/03/2004	10/11/2007
Dissolved organic carbon		39	82	02/18/2004	05/09/2006
Iodide		39	78	05/09/2005	04/07/2006
Orthophosphate		108	175	06/10/2003	07/19/2007
Oxygen 18		118	450	03/03/2004	10/11/2007
Perchlorate		29	46	06/10/2003	07/26/2005
Phosphate		38	123	07/01/1997	11/30/2001

TABLE 6-1

Summary of RFI/RI Groundwater Characterization Data, July 1997 - October 2007

RCRA Facility Investigation/Remedial Investigation Report (Volume 2)

PG&E Topock Compressor Station, Needles, California

Parameter	Groundwater COPC assigned in RFI/RI Volume 1	Number of Wells Sampled	Number of Primary Samples	First Sampling Date	Last Sampling Date[1]
General Chemistry					
Silica		109	146	02/18/2004	05/18/2006
Soluble silica		86	177	02/17/2004	05/04/2007
Sulfide		123	271	07/01/1997	07/19/2007
Total dissolved solids		153	1,009	07/01/1997	10/18/2007
Total Kjeldahl Nitrogen		73	133	01/10/2005	08/11/2007
Total organic carbon		155	514	07/01/1997	10/11/2007
Total phosphorus as p		3	3	12/15/2004	12/16/2004
Total suspended solids		38	81	05/09/2005	05/09/2006
Turbidity		54	256	09/30/2004	10/18/2007
Anions					
Bromide		100	324	03/03/2004	10/11/2007
Chloride		165	883	07/01/1997	10/18/2007
Fluoride		112	551	07/01/1997	10/18/2007
Nitrate		30	92	07/01/1997	11/30/2001
Nitrate as Nitrogen		163	645	07/01/1997	10/11/2007
Nitrate/Nitrite as Nitrogen		24	170	07/27/2005	10/18/2007
Nitrite		31	95	07/01/1997	11/30/2001
Nitrite as Nitrogen		68	100	09/08/2004	08/09/2007
Sulfate		165	884	07/01/1997	10/18/2007
Organics					
TPH as diesel	x	5	5	05/03/2007	07/18/2007
TPh as gasoline	x	5	5	05/03/2007	07/18/2007
TPH as motor oil	x	5	5	05/03/2007	07/18/2007
Volatile Organic Compounds		22	27	06/09/2004	05/04/2007
Semivolatile Organic Compounds		22	27	06/08/2004	05/04/2007
Polychlorinated Biphenyls		7	7	06/09/2004	09/30/2004
Radiochemistry					
Gross Alpha		2	2	07/29/2004	07/29/2004
Gross Beta		2	2	07/29/2004	07/29/2004
Radium 226		2	2	07/29/2004	07/29/2004
Radium 228		2	2	07/29/2004	07/29/2004
Tritium		15	30	05/09/2005	07/26/2005
Uranium		2	2	07/29/2004	07/29/2004

Notes:

COPC	constituent of potential concern
TPH	total petroleum hydrocarbons

[1] New bedrock monitoring well PGE-7BR was first sampled in December 2007 and is included in the RFI/RI characterization.

TABLE 6-2

Chemical Specific ARARs for Groundwater

RCRA Facility Investigation/Remedial Investigation Report (Volume 2)

PG&E Topock Compressor Station, Needles, California

		California Safe Drinking Water Act [3]		Federal Safe Drinking Water Act [4]	
	Units [1]	MCL / Standard [2]	Note	MCL / Standard [2]	Note
METALS					
Aluminum	µg/L	1,000		50-200	secondary MCL
Antimony	µg/L	6		6	
Arsenic	µg/L	50		10	as of 1/23/06
Barium	µg/L	1,000		2,000	
Beryllium	µg/L	4		4	
Cadmium	µg/L	5		5	
Hexavalent Chromium	µg/L	--		--	
Chromium (total)	µg/L	50		100	
Cobalt	µg/L	--		--	
Copper	µg/L	1,000	secondary MCL	1,000	secondary MCL
Iron	µg/L	300	secondary MCL	300	secondary MCL
Lead	µg/L	15	Action Level [5]	15	Action Level [5]
Manganese	µg/L	50	secondary MCL	50	secondary MCL
Mercury	µg/L	2		2	
Molybdenum	µg/L	--		--	
Nickel	µg/L	100		--	
Selenium	µg/L	50		50	
Silver	µg/L	100	secondary MCL	100	secondary MCL
Thallium	µg/L	2		2	
Vanadium	µg/L	--		--	
Zinc	µg/L	5,000	secondary MCL	5,000	secondary MCL
GENERAL CHEMISTRY					
Specific Conductance	µS/cm	900-1,600	secondary MCL	--	
pH	pH units	--		6.5-8.5	secondary MCL
Total Dissolved Solids	mg/L	500-1,000	secondary MCL	500	secondary MCL
Chloride	mg/L	250-500	secondary MCL	250	secondary MCL
Sulfate	mg/L	250-500	secondary MCL	250	secondary MCL
Fluoride	mg/L	2		2	
Nitrate + Nitrite (as nitrogen)	mg/L	10		--	
Perchlorate	µg/L	6		--	
RADIONUCLIDES					
Gross Alpha Particles	pCi/L	15		15	
Gross Beta Particles	pCi/L	4	(mrem/yr)	50	
Uranium	pCi/L	30		20	

Notes:

[1] Units: micrograms per liter (µg/L), milligrams per liter (mg/L), microSiemens per centimeter (µS/cm), picocuries per liter (pCi/L), millirems per year (mrem/yr)

[2] The chemical-specific ARARs listed are the Primary Maximum Contaminant Level (MCL) unless otherwise noted

[3] Title 22, CCR, Division 4, Chapter 15. Source: Appendix G

[4] 40 CFR 141- Subpart F, MCL Goals & Subpart G National Primary Drinking Water Regulations: Source: Appendix G

[5] Action level for lead if more than 10% of samples exceed action level

(--) denotes MCL or standard not assigned or applicable

Table 6-3

Calculated Site Background UTLs for Trace Metals in Groundwater

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	Units [1]	Upper Tolerance Limit (UTL) [2]	Elevated Percentile Estimated by UTL (with 95% confidence)
METALS			
Aluminum	µg/L	55.8	89
Antimony	µg/L	1.22	89
Arsenic	µg/L	24.3	95
Barium	µg/L	195	95
Beryllium	µg/L	0.663	89
Cadmium	µg/L	-- [3]	89
Chromium (total)	µg/L	34.1	89
Hexavalent Chromium	µg/L	31.8	89
Cobalt	µg/L	0.843	89
Copper	µg/L	10.5	95
Lead	µg/L	1.91	89
Mercury	µg/L	-- [3]	89
Molybdenum	µg/L	36.3	95
Nickel	µg/L	10.6	89
Selenium	µg/L	10.3	95
Silver	µg/L	2.13	89
Thallium	µg/L	0.908	89
Vanadium	µg/L	59.9	89
Zinc	µg/L	77.7	88

Notes:

[1] Units: micrograms per liter (µg/L)

[2] The site background concentration is the 95% upper tolerance limit (UTL) of the elevated percentile from the Steps 3 and 4 Groundwater Background Study Report (CH2M HILL 2008a)

[3] The background values for cadmium and mercury are detection limits of 1.0 and 0.2 mg/L, respectively

TABLE 6-4

Groundwater Analytical Results for Chromium, Specific Conductance and pH, October 2006 through October 2007

RCRA Facility Investigation/Remedial Investigation Report (Volume 2)
PG&E Topock Compressor Station, Needles, California

Well ID [1]	Monitoring Zone [2]	Sample Date	Hexavalent Chromium (µg/L)	Dissolved Chromium (µg/L)	Specific Conductance (µS/cm)	pH (pH units)
Groundwater Monitoring Wells						
MW-9	SA	10/12/2006	308	306	2,820	7.24
		05/03/2007	286	341	2,880	7.56 J
		10/04/2007	304	304	2,810	7.52 J
MW-10	SA	10/12/2006	2,510	2,480	2,350	7.52
		12/14/2006	2,380	3,040	2,140	7.79
		03/06/2007	1,640	1,700	2,760	7.67
		05/03/2007	1,230	1,440	2,840	7.58 J
		10/02/2007	1,010	1,050	2,700	7.74 J
MW-11	SA	10/12/2006	325	339	2,320	7.39
		05/03/2007	356	337	2,110	7.61 J
		07/17/2007	321	314	---	---
MW-12	SA	10/04/2006	1,740	1,790	4,590	7.92
		12/13/2006	2,050	1,880	4,490	8.44
		03/06/2007	2,630	2,440	4,820	8.41
		05/03/2007	2,620	2,880	5,220	8.40 J
		10/04/2007	2,970	2,800	5,560	8.47 J
MW-13	SA	10/02/2006	24.6	21.4	1,860	7.80
		03/05/2007	23.4	25.2	1,860	7.66
		10/02/2007	21.8	23.6	1,860	7.67 J
MW-14	SA	10/02/2006	32.6	28.9	1,440	7.88
		03/12/2007	13.0	13.4	1,450	7.75
		10/02/2007	27.2	31.2	1,410	7.86 J
MW-15	SA	10/05/2006	12.1	11.4	1,430	7.93 R
		05/04/2007	21.1	21.0	2,060	7.58 J
		10/02/2007	12.2	12.5	1,450	7.89 J
MW-16	SA	11/01/2006	7.00	6.30	1,090	8.04
		10/02/2007	8.80	9.70	1,040	8.12 J
MW-17	SA	10/02/2006	11.9	11.9	1,780	7.69
		10/03/2007	6.50	7.30	1,710	---
MW-18	SA	10/04/2006	33.5	29.1	1,250	7.46
		03/12/2007	35.6	35.6	1,200	7.73
		10/02/2007	27.9	27.5	1,250	7.78 J
MW-19	SA	10/02/2006	970	1,300	2,230	7.86
		12/15/2006	1,070 J	1,090	2,250	7.63
		03/06/2007	1,040	1,030	2,240	7.69
		05/02/2007	836	777	2,310	7.70 J
		10/05/2007	1,390	1,510	2,200	7.33 J
MW-20-70	SA	10/03/2006	3,410	3,390	2,840	7.38
		12/13/2006	3,430	3,120	2,850	7.55
		03/14/2007	2,820	2,720	2,850	7.62
		05/03/2007	2,790	3,050	2,750	7.62 J
		10/11/2007	2,400	2,140	2,800	7.66 J
MW-20-100	MA	10/03/2006	9,520	10,300	3,570	7.28
		12/13/2006	9,610	9,220 J	3,630	7.54
		03/14/2007	9,470	9,270	3,590	7.63
		05/03/2007	10,100	9,820	3,590	7.56 J
		10/10/2007	9,000	10,700	3,390	7.61 J
MW-20-130	DA	10/18/2006	11,600	16,400	17,000	7.61 R

TABLE 6-4

Groundwater Analytical Results for Chromium, Specific Conductance and pH, October 2006 through October 2007

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Well ID [1]	Monitoring Zone [2]	Sample Date	Hexavalent Chromium (µg/L)	Dissolved Chromium (µg/L)	Specific Conductance (µS/cm)	pH (pH units)
Groundwater Monitoring Wells						
MW-20-130	DA	12/13/2006	12,000	10,700	15,200	7.58
		03/08/2007	14,400	12,100	12,800	7.59
		05/03/2007	13,500	16,200	12,800	7.58 J
		10/05/2007	12,200	13,000	11,600	7.55 J
MW-21	SA	10/03/2006	ND (1.0)	ND (1.0)	16,500	7.27
		12/13/2006	ND (1.0)	ND (1.0)	13,900	7.33
		03/09/2007	ND (1.0)	ND (1.0)	11,100	7.26
		05/01/2007	ND (1.0)	1.40	12,200	7.23 J
		10/04/2007	ND (5.0)	ND (1.0)	14,100	7.21 J
MW-22	SA	10/13/2006	ND (1.0)	ND (1.0)	40,300	6.84
		03/08/2007	ND (1.0)	ND (1.0)	27,700	7.02
		10/10/2007	ND (1.0)	ND (1.0)	23,700	6.93 J
MW-23	BR-Tmc	10/04/2006	15.2	14.4	19,300	7.07
		12/12/2006	14.4 J	ND (1.0) J	21,200	7.50
		03/06/2007	1,020	1,020	10,200	7.75
		05/02/2007	13.0	10.9	17,100	7.38
		10/04/2007	19.2	22.2	15,800	7.50 J
MW-24A	SA	10/03/2006	4,300	4,260	3,170	7.66
		12/14/2006	3,310	4,250	3,220	7.70
		03/06/2007	3,540	3,600	3,190	7.69
		07/18/2007	2,480	2,550	2,690	7.76 J
MW-24B	DA	10/03/2006	6,120	5,830	17,100	7.69
		12/14/2006	5,520	5,060	18,800	7.97
		03/05/2007	5,980	6,100	14,900	7.92
		07/18/2007	5,540	6,020	15,200	7.93 J
MW-24BR	BR-pTbr	11/01/2006	ND (1.0)	ND (1.0)	16,700	7.98
		12/15/2006	ND (2.0)	1.00	16,500	8.56
		03/06/2007	ND (1.0)	ND (1.0)	14,200	8.26
		05/03/2007	ND (1.0)	ND (1.0)	14,000	8.29 J
		10/04/2007	ND (1.0)	ND (1.0)	13,500	8.72 J
MW-25	SA	10/03/2006	1,140	1,150	1,400	7.24
		03/06/2007	945	951	1,330	7.59
		10/02/2007	933	884	1,210	7.69 J
MW-26	SA	10/03/2006	3,590	3,850	3,600	7.52
		03/12/2007	3,440	3,540	3,580	7.57
		10/02/2007	3,510	3,740	3,490	7.58 J
MW-27-20	SA	10/03/2006	ND (0.2)	ND (1.0)	1,090	7.90 R
		10/02/2007	ND (0.2)	2.20	1,120	7.73 J
MW-27-60	MA	10/03/2006	ND (1.0)	ND (1.0)	9,700 J	7.23
		10/02/2007	ND (0.2)	ND (1.0)	7,400	7.51 J
MW-27-85	DA	10/13/2006	ND (1.0)	ND (1.0)	21,600	7.16
		11/16/2006	ND (1.0)	ND (1.0)	---	---
		12/11/2006	ND (1.0)	ND (1.0)	21,600	7.03
		01/10/2007	ND (1.0)	4.40	---	---
		02/06/2007	ND (1.0)	ND (1.0)	---	---
		03/07/2007	ND (0.2)	ND (1.0)	18,100	7.31
		04/03/2007	ND (1.0)	ND (1.0)	---	---
		05/01/2007	ND (1.0)	1.00	18,500	7.21 J

TABLE 6-4

Groundwater Analytical Results for Chromium, Specific Conductance and pH, October 2006 through October 2007

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Well ID[1]	Monitoring Zone[2]	Sample Date	Hexavalent Chromium (µg/L)	Dissolved Chromium (µg/L)	Specific Conductance (µS/cm)	pH (pH units)
Groundwater Monitoring Wells						
MW-27-85	DA	06/13/2007	ND (1.0)	ND (1.0)	---	---
		07/11/2007	ND (1.0)	ND (1.0)	---	---
		08/08/2007	ND (1.0)	ND (1.0)	---	---
		09/05/2007	ND (1.0)	ND (1.0)	---	---
		10/02/2007	ND (1.0)	ND (1.0)	16,300	7.24 J
MW-28-25	SA	10/11/2006	ND (0.2)	ND (1.0)	1,340	7.27
		10/04/2007	ND (1.0)	ND (1.0)	1,220	7.52 J
MW-28-90	DA	10/13/2006	ND (0.2)	ND (1.0)	8,510	7.56
		12/14/2006	ND (1.0)	ND (1.0)	7,740	7.54
		03/08/2007	ND (1.0)	ND (1.0)	7,450	7.56
		05/04/2007	ND (0.2)	ND (1.0)	7,560	7.49 J
		10/04/2007	ND (1.0)	ND (1.0)	7,020	7.42 J
MW-29	SA	10/13/2006	ND (0.2)	ND (1.0)	4,300	7.39
		10/04/2007	ND (1.0)	ND (1.0)	2,630	7.46 J
MW-30-30	SA	10/10/2006	ND (2.0)	ND (1.0)	49,300	7.04
		10/08/2007	ND (1.0)	ND (1.0)	35,800	7.14 J
MW-30-50	MA	10/11/2006	ND (0.2)	ND (1.0)	6,210	7.16
MW-31-60	SA	10/05/2006	773	849	2,440	7.60
		03/12/2007	626	638	2,730	7.69
		10/04/2007	726 J	669	2,840	7.60 J
MW-31-135	DA	10/05/2006	85.7	81.7	9,370	7.59
		03/08/2007	52.0	55.2	9,980	7.93
		05/01/2007	46.1	47.4	10,600	7.85 J
		10/01/2007	33.2	29.4	9,750	7.91 J
MW-32-20	SA	10/02/2006	ND (5.0)	ND (1.0)	65,200	7.03
		12/11/2006	ND (2.0)	ND (1.0)	57,100	6.85
		03/06/2007	ND (2.0)	ND (1.0)	37,200	6.85
		04/30/2007	ND (2.0)	ND (1.0)	27,500	6.86 J
		10/01/2007	ND (2.0)	ND (1.0)	47,700	6.79 J
MW-32-35	SA	10/02/2006	ND (1.0)	ND (1.0)	18,400	7.28
		12/11/2006	ND (1.0)	ND (1.0)	19,200	7.10
		03/06/2007	ND (1.0)	ND (1.0)	17,300	7.22
		04/30/2007	ND (1.0)	ND (1.0)	19,400	7.07 J
		10/01/2007	ND (1.0)	1.20	18,700	7.12 J
MW-33-40	SA	10/06/2006	ND (0.2)	ND (1.0)	4,170	8.00 J
		12/14/2006	ND (0.2)	1.20	6,790	8.20
		03/06/2007	ND (0.2)	ND (1.0)	4,960	8.31
		05/02/2007	ND (0.2)	ND (1.0)	4,500	8.38 J
		10/05/2007	ND (0.2)	1.10	6,260	8.14 J
MW-33-90	MA	10/06/2006	17.3	20.9	8,200	7.40 J
		12/15/2006	2.30 R	13.8	9,460	7.63
		03/12/2007	17.1	18.0	9,750	7.53
		05/02/2007	18.8	16.8	9,980	7.56 J
		10/05/2007	18.2	19.4	9,540	7.27 J
MW-33-150	DA	10/06/2006	7.70	5.70	18,400	7.30 J
		12/13/2006	10.8	9.80	19,500	7.59
		03/06/2007	6.90	7.00	15,900	7.67
		05/02/2007	6.80	6.10	16,000	7.61 J

TABLE 6-4

Groundwater Analytical Results for Chromium, Specific Conductance and pH, October 2006 through October 2007

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PG&E Topock Compressor Station, Needles, California

Well ID [1]	Monitoring Zone [2]	Sample Date	Hexavalent Chromium (µg/L)	Dissolved Chromium (µg/L)	Specific Conductance (µS/cm)	pH (pH units)
Groundwater Monitoring Wells						
MW-33-150	DA	10/09/2007	9.40	8.30	15,600	7.71 J
MW-33-210	DA	10/06/2006	10.2	10.0	20,100	7.25 J
		12/11/2006	11.1	8.00	22,200	7.46
		03/05/2007	11.2	11.0	18,900	7.45
		05/02/2007	9.20	9.30	18,800	7.46 J
		10/05/2007	11.9	11.5	17,500	7.30 J
MW-34-55	MA	10/04/2006	ND (0.2)	ND (1.0)	2,410	7.98
		10/03/2007	ND (0.2)	ND (1.0)	1,160	---
MW-34-80	DA	10/04/2006	ND (1.0)	ND (1.0)	14,200	7.00
		11/16/2006	ND (1.0)	ND (1.0)	---	---
		12/12/2006	ND (1.0)	ND (1.0)	11,900	7.39
		01/09/2007	ND (1.0)	3.20	---	---
		02/05/2007	ND (1.0)	ND (1.0)	---	---
		03/05/2007	ND (1.0)	ND (1.0)	10,000	7.33
		04/02/2007	ND (0.2)	ND (1.0)	---	---
		04/30/2007	ND (1.0)	1.10	10,000	7.40 J
		06/13/2007	ND (1.0)	ND (1.0)	---	---
		07/11/2007	ND (1.0)	ND (1.0)	---	---
		08/08/2007	ND (1.0)	ND (1.0)	---	---
		09/06/2007	ND (1.0)	ND (1.0)	---	---
		10/03/2007	ND (0.2)	ND (1.0)	8,790	---
MW-34-100	DA	10/04/2006	910	889	19,000	7.28
		10/18/2006	815	920	---	---
		11/01/2006	832	752	---	---
		11/16/2006	777	801	---	---
		11/30/2006	744	712	---	---
		12/12/2006	851	625 J	18,500	7.78
		12/28/2006	723	603	---	---
		01/09/2007	797	830	---	---
		01/24/2007	832	817	---	---
		02/05/2007	780	646	---	---
		02/21/2007	804	895	---	---
		03/07/2007	806	788	16,400	7.76
		03/21/2007	724	642	---	---
		04/02/2007	749	800	---	---
		04/18/2007	687	641	---	---
		04/30/2007	632	572	16,500	7.68 J
		05/16/2007	588	573	---	---
		05/30/2007	597	656	---	---
		06/13/2007	609	644	---	---
		06/27/2007	574	536	---	---
		07/12/2007	558	521	---	---
		07/25/2007	560	627	---	---
		08/08/2007	596	670	---	---
		08/22/2007	550	490	---	---
		09/06/2007	551	581	---	---
		09/19/2007	501	603	---	---
		10/03/2007	521	609 J	16,100	---
MW-35-60	SA	10/12/2006	28.6	29.1	8,850	7.43

TABLE 6-4

Groundwater Analytical Results for Chromium, Specific Conductance and pH, October 2006 through October 2007

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Well ID [1]	Monitoring Zone [2]	Sample Date	Hexavalent Chromium (µg/L)	Dissolved Chromium (µg/L)	Specific Conductance (µS/cm)	pH (pH units)
Groundwater Monitoring Wells						
MW-35-60	SA	03/08/2007	31.3	35.1	6,750	7.53
		10/01/2007	24.8	21.3	7,270	7.51 J
MW-35-135	DA	10/12/2006	35.4	34.6	9,570	7.60
		03/08/2007	32.0	39.2	9,820	7.76
		05/04/2007	27.8	26.2	10,800	7.65 J
		10/01/2007	32.4	28.9	9,150	7.83 J
MW-36-20	SA	10/02/2006	ND (1.0)	ND (1.0)	20,500	7.33
		10/03/2007	ND (1.0)	ND (1.0)	23,500	---
MW-36-40	SA	10/05/2006	ND (1.0)	ND (1.0)	11,600	7.30
		10/03/2007	ND (1.0)	ND (1.0)	8,390	---
MW-36-50	MA	10/05/2006	ND (0.2)	ND (1.0)	3,240 J	7.37
		10/10/2007	ND (0.2)	2.00	3,360	7.88 J
MW-36-70	MA	10/02/2006	ND (0.2)	ND (1.0)	4,900	7.81
		12/14/2006	ND (0.2)	ND (1.0)	3,580	7.75
		03/07/2007	ND (0.2)	ND (1.0)	2,780	7.93
		05/01/2007	ND (0.2)	ND (1.0)	2,210	8.02 J
		10/09/2007	ND (0.2)	ND (1.0)	1,520	8.29 J
MW-36-90	DA	10/02/2006	9.00	8.50	7,960	7.58
		11/15/2006	ND (1.0)	2.40	---	---
		12/14/2006	4.00	5.80 J	7,420	7.51
		01/10/2007	6.00	9.70	---	---
		02/05/2007	5.40	4.90	---	---
		03/07/2007	3.10	3.70	7,060	7.54
		04/03/2007	2.90	3.20	---	---
		05/02/2007	2.00	1.80	6,170	7.54 J
		06/12/2007	2.60	2.80	---	---
		07/12/2007	2.90	3.10	---	---
		08/07/2007	3.00	3.60	---	---
		09/06/2007	2.90	3.60	---	---
		10/09/2007	3.20	2.90	3,210	7.84 J
MW-36-100	DA	10/11/2006	556	629	17,500 J	7.16
		11/14/2006	657	764	---	---
		12/11/2006	586	513	16,400	7.22
		01/10/2007	571	554	---	---
		02/05/2007	538	474	---	---
		03/08/2007	436	454	14,100	7.33
		04/02/2007	366	378	---	---
		05/02/2007	297	348	13,500	7.25 J
		06/14/2007	181	192	---	---
		07/12/2007	180	219	---	---
		08/07/2007	159 J	187	---	---
		09/06/2007	157	184	---	---
		10/10/2007	228	196	12,500	7.27 J
MW-37S	MA	10/13/2006	7.60	6.10	4,580	7.73
		03/07/2007	7.80	8.50	4,640	7.86
		10/04/2007	7.70	7.50	4,530	7.91 J
MW-37D	DA	10/13/2006	1,330	1,160	15,900	7.68
		12/14/2006	1,310	1,130	17,000	7.85

TABLE 6-4

Groundwater Analytical Results for Chromium, Specific Conductance and pH, October 2006 through October 2007

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Well ID [1]	Monitoring Zone [2]	Sample Date	Hexavalent Chromium (µg/L)	Dissolved Chromium (µg/L)	Specific Conductance (µS/cm)	pH (pH units)
Groundwater Monitoring Wells						
MW-37D	DA	03/07/2007	1,420	1,310	14,700	7.84
		05/03/2007	1,350	1,260	14,400	7.56 J
		10/04/2007	834	794	13,600	7.78 J
MW-38S	SA	10/12/2006	846	905	3,480 J	7.49
		07/17/2007	911	920	---	---
MW-38D	DA	10/12/2006	104	104	27,100	7.38
		05/03/2007	68.9	69.6	21,000	7.82 J
		07/17/2007	104	72.1	---	---
MW-39-40	SA	10/05/2006	ND (0.2)	ND (1.0)	7,890	7.18
		12/14/2006	ND (1.0)	ND (1.0)	9,940	7.08
		03/05/2007	ND (1.0)	ND (1.0)	9,480	7.43
		05/03/2007	ND (1.0) J	ND (1.0)	9,490	7.26 J
		10/08/2007	ND (1.0)	ND (1.0)	10,800	7.18 J
MW-39-50	MA	10/05/2006	ND (0.2)	ND (1.0)	7,370	7.31
		10/08/2007	ND (0.2)	ND (1.0)	3,660	7.98 J
MW-39-60	MA	10/05/2006	ND (2.0)	ND (1.0)	7,800	7.38
		10/08/2007	ND (0.2)	ND (1.0)	4,550	7.72 J
MW-39-70	MA	10/05/2006	112	103	8,020	7.23
		12/14/2006	101	94.0	8,250	7.27
		03/05/2007	35.0	37.2	8,250	7.31
		05/03/2007	10.1 R	10.4	6,920	7.42 J
		06/07/2007	4.50	4.30	---	---
		10/08/2007	5.50	6.20	5,420	7.56 J
MW-39-80	DA	10/05/2006	580	594	16,600	7.09
		11/15/2006	339	422	---	---
		12/14/2006	326	272	18,000	7.12
		01/10/2007	302	292	---	---
		02/08/2007	286	247	---	---
		03/05/2007	151	144	13,300	7.10
		04/04/2007	112	126	---	---
		05/03/2007	156	146	12,400	7.27 J
		06/12/2007	83.6	72.7	---	---
		07/12/2007	62.8	56.2	---	---
		08/08/2007	43.3	45.2	---	---
		09/06/2007	65.3	65.7	---	---
		10/08/2007	58.6	48.3	11,800	7.24 J
MW-39-100	DA	10/11/2006	3,370	3,500	20,000	7.02
		11/15/2006	2,960	3,190	---	---
		12/12/2006	3,820	3,350	21,300	7.27
		01/10/2007	2,930	2,560	---	---
		02/08/2007	2,880	2,400	---	---
		03/12/2007	2,850	2,770	18,700	7.20
		04/04/2007	3,190	2,990	---	---
		05/03/2007	2,670	2,920	18,600	7.20 J
		06/13/2007	2,530	2,730	---	---
		07/12/2007	2,020	2,430	---	---
		08/07/2007	1,830	1,780	---	---
		09/07/2007	1,660	1,690	---	---

Well ID[1]	Monitoring Zone[2]	Sample Date	Hexavalent Chromium (µg/L)	Dissolved Chromium (µg/L)	Specific Conductance (µS/cm)	pH (pH units)
Groundwater Monitoring Wells						
MW-39-100	DA	10/10/2007	1,660	1,840	18,600	7.07 J
MW-40S	SA	10/05/2006	5.20	5.10	2,120	7.53
		10/04/2007	5.70	7.40	2,040	7.80 J
MW-40D	DA	10/05/2006	104	86.1	18,600	7.37
		12/13/2006	110	99.0	17,900	7.54
		03/09/2007	104	91.6	15,300	7.68
		05/04/2007	78.0	79.6	15,300	7.60 J
		10/04/2007	112	104	14,600	7.44 J
MW-41S	SA	10/05/2006	19.6	19.0	4,780	7.69
		03/08/2007	19.9	20.9	4,710	7.96
		10/03/2007	19.6	18.2	4,650	---
MW-41M	DA	10/05/2006	10.5	9.70	16,400	7.66
		03/08/2007	10.0	12.0	14,500	7.76
		10/03/2007	10.5	8.80	14,100	---
MW-41D	DA	10/04/2006	ND (1.0)	ND (1.0)	22,300	7.54 R
		03/07/2007	ND (1.0)	ND (1.0)	20,800	7.86
		10/03/2007	ND (1.0)	1.30	20,000	---
MW-42-30	SA	10/03/2006	ND (1.0)	ND (1.0)	19,400	7.14
		03/07/2007	ND (0.2)	ND (1.0)	13,300	7.38
		10/04/2007	ND (1.0)	ND (1.0)	20,600	7.17 J
MW-42-55	MA	10/03/2006	ND (1.0)	ND (1.0)	17,500	7.16
		12/14/2006	ND (2.0)	ND (1.0)	18,500	7.21
		03/07/2007	ND (0.2)	ND (1.0)	15,200	7.35
		05/01/2007	ND (1.0)	ND (1.0)	15,400	7.33 J
		10/04/2007	ND (1.0)	ND (1.0)	13,900	7.30 J
MW-42-65	MA	10/03/2006	ND (1.0)	ND (1.0)	19,900	7.02
		12/14/2006	ND (2.0)	ND (1.0)	22,300	7.12
		03/07/2007	ND (0.2)	ND (1.0)	17,500	7.06
		05/01/2007	ND (1.0)	ND (1.0)	16,300	7.10 J
		10/03/2007	ND (1.0)	ND (1.0)	14,400	---
MW-43-25	SA	10/02/2006	ND (0.2)	ND (1.0)	1,190	7.46
		03/06/2007	ND (0.2)	ND (1.0)	1,250	7.55
		10/02/2007	ND (1.0)	ND (1.0)	1,210	7.46 J
MW-43-75	DA	10/02/2006	ND (1.0)	ND (1.0)	17,400	7.49
		12/12/2006	ND (1.0)	ND (1.0)	16,300	7.48
		03/06/2007	ND (1.0)	ND (1.0)	13,800	7.47
		04/30/2007	ND (1.0)	ND (1.0)	13,600	7.46 J
		10/02/2007	ND (1.0)	ND (1.0)	13,400	7.53 J
MW-43-90	DA	10/02/2006	ND (1.0)	ND (1.0)	26,000	7.14
		12/12/2006	ND (1.0)	ND (1.0)	24,300	6.97
		03/06/2007	ND (1.0)	ND (1.0)	19,700	6.99
		04/30/2007	ND (1.0)	ND (1.0)	19,800	6.99 J
		10/02/2007	ND (1.0)	ND (1.0)	18,200	6.93 J
MW-44-70	MA	10/04/2006	ND (1.0)	ND (1.0)	8,220	7.16
		12/14/2006	ND (1.0)	ND (1.0)	6,640	7.48
		03/09/2007	ND (1.0)	ND (1.0)	6,320	7.50
		05/03/2007	ND (0.2)	ND (1.0)	5,890	7.38 J
		10/04/2007	ND (0.2)	ND (1.0)	4,790	7.65 J

Well ID [1]	Monitoring Zone [2]	Sample Date	Hexavalent Chromium (µg/L)	Dissolved Chromium (µg/L)	Specific Conductance (µS/cm)	pH (pH units)
Groundwater Monitoring Wells						
MW-44-115	DA	10/05/2006	1,300	1,310	13,800	7.55
		10/18/2006	1,250	1,380	---	---
		11/15/2006	1,210	1,480	---	---
		12/12/2006	1,310	1,090	15,200	7.89
		01/09/2007	1,140	1,260	---	---
		02/06/2007	1,140	1,020	---	---
		03/09/2007	1,210	1,340	13,000	7.81
		04/02/2007	1,210	1,420	---	---
		05/04/2007	1,080	1,190	13,200	7.81 J
		06/14/2007	1,030	1,110	---	---
		07/10/2007	919	1,060	---	---
		08/06/2007	834	924	---	---
		09/05/2007	872	850	---	---
		10/04/2007	783	866	12,300	7.95 J
MW-44-125	DA	10/05/2006	284	280	15,300	7.82
		10/18/2006	308	327	---	---
		11/15/2006	320	363	---	---
		12/13/2006	300	321	17,700	8.19
		01/09/2007	285	285	---	---
		02/06/2007	213	190	---	---
		03/09/2007	258	287	12,300	7.85
		04/03/2007	296	272	---	---
		05/03/2007	300	315	12,200	7.87 J
		06/14/2007	229	258	---	---
		07/11/2007	252	283	---	---
		08/07/2007	278	251	---	---
		09/04/2007	255	253	---	---
		10/04/2007	314	347	11,900	7.85 J
MW-45-095a	DA	05/04/2007	169	140	10,100	7.57 J
MW-46-175	DA	10/05/2006	195	192	17,700	7.92
		10/18/2006	204	253	---	---
		11/15/2006	163	147	---	---
		12/13/2006	187	174	21,900	8.36
		01/10/2007	138	133	---	---
		02/08/2007	130	108	---	---
		03/08/2007	153	147	16,200	8.47
		04/03/2007	113	95.8	---	---
		05/04/2007	86.4	114	16,100	8.35 J
		06/14/2007	101	109	---	---
		07/13/2007	103	101	---	---
		08/06/2007	94.0	98.9	---	---
		09/04/2007	88.1	94.8	---	---
		10/05/2007	100	86.7	15,500	8.45 J
MW-46-205	DA	10/05/2006	2.10	2.30	18,000	7.94
		12/13/2006	3.20	3.00	23,400	8.26
		03/08/2007	4.00	5.40	19,900	8.32
		05/04/2007	3.90	3.10	20,400	7.49 J
		10/05/2007	3.70	4.60	18,900	8.32 J
MW-47-55	SA	10/10/2006	56.9	56.8	3,670	7.56

Well ID [1]	Monitoring Zone [2]	Sample Date	Hexavalent Chromium (µg/L)	Dissolved Chromium (µg/L)	Specific Conductance (µS/cm)	pH (pH units)
Groundwater Monitoring Wells						
MW-47-55	SA	12/14/2006	61.2	82.0	3,960	7.69
		03/06/2007	54.6	53.0	3,610	7.70
		05/04/2007	30.3	31.6	3,990	7.64 J
		10/04/2007	61.9	59.2	3,660	7.79 J
MW-47-115	DA	10/10/2006	ND (3.5)	6.90	14,600	7.46
		12/14/2006	7.90	6.10	17,400	7.76
		03/06/2007	10.6	10.8	12,500	7.77
		05/04/2007	14.1	13.0	12,700	7.68 J
		10/04/2007	11.6	12.2	12,200	7.69 J
MW-48	BR-Tmc	10/06/2006	ND (1.0)	ND (1.0)	17,600	7.19 J
		12/15/2006	ND (2.0)	ND (1.0)	22,300	7.60
		03/07/2007	ND (1.0)	ND (1.0)	17,400	7.89
		05/01/2007	ND (1.0)	1.00	17,900	7.37 J
		10/04/2007	ND (1.0)	ND (1.0)	16,500	7.30 J
MW-49-135	DA	10/12/2006	ND (1.0)	ND (1.0)	17,000	7.24
		12/15/2006	ND (1.0)	ND (1.0)	15,700	7.55
		03/09/2007	ND (1.0)	ND (1.0)	13,500	7.67
		05/04/2007	ND (0.2)	ND (1.0)	13,400	7.83 J
		10/10/2007	ND (1.0)	2.80	12,300	7.81 J
MW-49-275	DA	10/12/2006	ND (1.0)	ND (1.0)	30,300	7.71
		12/15/2006	ND (1.0)	ND (1.0)	31,500	8.05
		03/09/2007	ND (1.0)	ND (1.0)	23,700	8.10
		05/04/2007	ND (0.2)	ND (1.0)	23,400	8.05 J
		10/09/2007	ND (1.0)	ND (1.0)	22,200	8.20 J
MW-49-365	DA	10/12/2006	ND (2.0)	ND (1.0)	46,000	7.05 R
		12/15/2006	ND (2.0)	1.10	45,700	7.91
		03/09/2007	ND (2.0)	ND (1.0)	36,100	7.98
		05/04/2007	ND (0.2)	ND (1.0)	36,900	7.91 J
		10/09/2007	ND (2.0)	ND (1.0)	34,200	8.08 J
MW-50-095	MA	10/10/2006	278	277	4,660	7.53
		12/12/2006	273	262	4,790	7.85
		03/07/2007	274	372	4,770	7.98
		05/02/2007	304	264	4,810	7.87 J
		10/04/2007	217	216	4,660	8.06 J
MW-50-200	DA	10/10/2006	9,660	11,800	18,400	7.34
		12/12/2006	10,100	9,250	23,400	7.90
		03/07/2007	12,300	14,600	20,700	7.92
		04/30/2007	10,900	12,100	20,300	7.83 J
		10/04/2007	9,430	9,780	18,800	7.37 J
MW-51	MA	10/06/2006	4,560	4,590	11,800	7.40 J
		12/12/2006	4,620	5,360	9,980	7.66
		03/06/2007	4,690	5,090	10,500	7.56
		05/01/2007	4,670	5,120	11,100	7.52 J
		10/05/2007	4,500	4,340	10,100	7.59 J
MW-52S	MA	03/13/2007	ND (1.0)	ND (1.0)	---	---
		05/01/2007	ND (1.0)	ND (1.0)	---	---
		06/05/2007	ND (1.0)	ND (1.0)	10,600	7.40 J
		07/12/2007	ND (1.0)	ND (1.0)	11,600	7.48 J

TABLE 6-4
Groundwater Analytical Results for Chromium, Specific Conductance and pH, October 2006 through October 2007
RCRA Facility Investigation/Remedial Investigation Report (Volume 2)
PG&E Topock Compressor Station, Needles, California

Well ID [1]	Monitoring Zone [2]	Sample Date	Hexavalent Chromium (µg/L)	Dissolved Chromium (µg/L)	Specific Conductance (µS/cm)	pH (pH units)
Groundwater Monitoring Wells						
MW-52S	MA	08/08/2007	ND (1.0)	ND (1.0)	11,600	7.65 J
		09/05/2007	ND (1.0)	ND (1.0)	10,800	7.45 J
		10/11/2007	ND (1.0)	ND (1.0)	11,000	7.50 J
MW-52M	DA	03/13/2007	ND (1.0)	ND (1.0)	---	---
		05/01/2007	ND (1.0)	ND (1.0)	---	---
		06/05/2007	ND (1.0)	ND (1.0)	16,100	7.94 J
		07/12/2007	ND (1.0)	ND (1.0)	15,900	7.77 J
		08/08/2007	ND (1.0)	ND (1.0)	16,400	7.94 J
		09/05/2007	ND (1.0)	ND (1.0)	15,100	7.93 J
		10/11/2007	ND (1.0)	ND (1.0)	15,800	8.01 J
MW-52D	DA	03/13/2007	ND (1.0)	ND (1.0)	---	---
		05/01/2007	ND (1.0)	ND (1.0)	---	---
		06/05/2007	ND (1.0)	ND (1.0)	20,700	8.03 J
		07/12/2007	ND (1.0)	ND (1.0)	20,600	7.44 J
		08/08/2007	ND (1.0)	ND (1.0)	20,500	7.96 J
		09/05/2007	ND (1.0)	ND (1.0)	19,200	7.98 J
		10/11/2007	ND (1.0)	ND (1.0)	19,700	8.02 J
MW-53M	DA	04/03/2007	ND (1.0)	ND (1.0)	---	---
		05/01/2007	ND (1.0)	ND (1.0)	---	---
		06/05/2007	ND (1.0)	ND (1.0)	14,400	8.71 J
		07/12/2007	ND (1.0)	ND (1.0)	15,400	8.52 J
		08/08/2007	ND (1.0)	ND (1.0)	16,200	8.50 J
		09/05/2007	ND (1.0)	ND (1.0)	15,500	8.48 J
		10/11/2007	ND (1.0)	ND (1.0)	16,900	8.57 J
MW-53D	DA	04/03/2007	ND (1.0)	ND (1.0)	---	---
		05/02/2007	ND (1.0)	1.41	---	---
		06/05/2007	ND (1.0)	ND (1.0)	26,100	8.91 J
		07/12/2007	ND (1.0)	ND (1.0)	25,500	8.79 J
		08/08/2007	ND (1.0)	ND (1.0)	25,700	8.98 J
		09/05/2007	ND (1.0)	ND (1.0)	24,200	8.67 J
		10/11/2007	ND (2.0)	ND (1.0) J	24,800	8.85 J
CW-1M	MA	10/11/2006	12.7	12.1	6,190	7.86 R
		05/02/2007	6.90	8.08	6,800	7.66 J
		10/17/2007	3.90 J	4.81	6,450	7.91 J
CW-1D	DA	10/10/2006	ND (1.0)	1.30	6,700	7.76
		05/02/2007	ND (1.0)	ND (1.0)	6,900	7.85 J
		10/17/2007	ND (0.2)	1.05	6,470	7.96 J
CW-2M	MA	10/11/2006	15.6	14.3	6,110	7.76 R
		05/04/2007	15.3	16.0	6,360	7.85 J
		10/18/2007	14.5	15.1	6,340	7.93 J
CW-2D	DA	10/11/2006	3.00	2.60	12,300	7.80 R
		05/04/2007	1.80	4.31	8,410	8.08 J
		10/18/2007	ND (1.0)	1.55	6,760	8.27 J
CW-3M	MA	10/10/2006	11.3	9.40	7,820	7.71 R
		05/02/2007	11.4	11.4	8,620	7.78 J
		10/18/2007	11.8	11.9	7,820	7.75 J
CW-3D	DA	10/11/2006	2.50	2.00	13,100	7.56 R
		05/02/2007	4.70	4.95	11,400	7.99 J

Well ID [1]	Monitoring Zone [2]	Sample Date	Hexavalent Chromium (µg/L)	Dissolved Chromium (µg/L)	Specific Conductance (µS/cm)	pH (pH units)
Groundwater Monitoring Wells						
CW-3D	DA	10/18/2007	2.50	2.63	7,970	8.09 J
CW-4M	MA	10/11/2006	21.2	16.8	5,310	7.76 R
		05/01/2007	20.8	21.8	5,720	7.86 J
		10/18/2007	21.0	21.7	5,560	7.86 J
CW-4D	DA	10/11/2006	2.30	2.40	11,500	7.75 R
		05/01/2007	2.80	3.60	10,500	7.97 J
		10/18/2007	3.40	3.73	9,700	8.02 J
OW-1S	SA	10/10/2006	19.9	16.2	2,090	7.67
		01/24/2007	20.1	18.8	2,070 J	7.63
		05/01/2007	18.0	20.0	2,380	7.69 J
		08/09/2007	19.8	19.4	2,400	7.82 J
		10/16/2007	21.6	19.7	2,220	7.85 J
OW-1M	MA	10/10/2006	0.81	ND (1.0)	6,180	7.70
		01/25/2007	ND (1.0)	1.50	6,150 J	7.71 R
		05/01/2007	0.75	1.31	6,540	7.72 J
		08/09/2007	0.57	ND (1.0)	6,590	7.90 J
		10/16/2007	1.10	ND (1.0)	6,710	7.73 J
OW-1D	DA	10/12/2006	1.00	ND (1.0)	8,380	7.71 R
		01/25/2007	ND (1.0)	ND (1.0)	6,040 J	7.75 R
		05/02/2007	ND (1.0)	1.75	6,610	7.81 J
		08/09/2007	0.50	1.10	6,540	7.73 J
		10/16/2007	1.00	1.15	6,360	7.93 J
OW-2S	SA	10/10/2006	34.8	36.2	1,700	7.91
		11/21/2006	38.0	40.0	---	---
		01/24/2007	37.2	38.8	1,680 J	7.82
		04/30/2007	35.0	37.4	1,780	8.01 J
		08/09/2007	35.1	32.3	1,780	8.07 J
		10/17/2007	34.1	33.6	1,680	8.05 J
OW-2M	MA	10/10/2006	1.40	ND (1.0)	6,570 J	7.68
		01/24/2007	2.40	2.90	5,740 J	7.50
		04/12/2007	---	---	---	7.71
		04/30/2007	1.50	2.50	6,580	7.82 J
		08/09/2007	0.76	ND (1.0)	6,550	7.80 J
		10/16/2007	1.20	1.11	6,750	7.72 J
OW-2D	DA	10/10/2006	0.24	ND (1.0)	6,020	7.67
		01/24/2007	ND (0.2)	ND (1.0)	6,140 J	7.61
		04/30/2007	0.29	ND (1.0)	6,500	7.80 J
		08/09/2007	0.60	ND (1.0)	6,580	7.83 J
		10/17/2007	ND (0.2)	ND (1.0)	6,860	7.73 J
OW-3S	SA	10/12/2006	22.1	20.7	1,640	7.37
		03/09/2007	22.8	22.1	1,730	7.71
		04/30/2007	20.0	23.4	1,850	7.65 J
		10/03/2007	22.3	21.8	1,690	---
OW-3M	MA	10/12/2006	17.9	20.0 J	5,100	7.49
		03/09/2007	18.3	17.0	5,100	8.07
		05/01/2007	17.8	18.2	5,240	8.01 J
		10/03/2007	16.5 J	18.5	4,980	---
OW-3D	DA	10/06/2006	2.70	3.60	7,630	7.70 J

TABLE 6-4

Groundwater Analytical Results for Chromium, Specific Conductance and pH, October 2006 through October 2007

RCRA Facility Investigation/Remedial Investigation Report (Volume 2)

PG&E Topock Compressor Station, Needles, California

Well ID[1]	Monitoring Zone[2]	Sample Date	Hexavalent Chromium (µg/L)	Dissolved Chromium (µg/L)	Specific Conductance (µS/cm)	pH (pH units)
Groundwater Monitoring Wells						
OW-3D	DA	03/09/2007	3.10	3.00	7,680	8.18
		10/03/2007	3.90	4.20	7,710	---
OW-5S	SA	10/10/2006	25.4	22.1	1,590	7.76
		01/25/2007	27.8	28.5	1,450 J	7.96 R
		04/30/2007	24.1	25.6	1,760	7.82 J
		08/09/2007	26.5	25.3	1,660	7.87 J
		10/17/2007	26.3	25.6	1,580	7.94 J
OW-5M	DA	10/11/2006	2.00	2.00	6,870	7.91 R
		01/25/2007	ND (0.2)	1.50	6,090 J	7.83 R
		04/30/2007	0.36	ND (1.0)	6,980	7.83 J
		08/08/2007	2.50	3.00	6,800	7.80 J
		10/17/2007	ND (1.0)	ND (1.0)	6,630	7.79 J
OW-5D	DA	10/11/2006	ND (0.2)	ND (1.0)	6,550	7.88 R
		01/25/2007	ND (0.2)	ND (1.0)	6,080 J	7.72 R
		05/01/2007	ND (0.2)	ND (1.0)	6,480	7.74 J
		08/09/2007	ND (0.2)	ND (1.0)	6,860	7.69 J
		10/17/2007	ND (0.2)	1.38	6,920	7.69 J
PGE-7BR	BR-pTbr	12/19/2007	ND (1.0)	ND (1.0)	---	---
Extraction, Test & Injection Wells						
P-2	DA	05/02/2007	2.50	2.70	5,340	7.72 J
PE-1	DA	10/04/2006	90.1	83.9	10,300	7.18
		11/01/2006	92.5	83.3	10,800	7.56
		12/06/2006	97.2	85.8	10,000	7.48
		01/10/2007	88.9	103	8,410	7.75
		02/06/2007	80.8	89.5	8,390	7.49
		03/07/2007	84.7	91.0	8,360	7.52
		06/13/2007	52.0	48.1	7,650	7.52 J
		07/11/2007	47.1	39.7	7,450	7.55 J
		08/08/2007	51.4	60.7	7,290	7.59 J
		09/05/2007	49.1	49.2	6,590	7.55 J
		10/03/2007	52.6	45.4	6,550	7.53 J
PGE-8	BR-pTbr	08/11/2007	ND (1.0)	ND (1.0)	18,000	8.46 J
TW-1	SA-MA-DA	10/11/2007	4,610	4,220	6,200	7.54 J
TW-2S	SA-MA	10/04/2006	1,920	2,130	2,690	7.55
		10/04/2007	1,250	1,220	2,380	7.93 J
TW-2D	DA	10/04/2006	872	910	9,320	7.23
		10/04/2007	210	228	7,350	7.40 J
TW-3D	DA	10/04/2006	2,470	2,460	10,500	7.02
		11/01/2006	2,490	3,180	10,600	7.34
		12/06/2006	2,500	2,090	10,000	7.38
		01/10/2007	2,440	2,580	8,670	7.34
		02/06/2007	2,400	2,310	8,610	7.30
		03/07/2007	2,420	2,500	8,740	7.37
		06/13/2007	2,000	2,350	8,670	7.32 J
		07/11/2007	2,000	2,390	8,750	7.37 J
		08/08/2007	1,930	1,800	8,660	7.28 J
		09/05/2007	2,260	2,110	7,750	7.28 J
		10/03/2007	2,000	1,860	8,200	7.29 J

TABLE 6-4

Groundwater Analytical Results for Chromium, Specific Conductance and pH, October 2006 through October 2007

RCRA Facility Investigation/Remedial Investigation Report (Volume 2)

PG&E Topock Compressor Station, Needles, California

Well ID [1]	Monitoring Zone [2]	Sample Date	Hexavalent Chromium (µg/L)	Dissolved Chromium (µg/L)	Specific Conductance (µS/cm)	pH (pH units)
Extraction, Test & Injection Wells						
TW-4	DA	10/09/2006	28.5	26.6	21,900	7.25
		03/07/2007	35.5	36.9	20,800	7.85
		10/03/2007	33.6	32.7	19,600	---
TW-5	DA	10/09/2006	3.60	3.20	14,900	7.67
		10/04/2007	6.60	7.50	12,200	7.91 J
In-Situ Pilot Test Wells (Baseline Sampling)						
PT-7S	SA	07/18/2007	1,200	1,260	---	---
PT-7M	MA	07/19/2007	2,320	2,240	---	---
PT-7D	DA	07/18/2007	7,260	7,890	---	---
PT-8S	SA	07/16/2007	1,750	1,660	---	---
PT-8M	MA	07/18/2007	3,960	4,120	---	---
PT-8D	DA	07/16/2007	6,540	7,260	---	---
PT-9S	SA	07/17/2007	1,180	1,150	---	---
PT-9M	MA	07/17/2007	2,340	2,270	---	---
PT-9D	DA	07/17/2007	15,700	15,600	---	---
PTR-1	MA-DA	07/19/2007	538	713	---	---
PTR-2	MA-DA	07/18/2007	3,190	3,380	---	---
Water Supply Wells						
Park Moabi-3	MA	10/04/2006	2.00	6.30	1,150	7.25
		05/02/2007	0.90	1.30 *	1,890	7.82 J
		10/04/2007	ND (1.0)	ND (1.0) *	1,920	7.93 J
Park Moabi-4	MA	05/02/2007	ND (0.2)	ND (1.0) *	1,530	7.99 J
		10/04/2007	21.4	23.5 *	1,720	8.14 J

Notes:

Results shown are maximum concentrations in primary and duplicate samples for sampling events listed.

Groundwater samples collected using conventional casing volume purge method.

Samples which were analyzed dissolved chromium (total) were field-filtered, except where noted.

[1] New bedrock monitoring well PGE-7BR was first sampled in December 2007 and is included in the RFI/RI characterization.

[2] Monitoring Zone:
SA - Shallow zone of the Alluvial Aquifer
MA - Mid-depth zone of the Alluvial Aquifer
DA - Deep zone of the Alluvial Aquifer
BR-Tmc - Bedrock well, completed in Miocene Conglomerate
BR-pTbr - Bedrock well, completed in pre-Tertiary crystalline bedrock

ND	not detected at listed reporting limit
J	concentration or reporting limit estimated by laboratory or data validation
R	result exceeded analytical criteria for precision and accuracy; should not be used for project decision-making
µS/cm	microsiemens per centimeter
µg/L	micrograms per liter
(---)	data not collected or available
*	total metal concentrations from samples that were not filtered

TABLE 6-5

Summary of Specific Conductance and pH Groundwater Results, July 1997 through October 2007
RCRA Facility Investigation/Remedial Investigation Report (Volume 2)
PG&E Topock Compressor Station, Needles, California

Monitoring Zone [1]	Results Summary for RFI/RI Wells				
	Number of Wells Sampled	Number of Primary Samples	Average Result	Minimum Result	Maximum Result
Specific Conductance (µS/cm)					
Shallow Zone	47	976	5,967	602	65,300
Middle Zone	31	337	7,218	877	22,300
Deep Zone	50	523	14,451	1,430	46,000
Bedrock Wells	4	87	16,545	10,200	29,900
pH (pH units)					
Shallow Zone	47	965	7.64	6.26	9.00
Middle Zone	31	322	7.66	6.65	8.36
Deep Zone	50	492	7.74	5.50	9.44
Bedrock Wells	4	87	8.08	6.83	12.62

Notes:

[1] Monitoring zone refers to depth in Alluvial Aquifer or wells completed in Bedrock.

TABLE 6-6

Summary of Cr(T), Cr(VI), Cu, Pb, Ni, and Zn Groundwater Results, July 1997 through October 2007
RCRA Facility Investigation/Remedial Investigation Report (Volume 2)
PG&E Topock Compressor Station, Needles, California

	Results Summary for RFI/RI Wells [1]						Background Comparison [2]				Chemical-Specific ARAR [3]			
Parameter	Number of Wells Sampled	Number of Primary Samples	Number of Detects	Detection Frequency %	Average Concentration (µg/L)	Maximum Concentration (µg/L)	UTL Value (µg/L)	Number of Wells with Average Exceeding UTL[4]	Number of Wells with Max Exceeding UTL	Frequency of UTL Exceedances	ARAR Value (µg/L)	Number of Wells with Average Exceeding ARAR[5]	Number of Wells with Max Exceeding ARAR	Frequency of ARAR Exceedances
Chromium, Hexavalent	167	2,926	1,750	59.8	921	15,700	31.8	63	73	1,142 / 2,926 (39.0%)	---	---	---	--- ---
Chromium (total)	166	2,945	1,956	66.4	917	16,400	34.1	66	79	1,129 / 2,945 (38.3%)	50	62	73	1,074 / 2,945 (36.5%)
Copper	89	1,133	421	37.2	10.5	306	10.5	24	47	96 / 1,133 (8.5%)	1,000	0	0	0 / 1,133 (0.0%)
Nickel	89	1,133	542	47.8	11.5	500	10.6	24	40	128 / 1,133 (11.3%)	100	0	9	10 / 1,133 (0.9%)
Lead	85	488	65	13.3	2.35	76	1.91	24	35	44 / 488 (9.0%)	15	3	8	9 / 488 (1.8%)
Zinc	89	1,133	826	72.9	67.6	1,870	77.7	20	48	230 / 1,133 (20.3%)	5,000	0	0	0 / 1,133 (0.0%)

Notes:

[1] See Table 4-4 for listing of wells in monitoring network.
- Wells Sampled is the number of wells sampled for each parameter.
- Number of Samples is the total number of primary samples analyzed for each parameter.
- Detection Frequency is the number of times each parameter was detected over the total number of samples analyzed.
- Average concentration is the average of all results using one-half the reporting limit for non detects. Rejected data is not included.
- For duplicate results, the highest concentration between the two results is included. If one result was found above the analytical reporting limit while the other was not, the detected concentration was used, regardless of the analytical reporting limit for the other result. If both results were found to be non-detect, the minimum reporting limit was used.

[2] Site background concentration is the 95% upper tolerance limit (UTL) of the elevated percentile from the Steps 3 and 4 Groundwater Background Study Report (CH2M HILL, 2008), see Table 6-3. Number of Exceedances is the number of times each parameter was detected above the background concentration.

[3] Chemical-specific applicable or relevant and appropriate requirements (ARARs) listed are the most stringent drinking water standard from regulatory standards, see Table 6-2.

[4] In several cases, the laboratory reporting limit was over two times the UTL and/or ARAR. Assigning half the reporting limit for these samples during calculation of averages will result in a UTL/ARAR exceedence being counted toward the average. As a result, many wells were found to have averages exceeding UTL/ARAR mainly due to this assignment.

µg/L	dissolved metals concentrations in micrograms per liter
---	not assigned or not applicable

TABLE 6-7

Groundwater Analytical Results for Total Petroleum Hydrocarbons, May - July 2007 Sampling Event

RCRA Facility Investigation/Remedial Investigation Report (Volume 2)

PG&E Topock Compressor Station, Needles, California

			Total Petroleum Hydrocarbons (SW8015)		
Well ID	**Sample Date**		**TPH as Gasoline**	**TPH as Diesel**	**TPH as Motor Oil**
Monitoring Wells					
MW-10	05/03/2007		ND (100)	ND (470)	ND (470)
MW-10	05/03/2007	(FD)	ND (100)	ND (470)	ND (470)
MW-11	05/03/2007		ND (100)	ND (470)	ND (470)
MW-12	05/03/2007		ND (100)	ND (500)	ND (500)
MW-24A	07/18/2007		ND (100)	ND (480)	ND (480)
MW-25	05/04/2007		ND (100)	ND (500)	ND (500)

Notes:

Results from PG&E's supplemental groundwater sampling.

Refer to Appendix H for complete analytical data for total petroleum hydrocarbons (TPH) analyses.

All concentrations in micrograms per liter (µg/L)

ND	not detected at listed reporting limit
FD	field duplicate sample

TABLE 6-8

Summary of Other Trace Metals Groundwater Results, July 1997 through October 2007
RCRA Facility Investigation/Remedial Investigation Report (Volume 2)
PG&E Topock Compressor Station, Needles, California

	Results Summary for RFI/RI Wells [1]						Background Comparison [2]				Chemical-Specific ARAR [3]			
Parameter	Number of Wells Sampled	Number of Samples	Number of Detects	Detection Frequency %	Average Concentration (µg/L)	Maximum Concentration (µg/L)	UTL Value (µg/L)	Number of Wells With Average Exceeding UTL [4]	Number of Wells with Max Exceeding UTL	Frequency of UTL Exceedances	ARAR Value (µg/L)	Number of Wells with Average Exceeding ARAR [4]	Number of Wells with Max Exceeding ARAR	Frequency of ARAR Exceedances
Aluminum	72	339	27	8.0	38.9	749	55.8	12	20	25 / 339 (7.4%)	200	0	2	2 / 339 (0.6%)
Antimony	66	387	9	2.3	2.60	155	1.22	38	8	9 / 387 (2.3%)	6	4	7	8 / 387 (2.1%)
Arsenic	109	464	217	46.8	7.50	157	24.3	3	4	26 / 464 (5.6%)	10	11	15	44 / 464 (9.5%)
Barium	111	578	418	72.3	116	5,300	195	17	9	12 / 578 (2.1%)	1,000	2	3	3 / 578 (0.5%)
Beryllium	66	377	19	5.0	0.953	8.80	0.663	36	13	19 / 377 (5.0%)	4	1	1	1 / 377 (0.3%)
Cadmium	66	377	1	0.3	0.934	10.5	---	---	---	--- ---	5	1	1	1 / 377 (0.3%)
Cobalt	66	377	15	4.0	1.34	10.0	0.843	39	9	15 / 377 (4.0%)	---	---	---	--- ---
Mercury	67	383	0	0.0	ND	ND	---	---	---	--- ---	2	0	0	0 / 383 (0.0%)
Molybdenum	85	577	542	93.9	27.7	301	36.3	22	33	138 / 577 (23.9%)	---	---	---	--- ---
Selenium	74	400	179	44.8	4.68	155	10.3	7	15	35 / 400 (8.8%)	50	1	1	1 / 400 (0.3%)
Silver	66	377	9	2.4	2.03	87.3	2.13	9	7	7 / 377 (1.9%)	100	0	0	0 / 377 (0.0%)
Thallium	66	377	3	0.8	2.31	1.20	0.908	36	3	3 / 377 (0.8%)	2	36	0	0 / 377 (0.0%)
Vanadium	85	475	401	84.4	20.1	326	59.9	1	28	35 / 475 (7.4%)	---	---	---	--- ---

Notes:

[1] See Table 4-4 for listing of wells in monitoring network.
- Wells Sampled is the number of wells sampled for each parameter.
- Number of Samples is the total number of primary samples analyzed for each parameter.
- Detection Frequency is the number of times each parameter was detected over the total number of samples analyzed.
- Average concentration is the average of all results using one-half the reporting limit for non detects. Rejected data is not included.
- For duplicate results, the highest concentration between the two results is included. If one result was found above the analytical reporting limit while the other was not, the detected concentration was used, regardless of the analytical reporting limit for the other result. If both results were found to be non-detect, the minimum reporting limit was used.

[2] Site background concentration is the 95% upper tolerance limit (UTL) of the elevated percentile from the Steps 3 and 4 Groundwater Background Study Report (CH2M HILL, 2008), see Table 6-3. Number of Exceedances is the number of times each parameter was detected above the background concentration.

[3] Chemical-specific applicable or relevant and appropriate requirements (ARARs) listed are the most stringent drinking water standard from regulatory standards, see Table 6-2.

[4] In several cases, the laboratory reporting limit was over two times the UTL and/or ARAR. Assigning half the reporting limit for these samples during calculation of averages will result in a UTL/ARAR exceedence being counted toward the average. As a result, many wells were found to have averages exceeding UTL/ARAR mainly due to this assignment.

ND	not detected
µg/L	dissolved metals concentrations in micrograms per liter
---	not assigned or not applicable

TABLE 6-9

Groundwater Analytical Results for Organic Compounds, 2004, 2005 and 2007 Sampling Events

RCRA Facility Investigation/Remedial Investigation Report (Volume 2)

PG&E Topock Compressor Station, Needles, California

			Volatile Organic Compounds (SW8260)			
Well ID	**Sample Date**		**Chloroform**	**All Other Analytes**	**Semivolatile Organic Compounds (SW8270)**	**Polychlorinated Biphenyls (SW8082)**
Monitoring Wells						
MW-10	06/10/2004		0.8	ND (0.5-10)	All analytes ND (10-30)	---
	07/29/2004		---	---	---	All analytes ND (0.3)
	05/03/2007		1.1	ND (1 - 80)	All analytes ND (9.4-55)	---
	05/03/2007	(FD)	ND (1)	ND (1 - 80)	All analytes ND (9.4-55)	---
MW-11	06/10/2004		ND (0.5) J	ND (0.5-10)	All analytes ND (10-30)	---
	07/29/2004		---	---	---	All analytes ND (0.3)
	05/03/2007		ND (1)	ND (1 - 80)	All analytes ND (9.4-55)	---
MW-12	06/09/2004		ND (0.5)	ND (0.5-10)	All analytes ND (10-30)	All analytes ND (0.3)
	06/09/2004	(FD)	ND (0.5)	ND (0.5-10)	All analytes ND (10-30)	All analytes ND (0.3)
	05/03/2007		ND (1)	ND (1 - 80)	All analytes ND (9.4-55)	---
MW-20-70	05/03/2007		ND (1)	ND (1 - 80)	All analytes ND (9.4-55)	---
MW-20-100	05/03/2007		1.3	ND (1 - 80)	All analytes ND (9.4-55)	---
MW-20-130	05/03/2007		ND (1)	ND (1 - 80)	All analytes ND (9.4-55)	---
MW-25	06/09/2004		ND (0.5)	ND (0.5-10)	All analytes ND (10-30)	All analytes ND (0.3)
	05/04/2007		ND (1)	ND (1 - 80)	All analytes ND (9.4-55)	---
MW-34-55	06/08/2004		---	---	All analytes ND (10-30)	---
	06/23/2004		ND (0.5)	ND (0.5-10)	---	---
MW-34-80	06/08/2004		---	---	All analytes ND (10-30)	---
	06/23/2004		ND (0.5)	ND (0.5-10)	---	---
MW-37D	06/11/2004		0.5	ND (0.5-10)	All analytes ND (10-30)	---
CW-2D	02/23/2005		ND (1)	ND (1 - 80)	All analytes ND (9.4-55)	---
	02/23/2005		---	---	---	---
OW-1D	09/30/2004		ND (0.5)	ND (1 - 80)	All analytes ND (9.4-55)	All analytes ND (0.3)
	09/30/2004		---	---	---	---
	05/10/2005		ND (1) J	ND (1 - 80)	All analytes ND (9.4-55)	---
OW-1M	05/10/2005		ND (1)	ND (1 - 80)	All analytes ND (9.4-55)	---
OW-1S	07/28/2005		---	---	---	---
	07/28/2005		ND (1)	ND (1 - 80)	All analytes ND (9.4-55)	---
	07/28/2005	(FD)	ND (1)	ND (1 - 80)	All analytes ND (9.4-55)	---
OW-2D	05/10/2005		ND (1)	ND (1 - 80)	All analytes ND (9.4-55)	---
OW-2M	05/11/2005		ND (1)	ND (1 - 80)	All analytes ND (9.4-55)	---
OW-2S	07/28/2005		ND (1)	ND (1 - 80)	All analytes ND (9.4-55)	---

TABLE 6-9

Groundwater Analytical Results for Organic Compounds, 2004, 2005 and 2007 Sampling Events

RCRA Facility Investigation/Remedial Investigation Report (Volume 2)

PG&E Topock Compressor Station, Needles, California

Well ID	Sample Date		Volatile Organic Compounds (SW8260)		Semivolatile Organic Compounds (SW8270)	Polychlorinated Biphenyls (SW8082)
			Chloroform	All Other Analytes		
Monitoring Wells						
OW-2S	07/28/2005		---	---	---	---
OW-5D	05/11/2005		ND (1)	ND (1 - 80)	All analytes ND (9.4-55)	---
OW-5M	05/11/2005		ND (1)	ND (1 - 80)	All analytes ND (9.4-55)	---
OW-5S	05/11/2005		ND (1)	ND (1 - 80)	All analytes ND (9.4-55)	---
	05/11/2005	(FD)	ND (1)	ND (1 - 80)	All analytes ND (9.4-55)	---
Extraction Wells						
TW-2D	07/29/2004		0.8	ND (0.5-10)	All analytes ND (10-30)	All analytes ND (0.3)
TW-2S	07/29/2004		ND (0.5)	ND (0.5-10)	All analytes ND (10-30)	All analytes ND (0.3)

Notes:

Results from PG&E's supplemental groundwater sampling.

Refer to Appendix H for complete analytical data for the volatile organic compounds, semivolatile organic compounds, and polychlorinated biphenyls analyses.

All concentrations in micrograms per liter (µg/L)

ND	not detected at listed reporting limit range
J	concentration or reporting limit estimated by laboratory or data validation
---	not analyzed
FD	field duplicate sample

TABLE 6-10

Groundwater Analytical Results for Perchlorate, 2003-2005 Sampling Events

RCRA Facility Investigation/Remedial Investigation Report (Volume 2)

PG&E Topock Compressor Station, Needles, California

Well ID	Sample Date		Perchlorate (µg/L)
Groundwater Wells			
MW-1	05/09/2005		ND (2)
	07/18/2005		ND (2)
MW-3	05/09/2005		2.43
	07/18/2005		ND (2)
MW-4	05/09/2005		ND (2)
	07/18/2005		ND (2)
MW-5	05/13/2005		3
	07/18/2005		3.77
MW-6	05/13/2005		ND (2)
	07/18/2005		ND (2)
MW-7	05/13/2005		ND (2)
	07/18/2005		ND (2)
MW-8	05/13/2005		ND (2)
	07/18/2005		ND (2)
MW-16	05/13/2005		ND (2)
	05/13/2005	FD	ND (2)
	07/26/2005		ND (2)
	07/26/2005	FD	ND (2)
MW-17	05/19/2005		ND (2) J
	05/19/2005	FD	ND (2) J
	07/26/2005		ND (2)
	07/26/2005	FD	ND (2)
MW-18	05/11/2005		ND (2)
	07/26/2005		ND (2)
MW-20-70	06/11/2003		ND (20)
MW-20-100	06/11/2003		ND (28)
MW-20-130	06/11/2003		ND (40)
MW-25	06/12/2003		ND (8)
MW-27-20	06/10/2003		ND (4)
	06/08/2004		ND (4)
MW-28-25	06/07/2004		ND (4)
MW-29	06/11/2003		ND (24)
	06/09/2004		ND (8)
MW-30-50	06/10/2003		ND (24)
MW-33-40	06/11/2003		ND (20)
MW-34-55	06/08/2004		ND (20)
MW-34-80	06/08/2004		ND (40)
OW-1D	09/30/2004		ND (20)
P-2	05/13/2005		ND (2)
	07/26/2005		ND (4)
PGE-9N	05/11/2005		ND (2) J
	07/20/2005		ND (10)
PGE-9S	05/11/2005		ND (2) J
	07/20/2005		ND (10)

TABLE 6-10
Groundwater Analytical Results for Perchlorate, 2003-2005 Sampling Events
RCRA Facility Investigation/Remedial Investigation Report (Volume 2)
PG&E Topock Compressor Station, Needles, California

Well ID	Sample Date		Perchlorate (µg/L)
Groundwater Wells			
Park Moabi-3	05/18/2005		ND (2)
	05/18/2005	FD	ND (2)
	07/21/2005		ND (2)
	07/21/2005	FD	ND (2)
Sanders	05/18/2005		ND (2)
	07/25/2005		ND (2)
Extraction Wells			
TW-2S	07/29/2004		ND (8)
TW-2D	07/29/2004		ND (40)

Notes:

Perchlorate analyses by EPA Method 314.0.

FD	Field duplicate
J	concentration or reporting limit estimated by laboratory or data validation
ND	not detected at listed reporting limt. Some reporting detection limits increased due to required dilution for sample matrix interference.
µg/L	micrograms per liter

TABLE 6-11

Chromium Groundwater Analyses for Bedrock Wells, March 2001 through October 2007

RCRA Facility Investigation/Remedial Investigation Report (Volume 2)

PG&E Topock Compressor Station, Needles, California

Well ID[1,2]	Sample Date	Hexavalent Chromium (µg/L)	Dissolved Chromium (µg/L)
MW-23	03/28/2001	ND (10)	ND (20)
	06/06/2001	ND (10)	ND (20)
	09/12/2001	ND (10)	ND (20)
	11/30/2001	ND (10)	ND (800)
	03/08/2002	ND (10)	19.2 (TOT)
	06/13/2002	ND (10)	3.60
	09/18/2002	ND (10)	7.20
	12/11/2002	ND (10)	9.50
	03/21/2003	ND (10)	11.9
	06/12/2003	ND (10)	1.10 J
	09/10/2003	ND (0.2)	ND (1.0)
	12/11/2003	ND (0.2)	3.30
	03/16/2004	3.30 J	ND (1.0)
	06/08/2004	10.1	10.5
	09/21/2004	6.80	7.90
	12/17/2004	1.10	1.50
	03/08/2005	ND (1.0)	2.90
	06/14/2005	8.90	7.70
	10/04/2005	ND (1.0)	ND (1.0)
	12/14/2005	8.80	10.5
	03/08/2006	11.9	ND (1.0)
	05/02/2006	16.8	18.2
	10/04/2006	15.2	14.4
	12/12/2006	1,920 R	ND (1.0)J
	(FD) 12/12/2006	14.4 J	8.60 J
	03/06/2007	1,020	1,020
	05/02/2007	13.0	10.9
	10/04/2007	19.2	22.2
MW-24BR	03/28/2001	ND (10)	ND (20)
	06/06/2001	ND (10)	10.0 J
	09/12/2001	ND (10)	ND (20)
	11/29/2001	ND (10)	ND (800)
	03/08/2002	ND (10)	68.8 (TOT)
	06/13/2002	ND (10)	3.70
	09/18/2002	ND (10)	3.50
	12/12/2002	ND (10)	3.40
	03/19/2003	ND (10)	16.0
	06/13/2003	ND (10)	2.90 J
	09/12/2003	ND (0.2)	3.60 J
	12/11/2003	ND (0.2)	4.60
	03/17/2004	ND (1.0)J	4.80
	06/08/2004	ND (1.0)	ND (1.0)
	09/21/2004	ND (1.0)	ND (1.0)
	12/17/2004	ND (1.0)	3.50
	03/08/2005	ND (1.0)	ND (1.0)
	12/15/2005	ND (1.0)	ND (1.0)

TABLE 6-11

Chromium Groundwater Analyses for Bedrock Wells, March 2001 through October 2007

RCRA Facility Investigation/Remedial Investigation Report (Volume 2)

PG&E Topock Compressor Station, Needles, California

Well ID[1,2]	Sample Date	Hexavalent Chromium (µg/L)	Dissolved Chromium (µg/L)
MW-24BR	03/16/2006	ND (1.0)	1.20
	05/10/2006	1.00 R	ND (1.0)
	06/05/2006	ND (1.0)	---
	11/01/2006	ND (1.0)	ND (1.0)
	12/15/2006	ND (2.0)	1.00
	03/06/2007	ND (1.0)	ND (1.0)
	05/03/2007	ND (1.0)	ND (1.0)
	10/04/2007	ND (1.0)	ND (1.0)
MW-48	05/18/2006	ND (1.0)	ND (1.0)
	06/06/2006	ND (1.0)	ND (1.0)
	10/06/2006	ND (1.0)	ND (1.0)
	12/15/2006	ND (2.0)	ND (1.0)
	03/07/2007	ND (1.0)	ND (1.0)
	05/01/2007	ND (1.0)	1.00
	10/04/2007	ND (1.0)	ND (1.0)
PGE-07BR [2]	12/19/2007	ND (1.0)	ND (1.0)
PGE-08	03/28/2001	ND (10)	13.0 J
	06/06/2001	ND (10)	26.0
	08/25/2001	ND (10)	ND (20)
	09/12/2001	ND (10)	15.0 J
	11/29/2001	ND (10)	ND (800)
	12/09/2003	ND (0.2)	3.80
	10/13/2005	ND (1.0)J	2.10
	08/11/2007	ND (1.0)	ND (1.0)

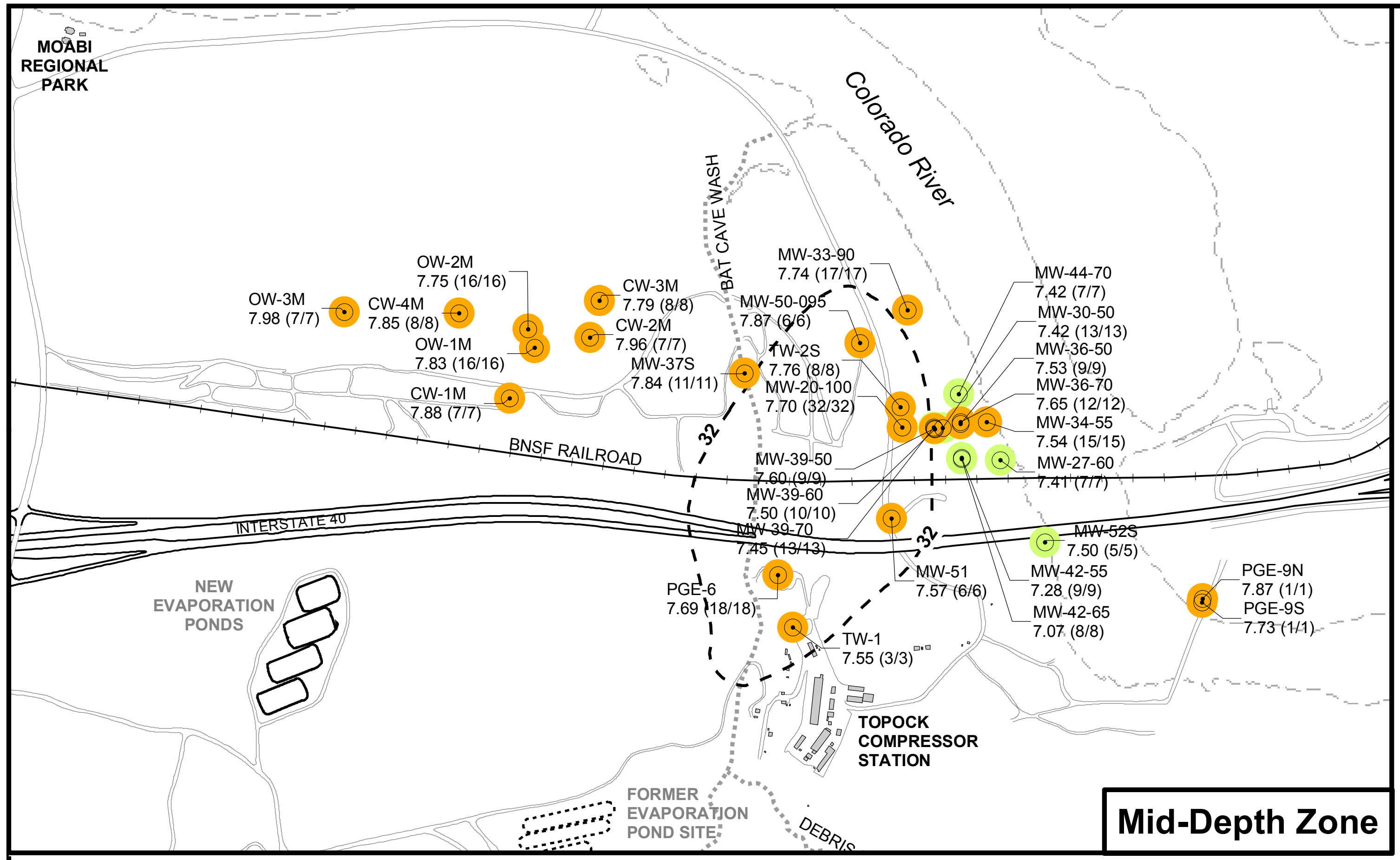
Notes:

[1] The August 2007 samples from PGE-08 were collected during a hydraulic pumping test (not routine GMP sampling). This is the only available sampling data for 2007. See hydraulic testing report (CH2M HILL, 2008) for discussion.

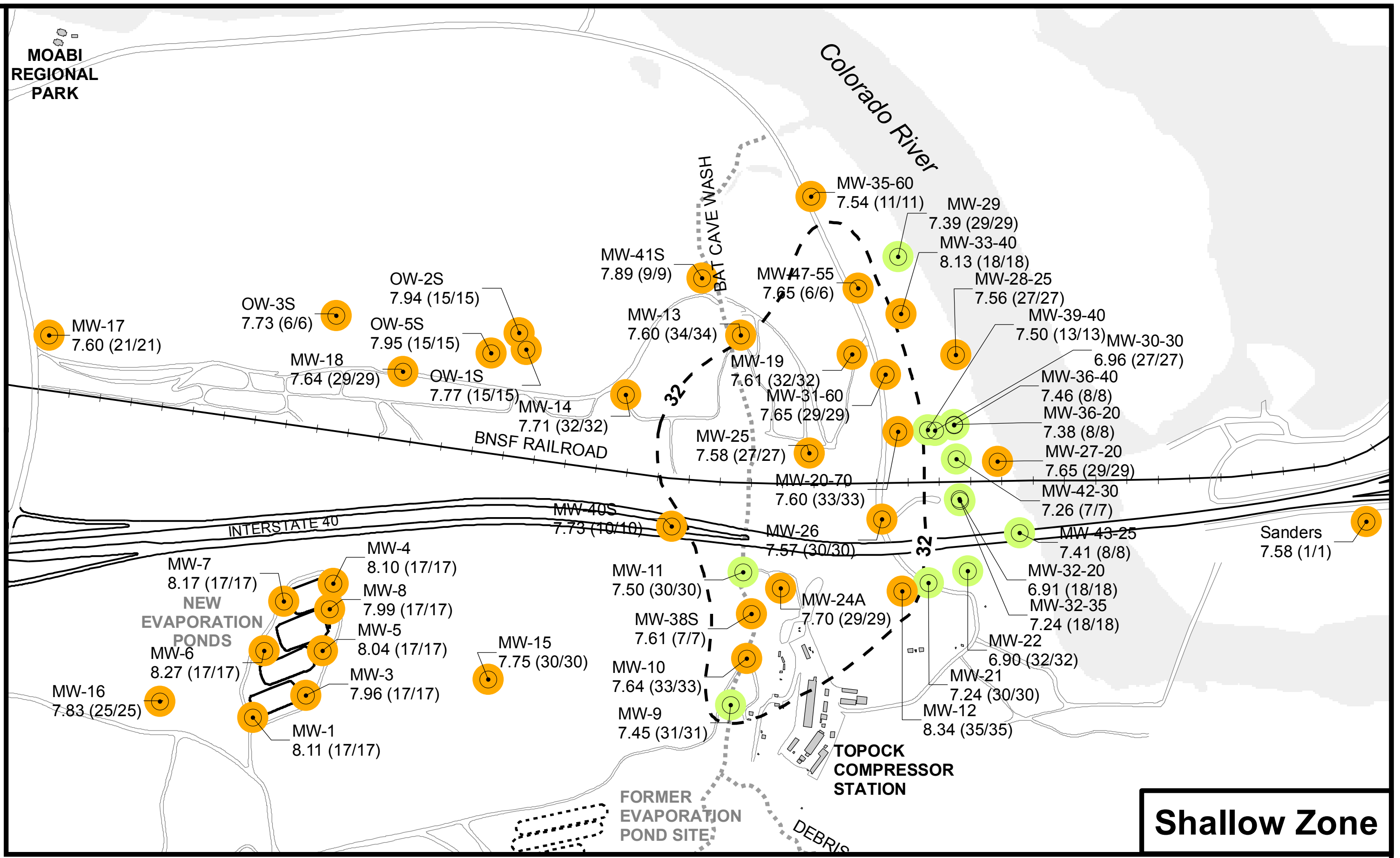
[2] New bedrock monitoring well PGE-7BR was first sampled in December 2007 and is included in the RFI/RI characterization.

Abbreviations:

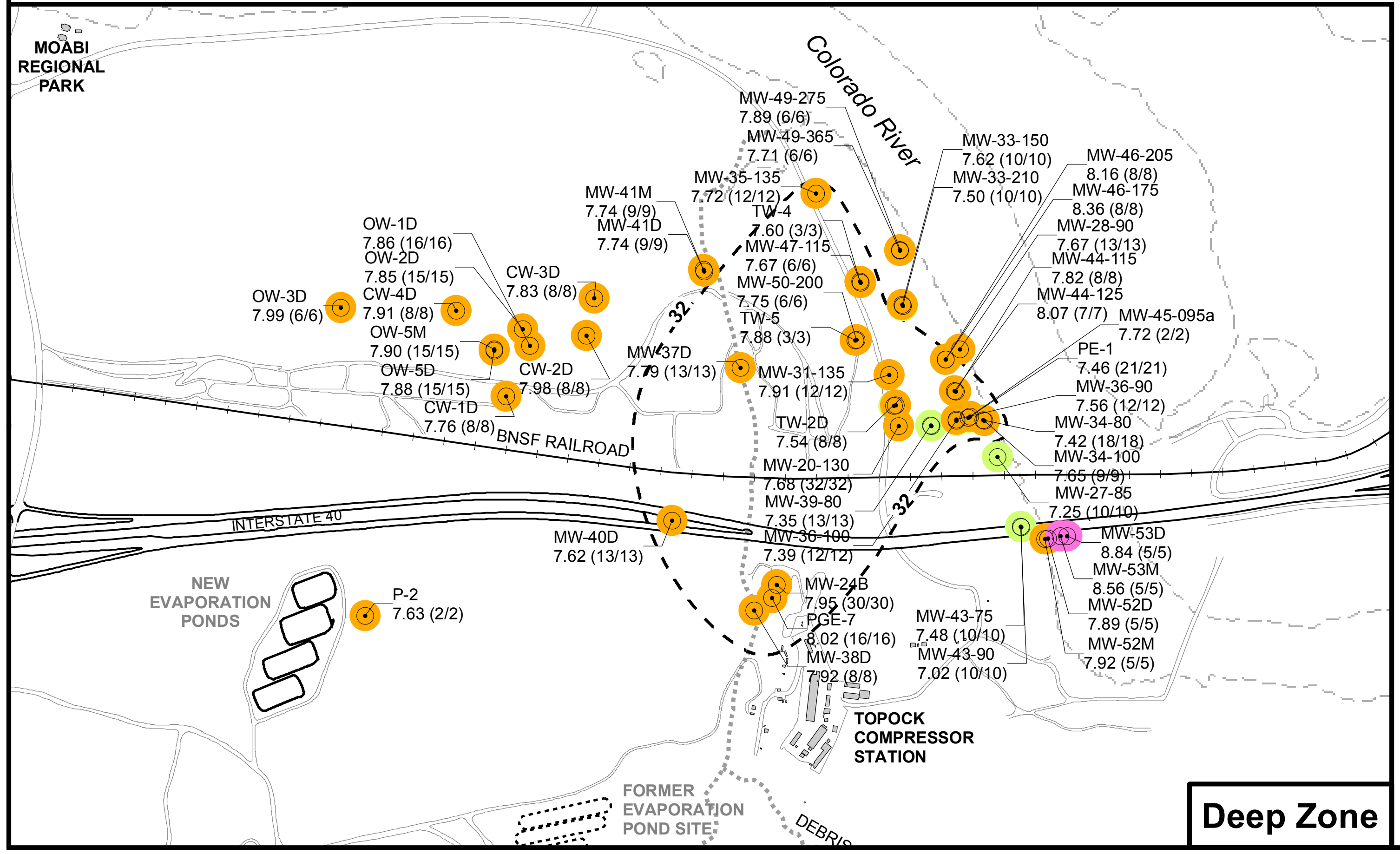
FD	field duplicate
J	concentration or RL estimated by laboratory or data validation
ND	Parameter not detected at the listed reporting limit (RL)
R	result exceeded analytical criteria for precision and accuracy; should not be used for project decision making
TOT	total chromium
µg/L	micrograms per liter
---	data not collected or not available



Mid-Depth Zone



Shallow Zone



Deep Zone

LEGEND

⊙ Groundwater Well completed in Alluvial Aquifer (Shallow, Mid-depth or Deep Zones)

Laboratory pH Average Results

MW-17 ← Well ID

5.8 (16/16) ← (No. of detections / No. of samples)

↑ Average pH results, pH Units
1997 - 2007 groundwater sampling

- - - Approximate outline of Cr(VI) in Alluvial Aquifer depth zone >/= 32 μg/L, October 2007

⊙ < 6.50 pH Units

⊙ 6.50 - 7.50 pH Units

⊙ 7.51 - 8.50 pH Units

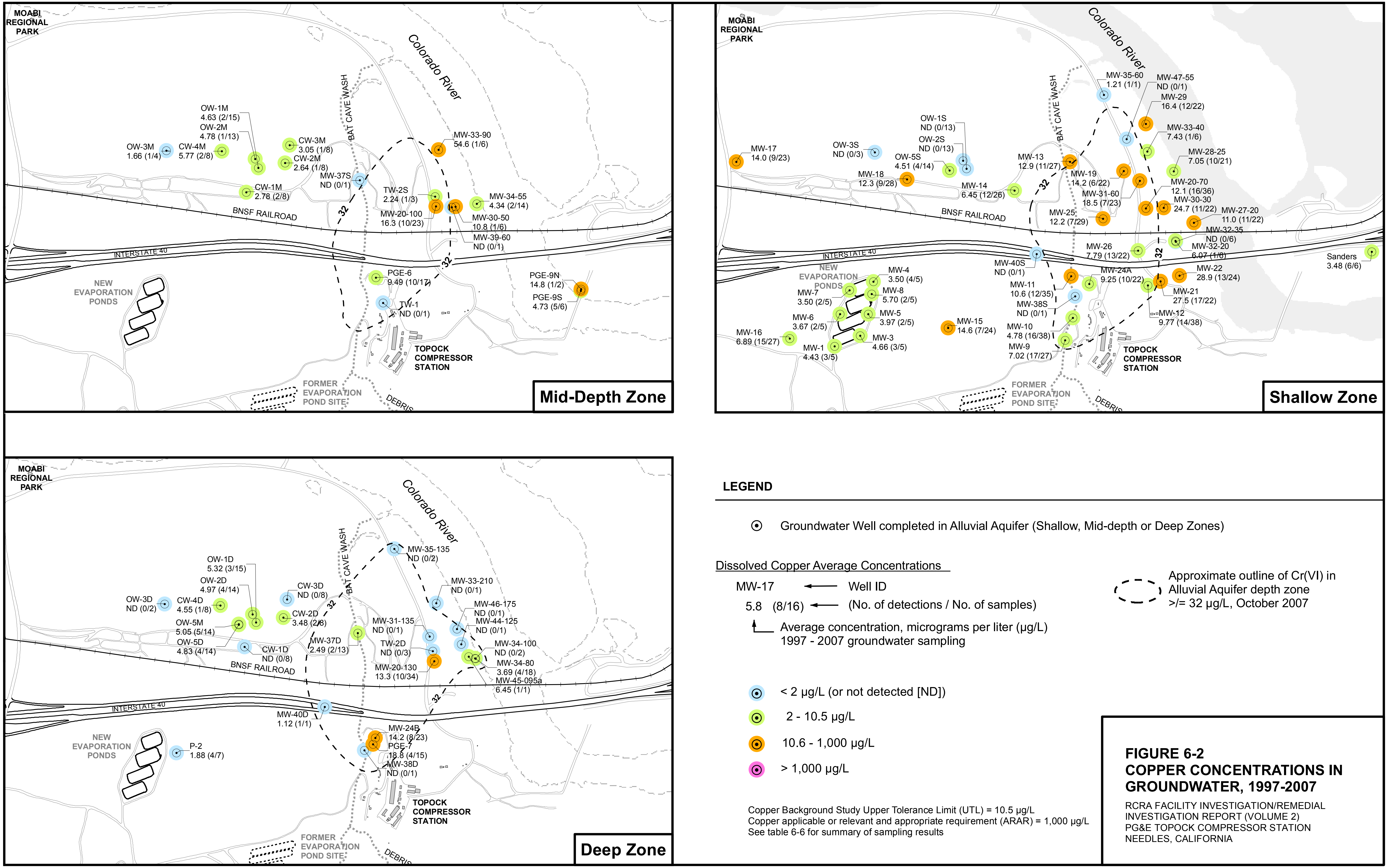
⊙ > 8.50 pH Units

pH applicable or relevant and appropriate requirement (ARAR)= 6.5 - 8.5 units

FIGURE 6-1
pH RESULTS IN GROUNDWATER, 1997-2007

RCRA FACILITY INVESTIGATION/REMEDIAL
INVESTIGATION REPORT (VOLUME 2)
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

BAO \\ZINFANDEL\PROJ\PACIFICGASELECTRICCO\TOPOCKPROGRAM\GIS\MAPFILES\2007\RFI\RFI_REVSEC6_METALSDIST_PH.MXD RFI_REVSEC6_METALSDIST_PH 12/29/2008 16:58:38



LEGEND

⊙ Groundwater Well completed in Alluvial Aquifer (Shallow, Mid-depth or Deep Zones)

Dissolved Copper Average Concentrations

MW-17 ← Well ID

5.8 (8/16) ← (No. of detections / No. of samples)

Average concentration, micrograms per liter (µg/L)
1997 - 2007 groundwater sampling

Approximate outline of Cr(VI) in Alluvial Aquifer depth zone >/= 32 µg/L, October 2007

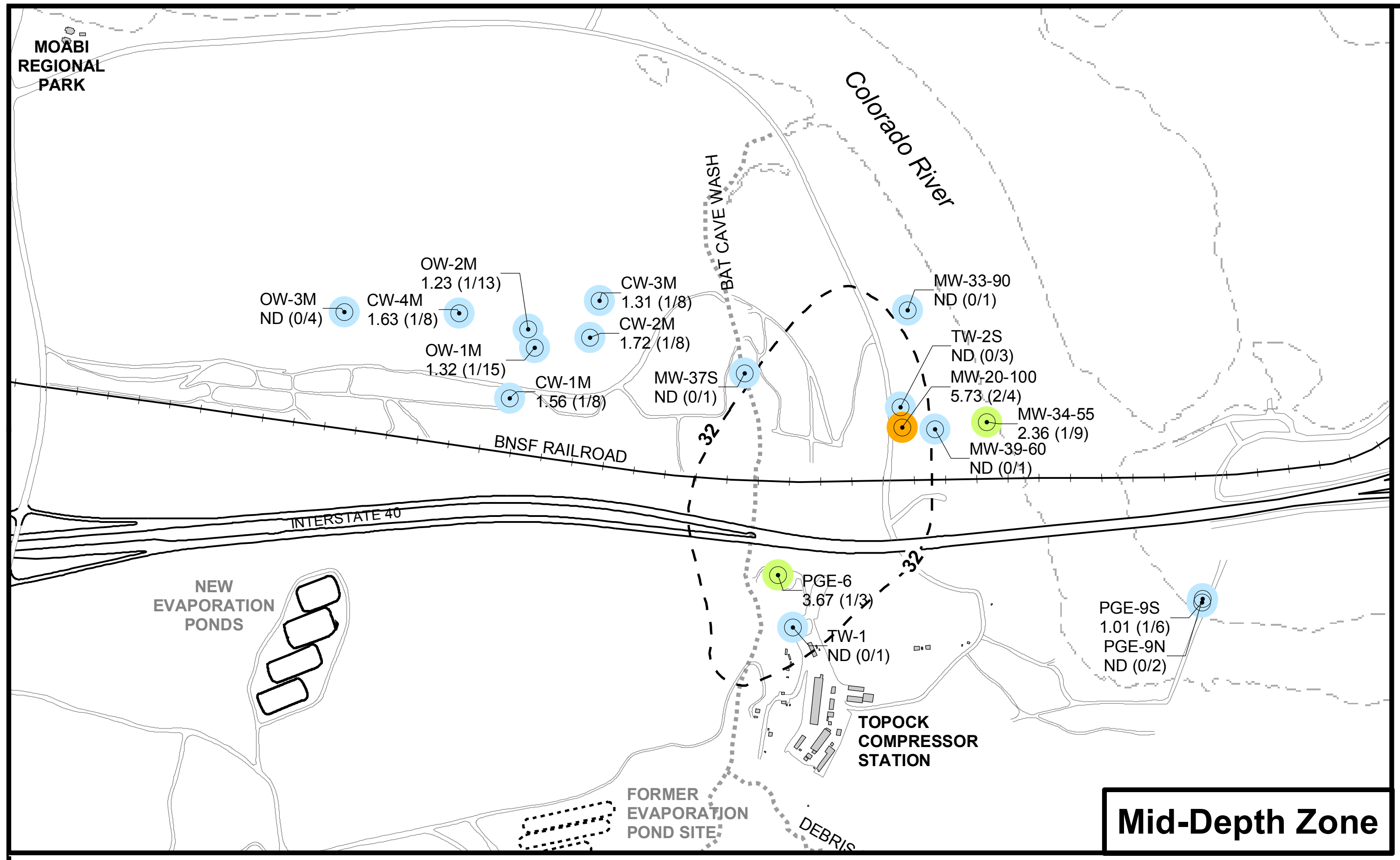
- ⊙ < 2 µg/L (or not detected [ND])
- ⊙ 2 - 10.5 µg/L
- ⊙ 10.6 - 1,000 µg/L
- ⊙ > 1,000 µg/L

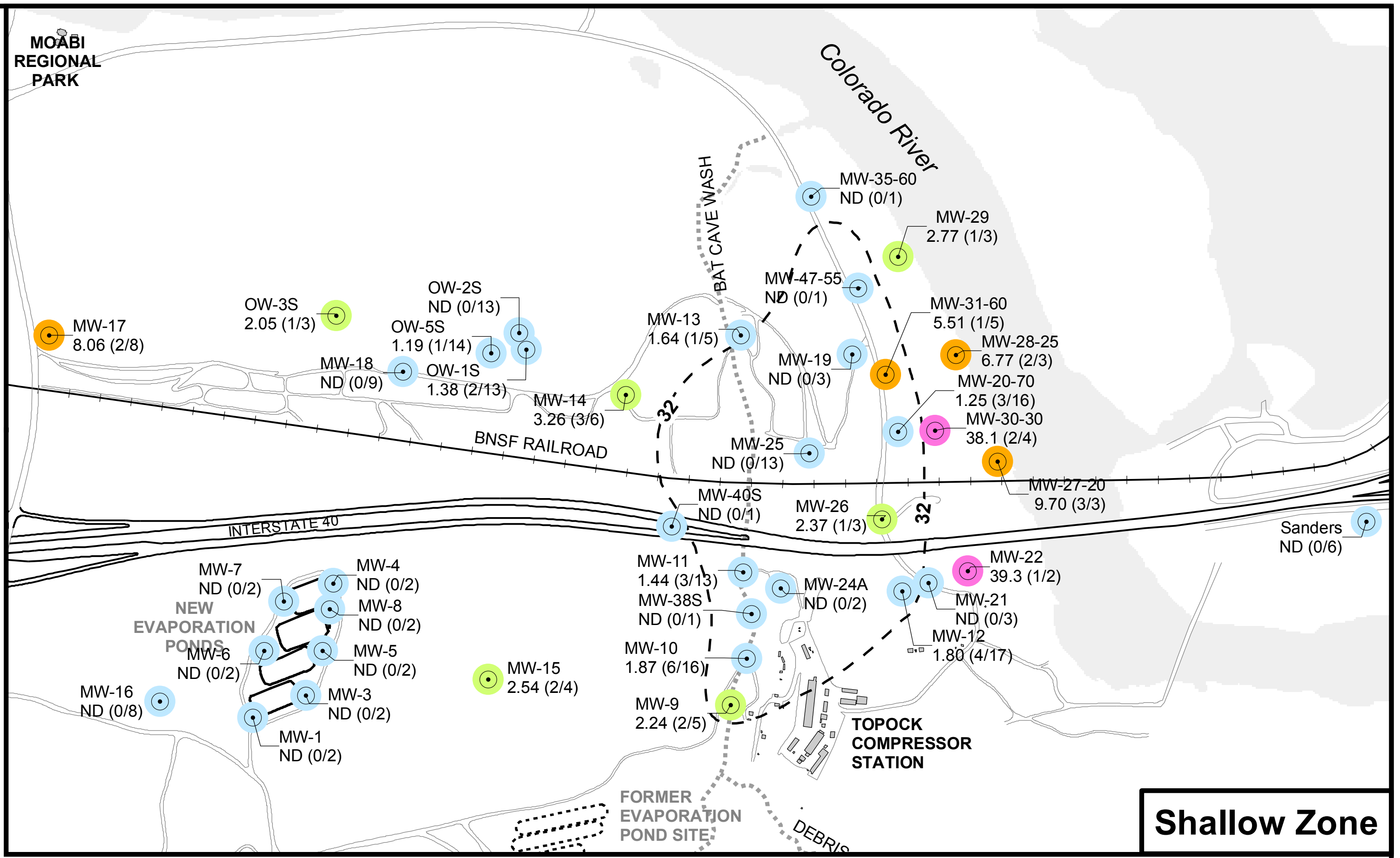
Copper Background Study Upper Tolerance Limit (UTL) = 10.5 µg/L
Copper applicable or relevant and appropriate requirement (ARAR) = 1,000 µg/L
See table 6-6 for summary of sampling results

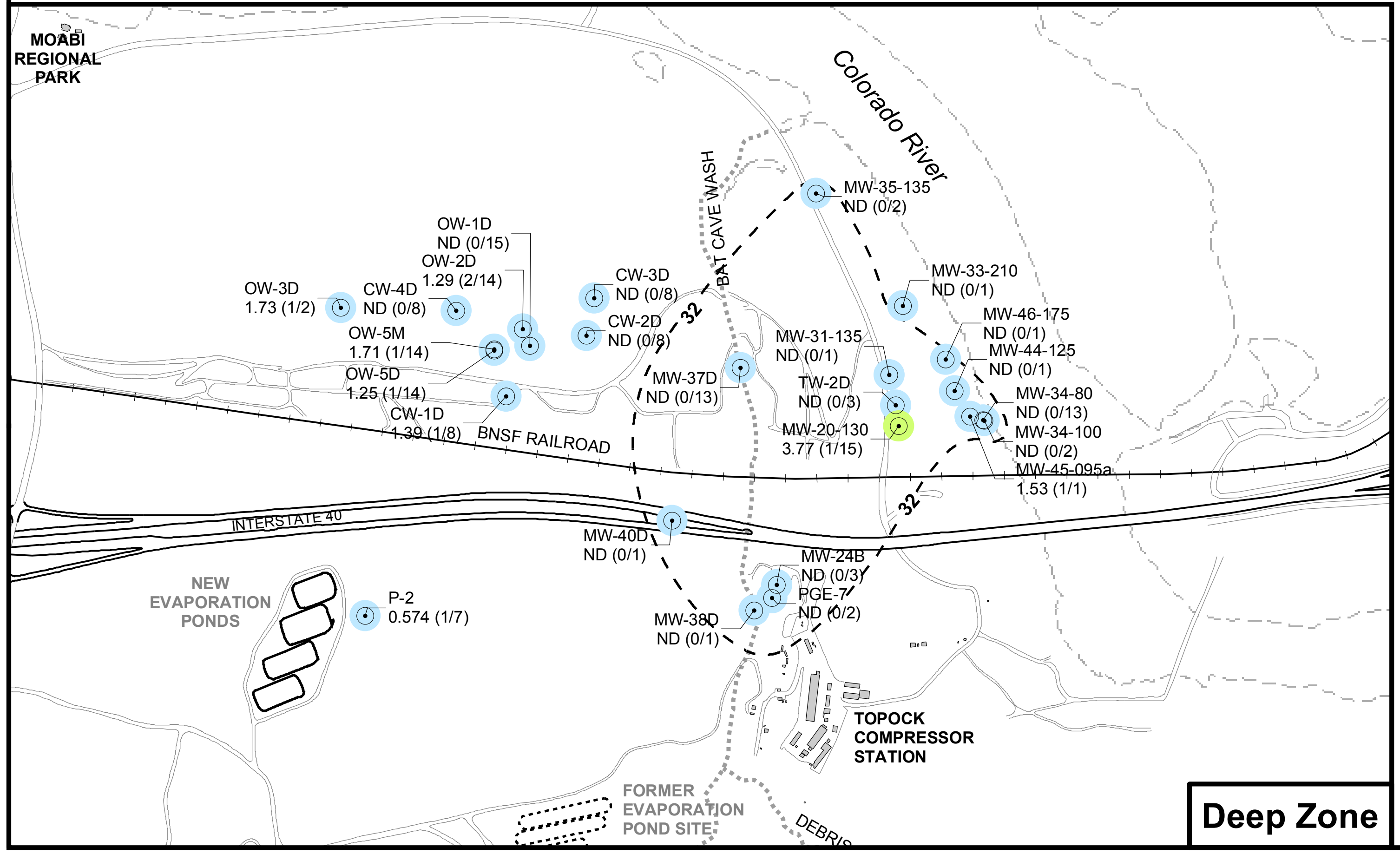
FIGURE 6-2
COPPER CONCENTRATIONS IN GROUNDWATER, 1997-2007

RCRA FACILITY INVESTIGATION/REMEDIAL INVESTIGATION REPORT (VOLUME 2)
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

BAO \\ZINFANDEL\PROJ\PACIFICGASELECTRICCO\TOPOCKPROGRAM\GIS\MAPFILES\2007\RFI\RFI_REVSEC6_METALSDIST_CUD.MXD RFI_REVSEC6_METALSDIST_CUD 1/12/2009 09:04:58







LEGEND

⊙ Groundwater Well completed in Alluvial Aquifer (Shallow, Mid-depth or Deep Zones)

Dissolved Lead Average Concentrations

MW-17 ← Well ID

5.8 (8/16) ← (No. of detections / No. of samples)

↑ Average concentration, micrograms per liter (µg/L) 1997 - 2007 groundwater sampling

Approximate outline of Cr(VI) in Alluvial Aquifer depth zone >/= 32 µg/L, October 2007

⊙ < 1.9 µg/L (or not detected [ND])

⊙ 1.9 - 4 µg/L

⊙ 4.1 - 15 µg/L

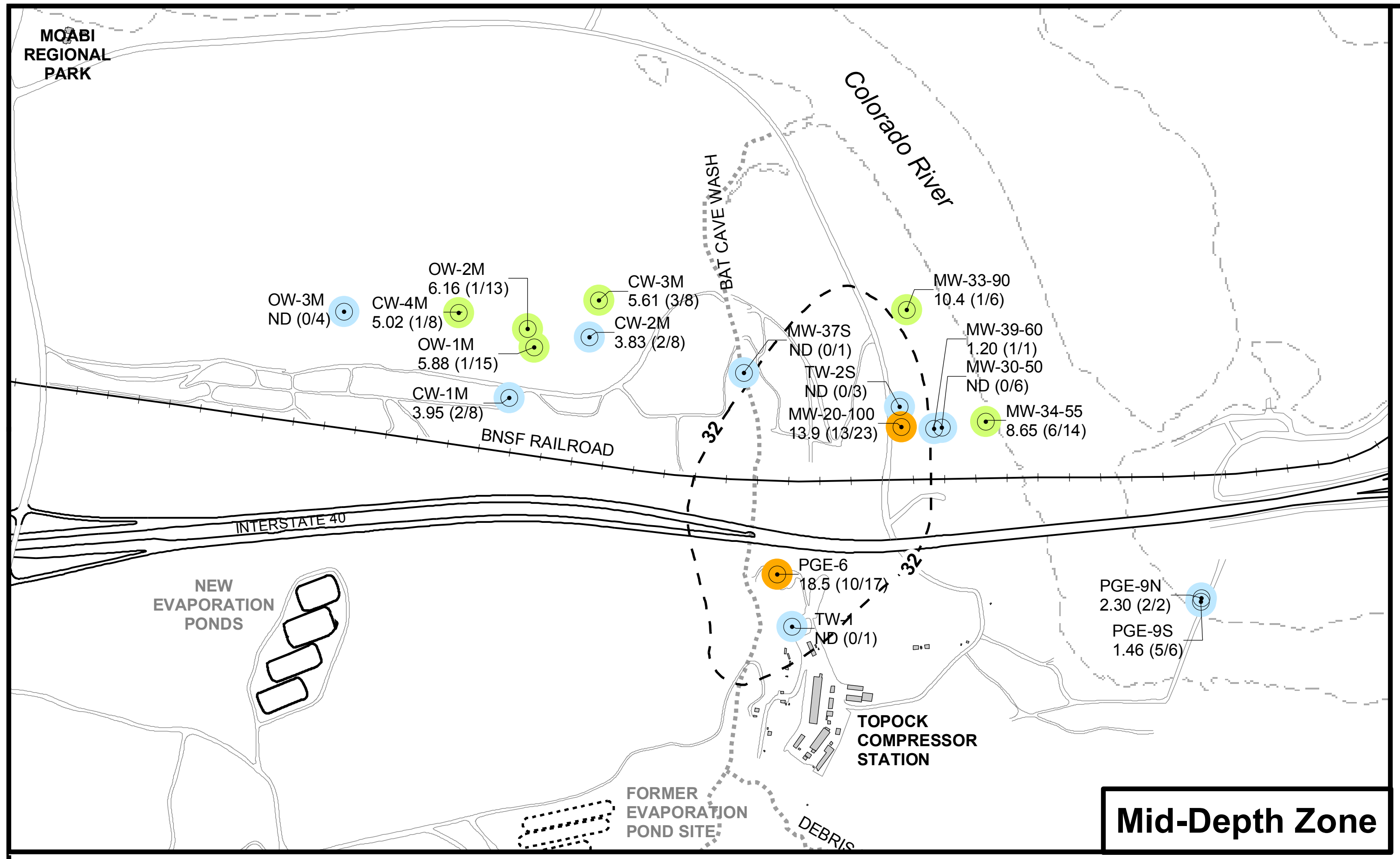
⊙ > 15 µg/L

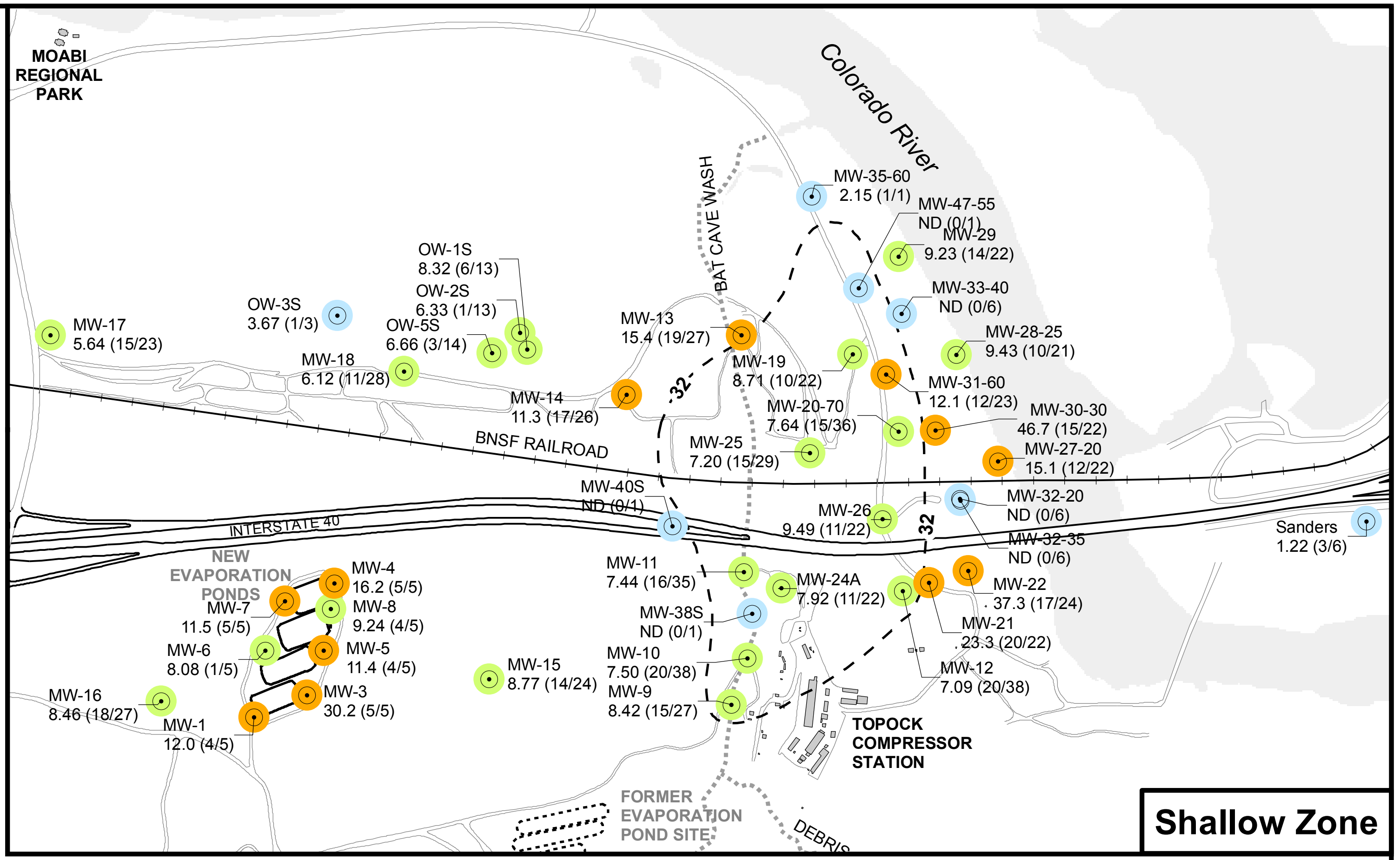
Lead Background Study Upper Tolerance Limit (UTL) = 1.91 µg/L
Lead applicable or relevant and appropriate requirement (ARAR) = 15 µg/L
See Table 6-6 for summary of sampling results

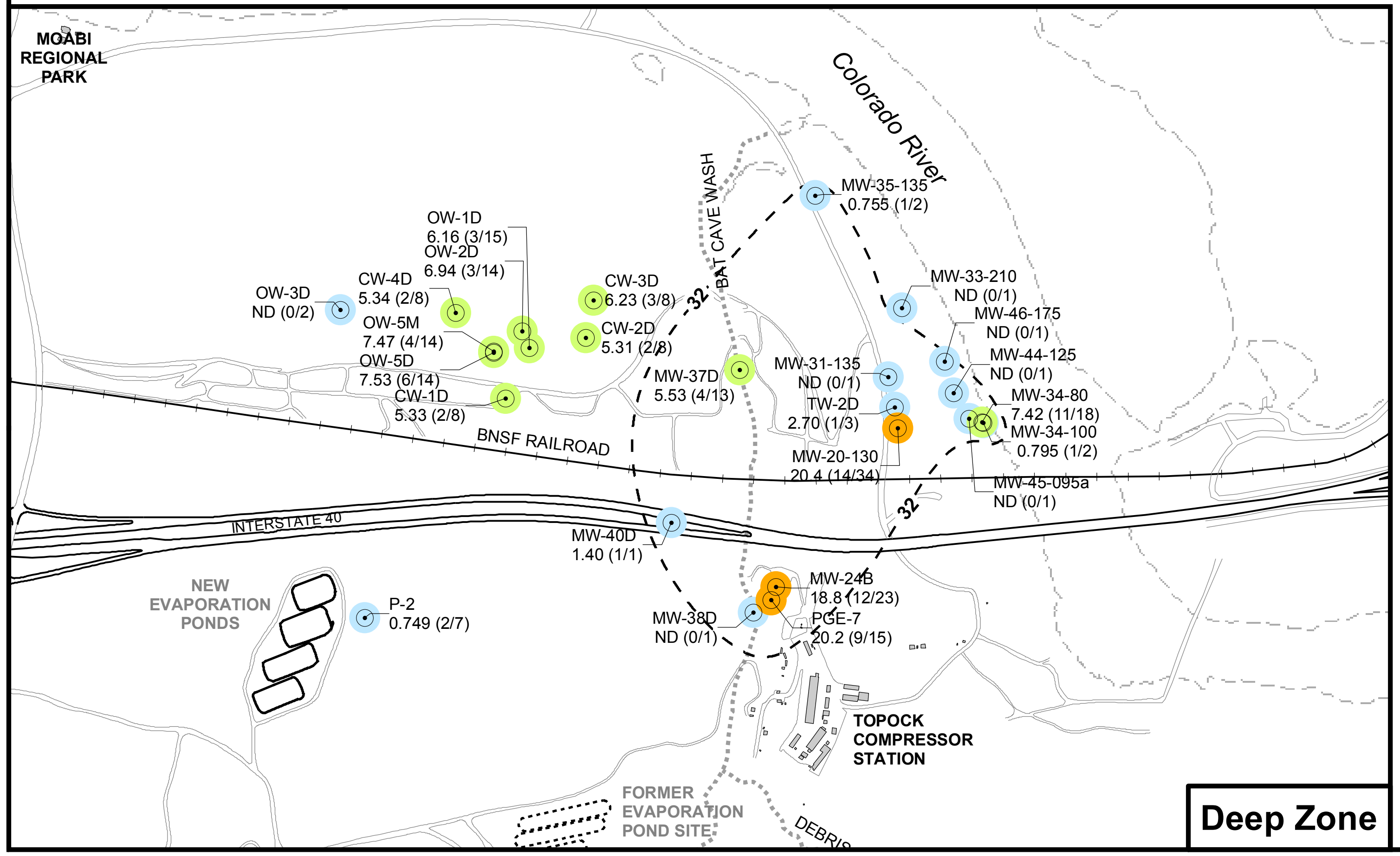
FIGURE 6-3
LEAD CONCENTRATIONS IN GROUNDWATER, 1997-2007

RCRA FACILITY INVESTIGATION/REMEDIAL INVESTIGATION REPORT (VOLUME 2)
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

BAO \\ZINFANDEL\PROJ\PACIFICGASELECTRICCO\TOPOCKPROGRAM\GIS\MAPFILES\2007\RFI\RFI_REVSEC6_METALSDIST_PBD.MXD RFI_REVSEC6_METALSDIST_PBD 12/29/2008 17:14:13







LEGEND

⊙ Groundwater Well completed in Alluvial Aquifer (Shallow, Mid-depth or Deep Zones)

Dissolved Nickel Average Concentrations

MW-17 ← Well ID
5.8 (8/16) ← (No. of detections / No. of samples)
Average concentration, micrograms per liter (µg/L)
1997 - 2007 groundwater sampling

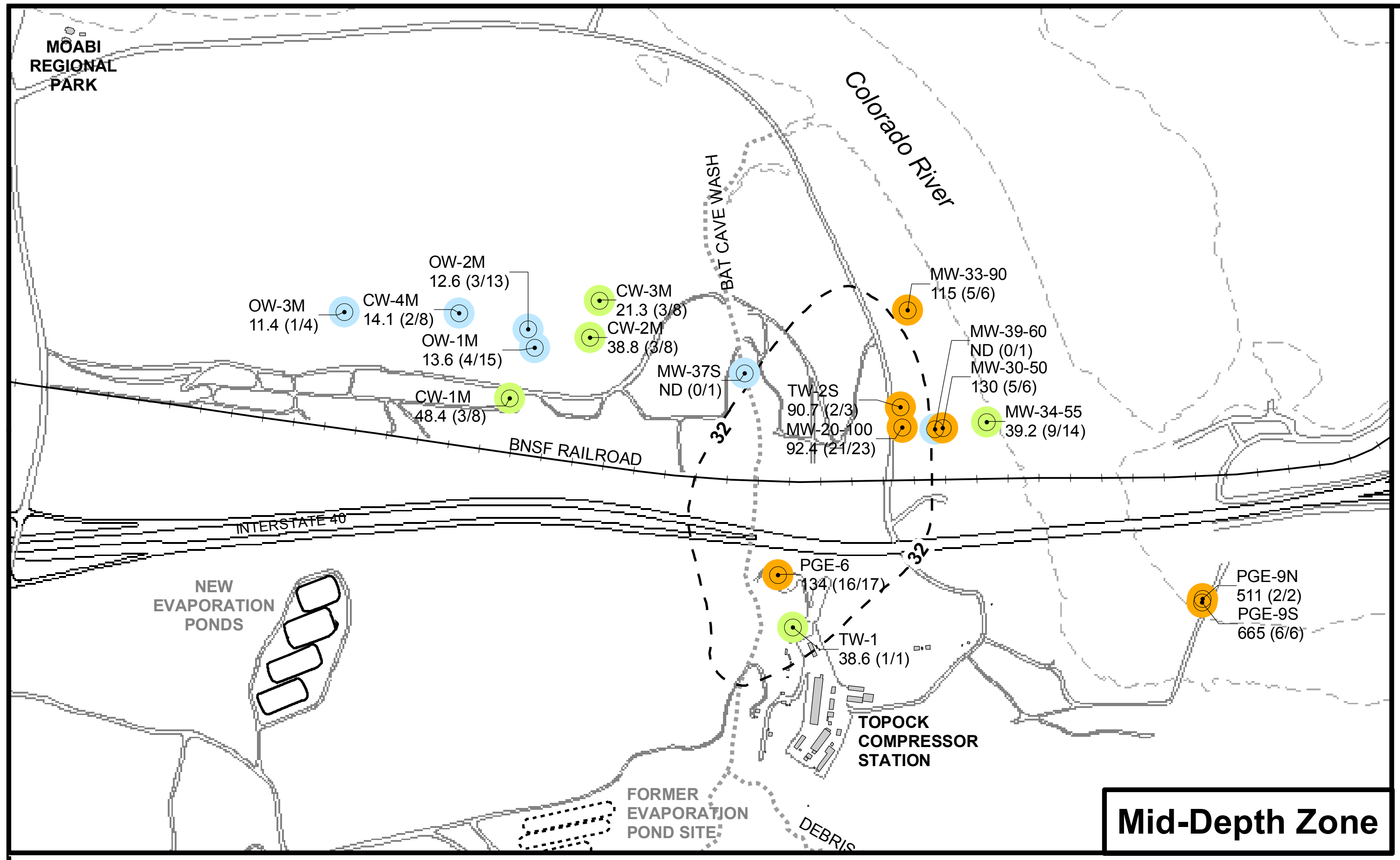
Approximate outline of Cr(VI) in Alluvial Aquifer depth zone >/= 32 µg/L, October 2007

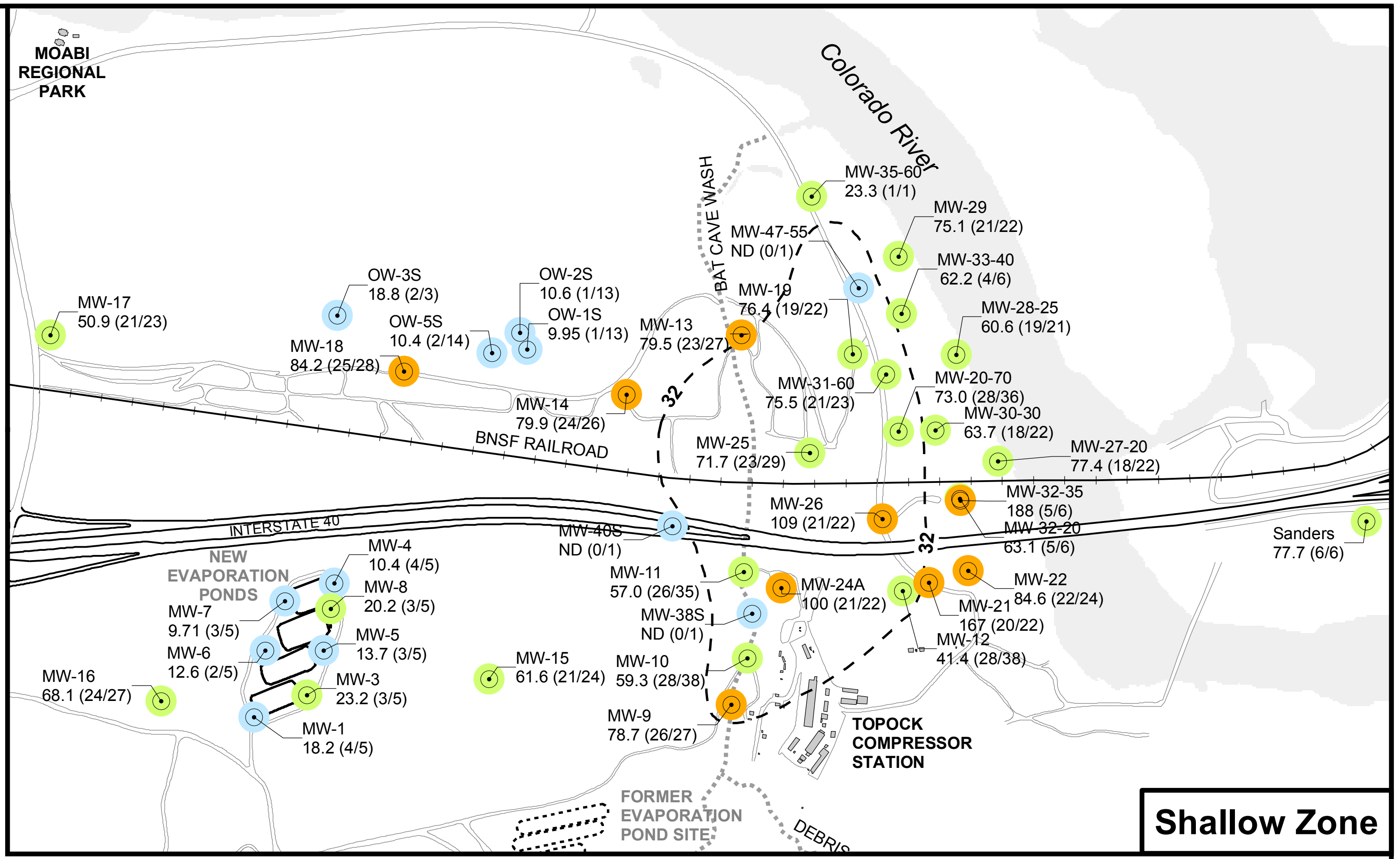
- 🔵 < 5 µg/L (or not detected [ND])
- 🟢 5 - 10.6 µg/L
- 🟠 10.7 - 100 µg/L
- 🟣 > 100 µg/L

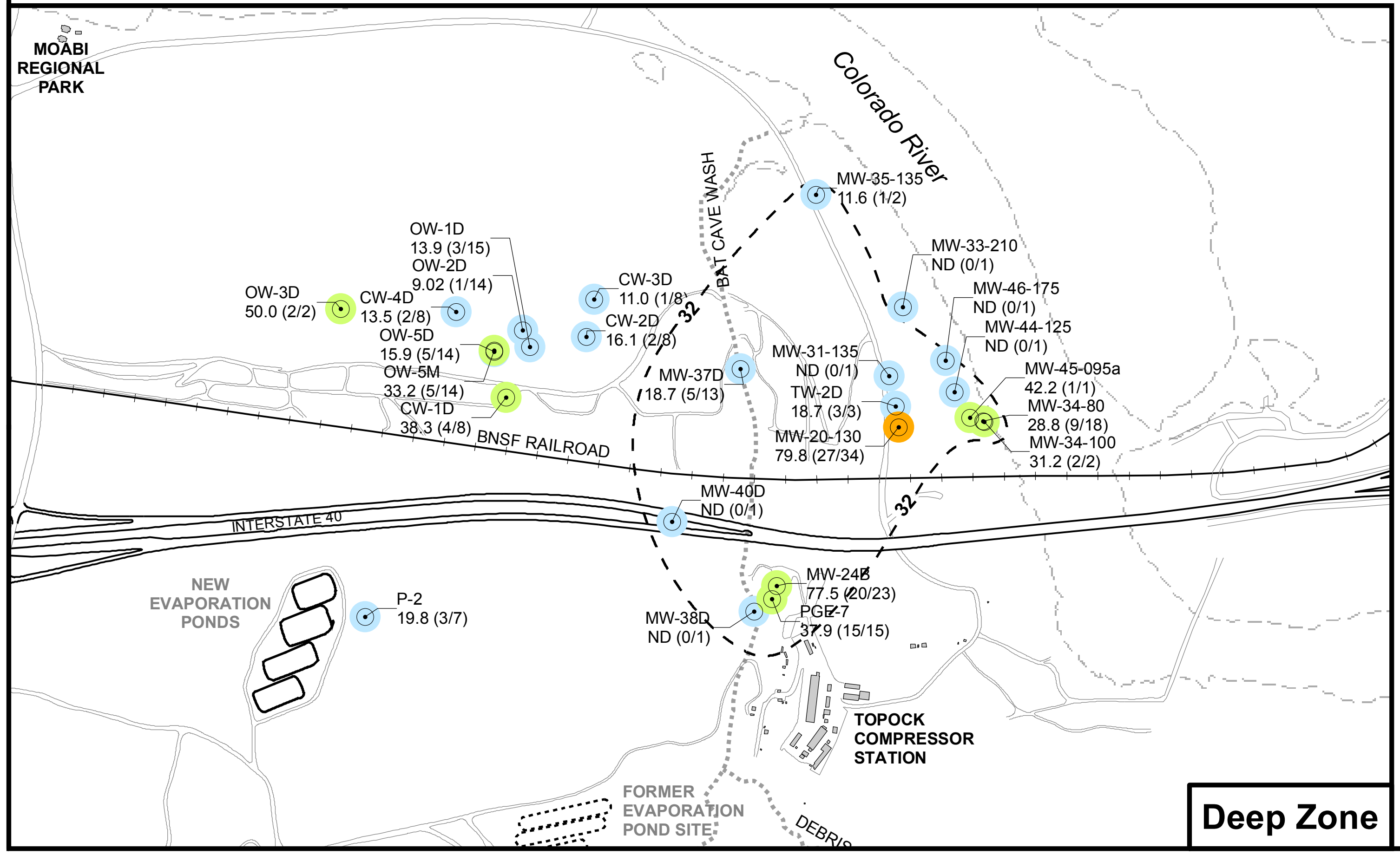
Nickel Background Study Upper Tolerance Limit (UTL) = 10.6 µg/L
Nickel applicable or relevant and appropriate requirement (ARAR) = 100 µg/L
See Table 6-6 for summary of sampling results

FIGURE 6-4
NICKEL CONCENTRATIONS IN GROUNDWATER, 1997-2007

RCRA FACILITY INVESTIGATION/REMEDIAL INVESTIGATION REPORT (VOLUME 2)
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA







LEGEND

⊙ Groundwater Well completed in Alluvial Aquifer (Shallow, Mid-depth or Deep Zones)

Dissolved Zinc Average Concentrations

MW-17 ⟵ Well ID
5.8 (8/16) ⟵ (No. of detections / No. of samples)
↑ Average concentration, micrograms per liter (µg/L)
1997 - 2007 groundwater sampling

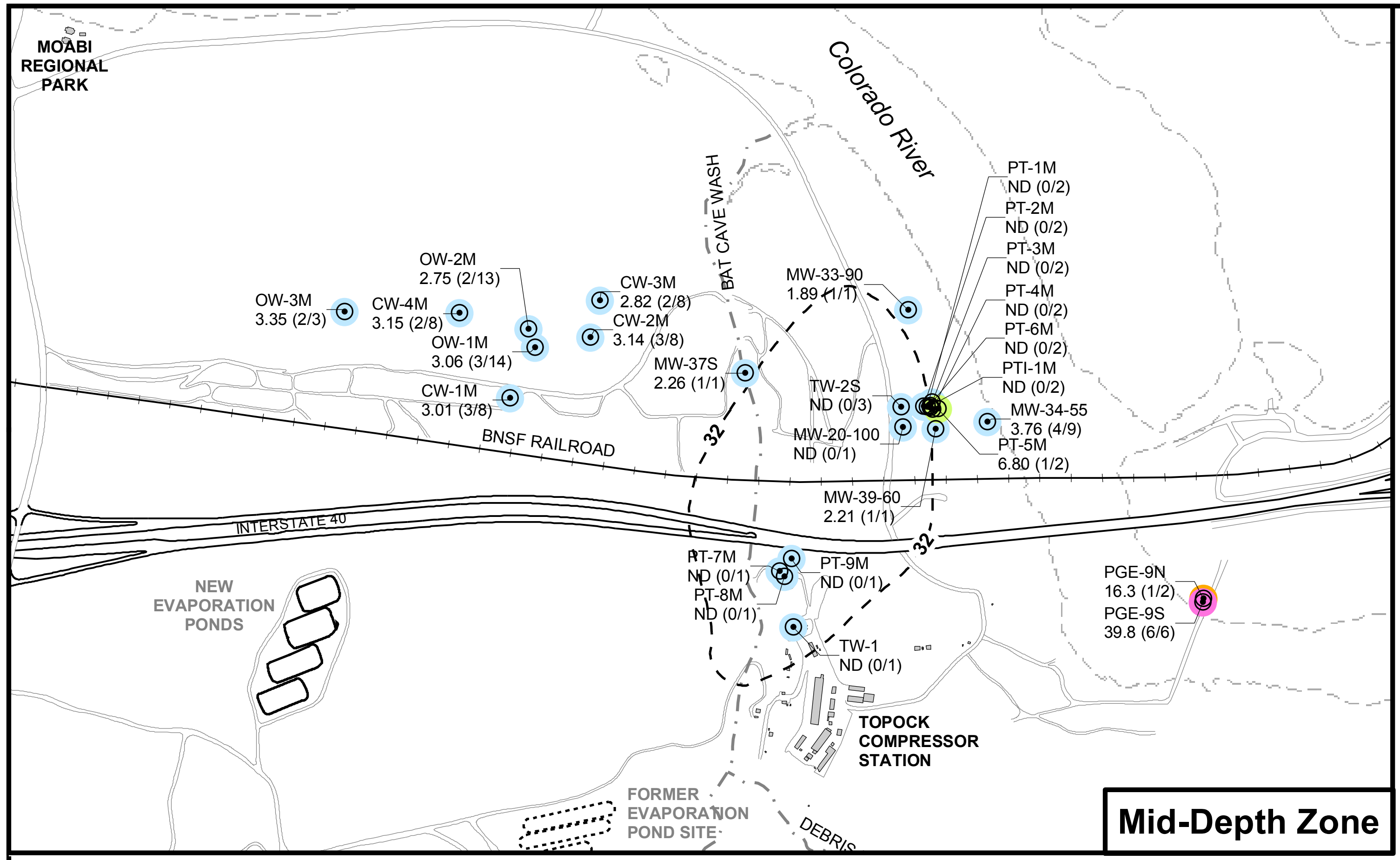
(- -) Approximate outline of Cr(VI) in Alluvial Aquifer depth zone >/= 32 µg/L, October 2007

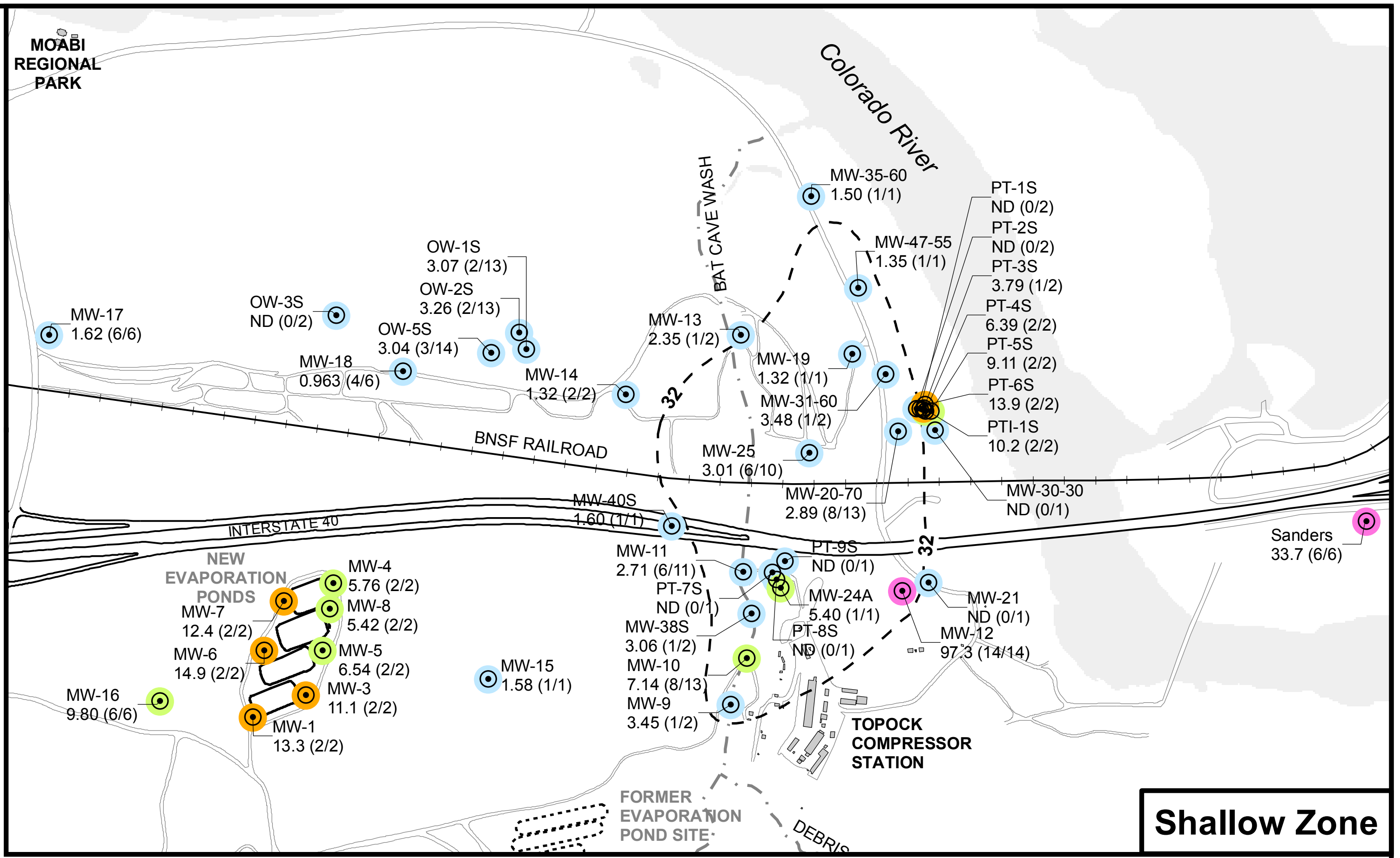
🔵 < 20 µg/L (or not detected [ND])
🟢 20 - 77.7 µg/L
🟠 77.8 - 5,000 µg/L
🟣 > 5,000 µg/L

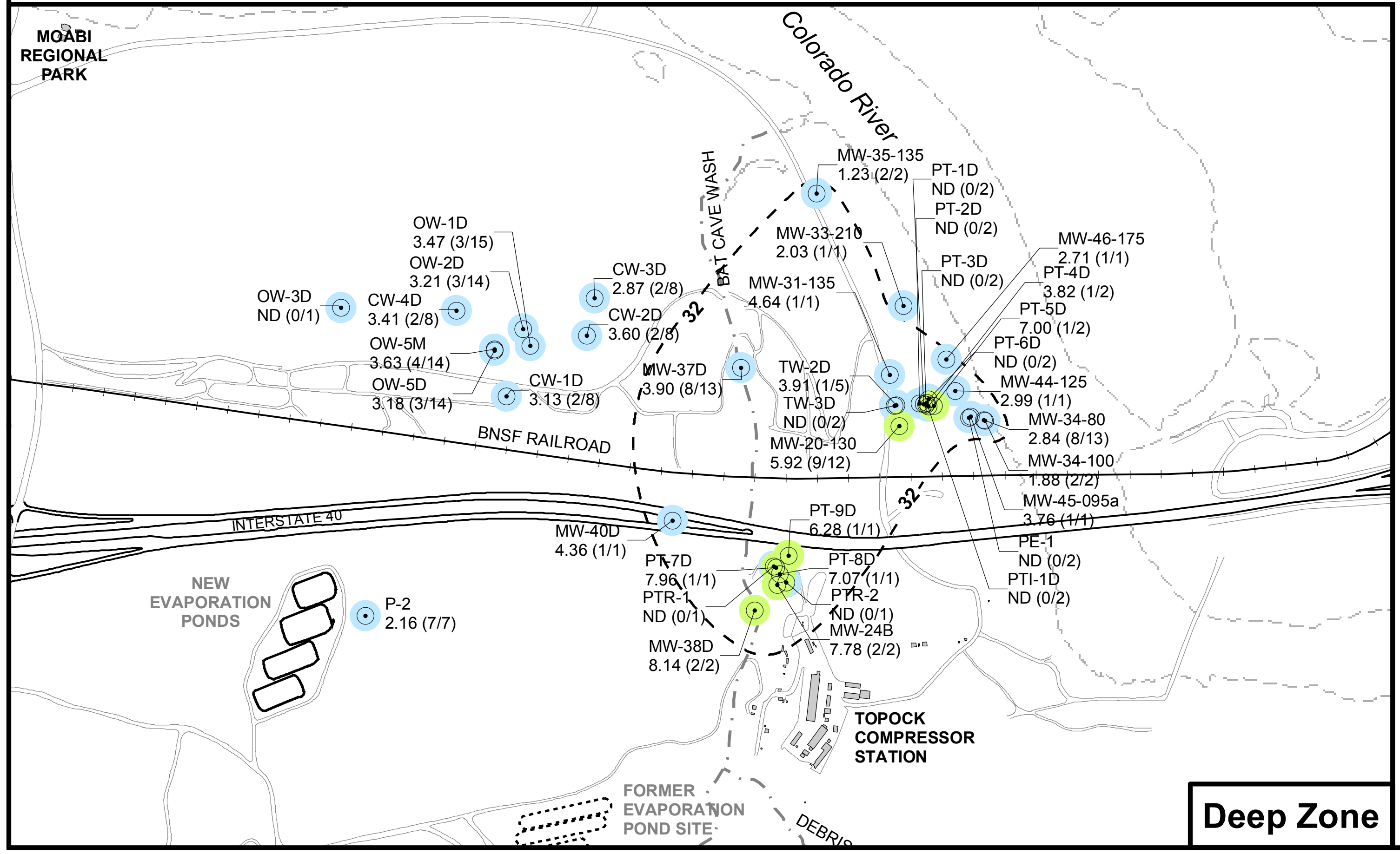
Zinc Background Study Upper Tolerance Limit (UTL) = 77.7 µg/L
Zinc applicable or relevant and appropriate requirement (ARAR) = 5,000 µg/L
See Table 6-6 for summary of sampling results

FIGURE 6-5
ZINC CONCENTRATIONS IN GROUNDWATER, 1997-2007

RCRA FACILITY INVESTIGATION/REMEDIAL
INVESTIGATION REPORT (VOLUME 2)
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA







LEGEND

⊙ Groundwater Well completed in Alluvial Aquifer (Shallow, Mid-depth or Deep Zones)

Dissolved Arsenic Average Concentrations

MW-17 ← Well ID
5.8 (8/16) ← (No. of detections / No. of samples)
↑ Average concentration, micrograms per liter (µg/L) 1997 - 2007 groundwater sampling

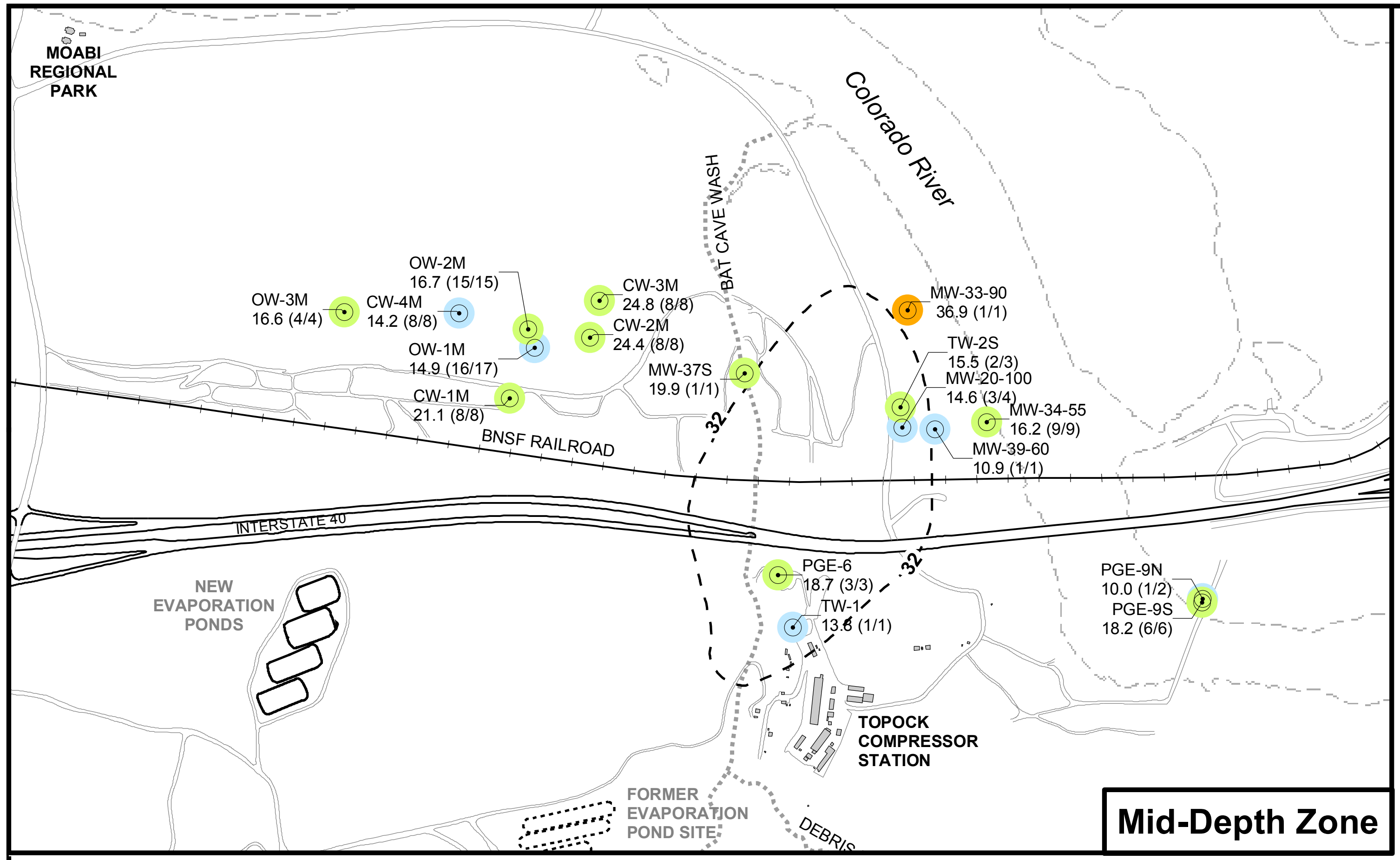
Approximate outline of Cr(VI) in Alluvial Aquifer depth zone >/= 32 µg/L, October 2007

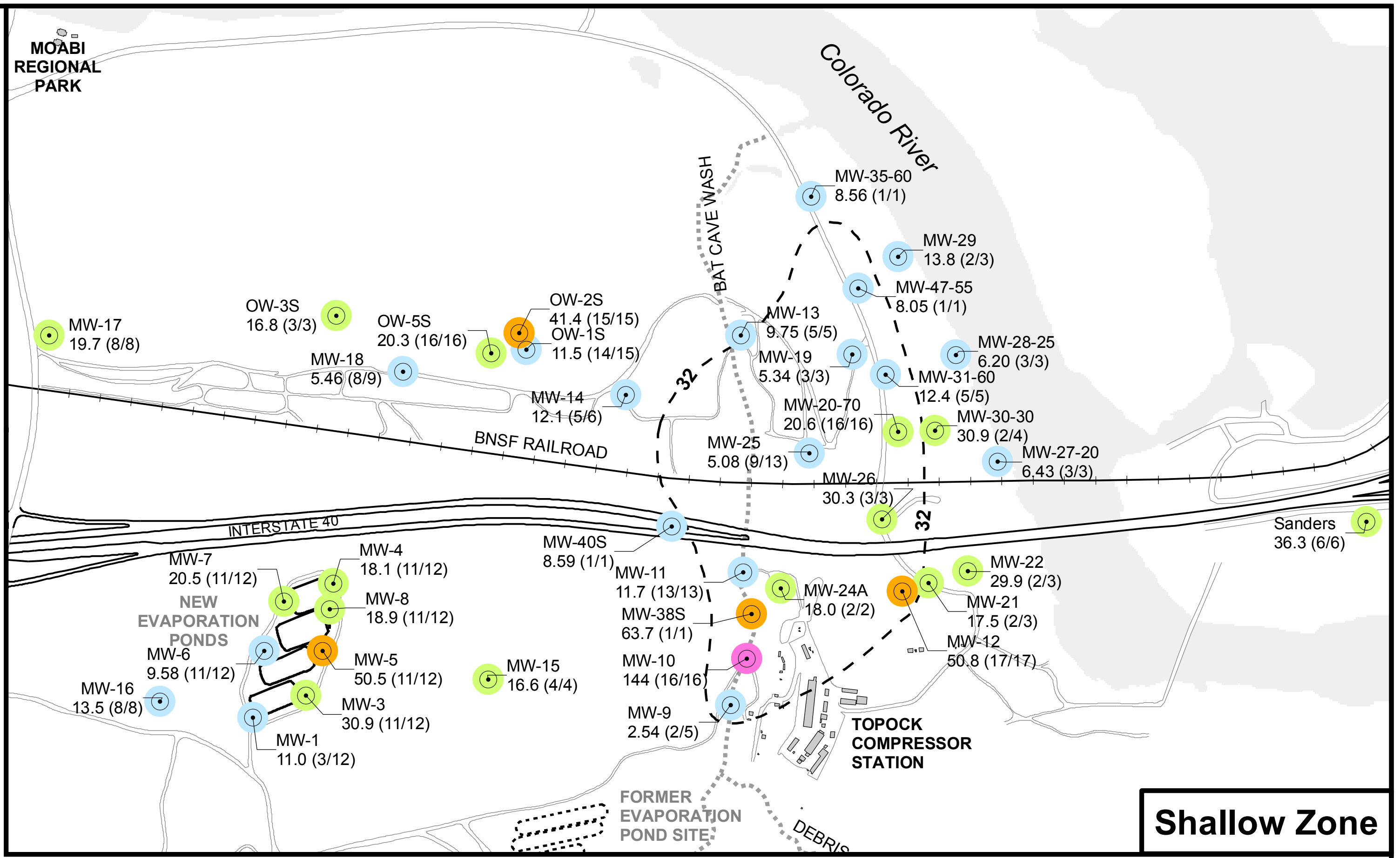
⊙ < 5 µg/L (or not detected [ND])
⊙ 5 - 10 µg/L
⊙ 10.1 - 24.3 µg/L
⊙ > 24.3 µg/L

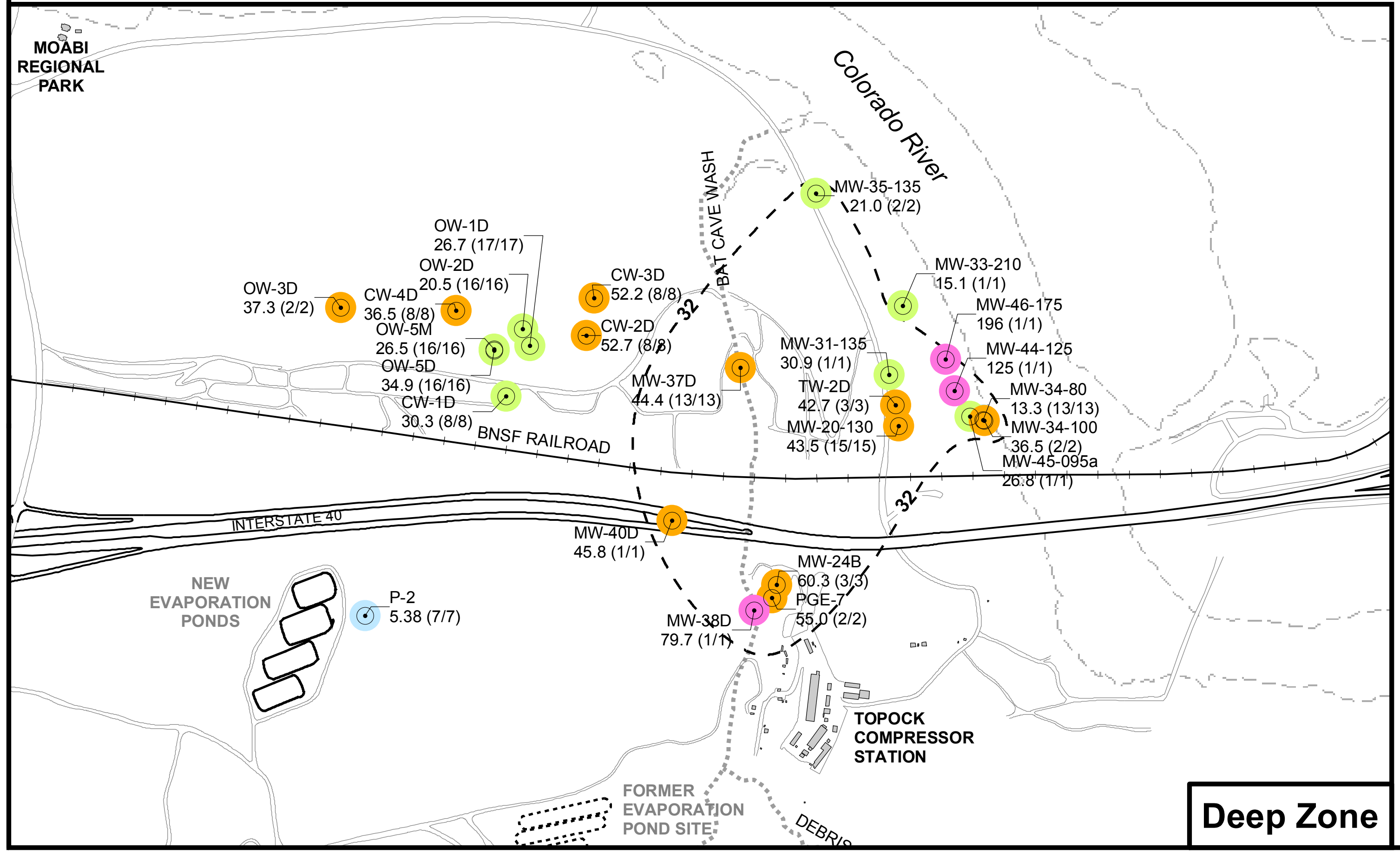
Arsenic Background Study Upper Tolerance Limit (UTL) = 24.3 µg/L
Arsenic applicable or relevant and appropriate requirement (ARAR) = 10 µg/L
See Table 6-8 for summary of sampling results

FIGURE 6-6
ARSENIC CONCENTRATIONS IN GROUNDWATER, 1997-2007

RCRA FACILITY INVESTIGATION/REMEDIAL INVESTIGATION REPORT (VOLUME 2)
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA







LEGEND

⊙ Groundwater Well completed in Alluvial Aquifer (Shallow, Mid-depth or Deep Zones)

Dissolved Molybdenum Average Concentrations

MW-17 ← Well ID
5.8 (8/16) ← (No. of detections / No. of samples)
↑ Average concentration, micrograms per liter (µg/L) 1997 - 2007 groundwater sampling

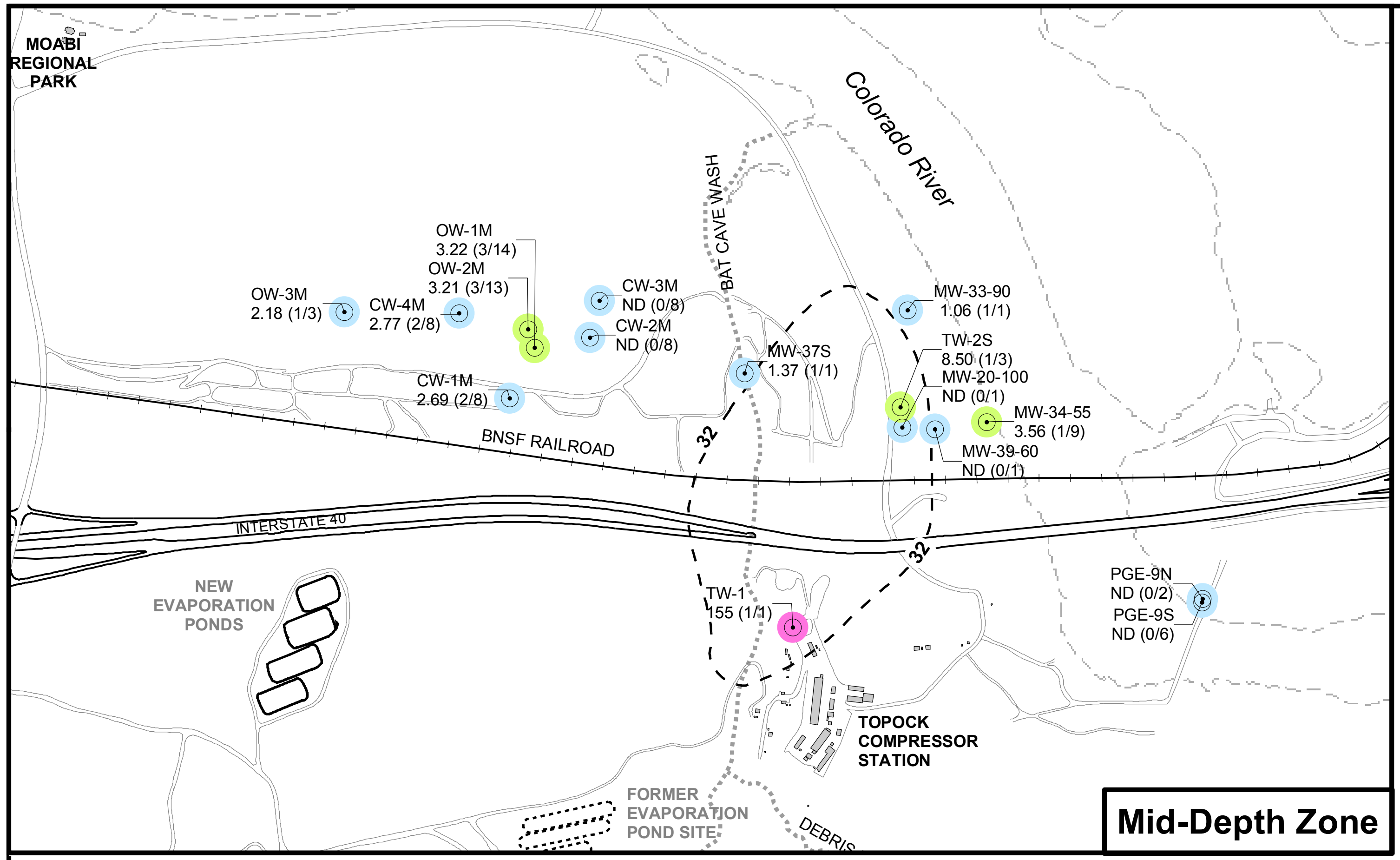
- - - Approximate outline of Cr(VI) in Alluvial Aquifer depth zone >/= 32 µg/L, October 2007

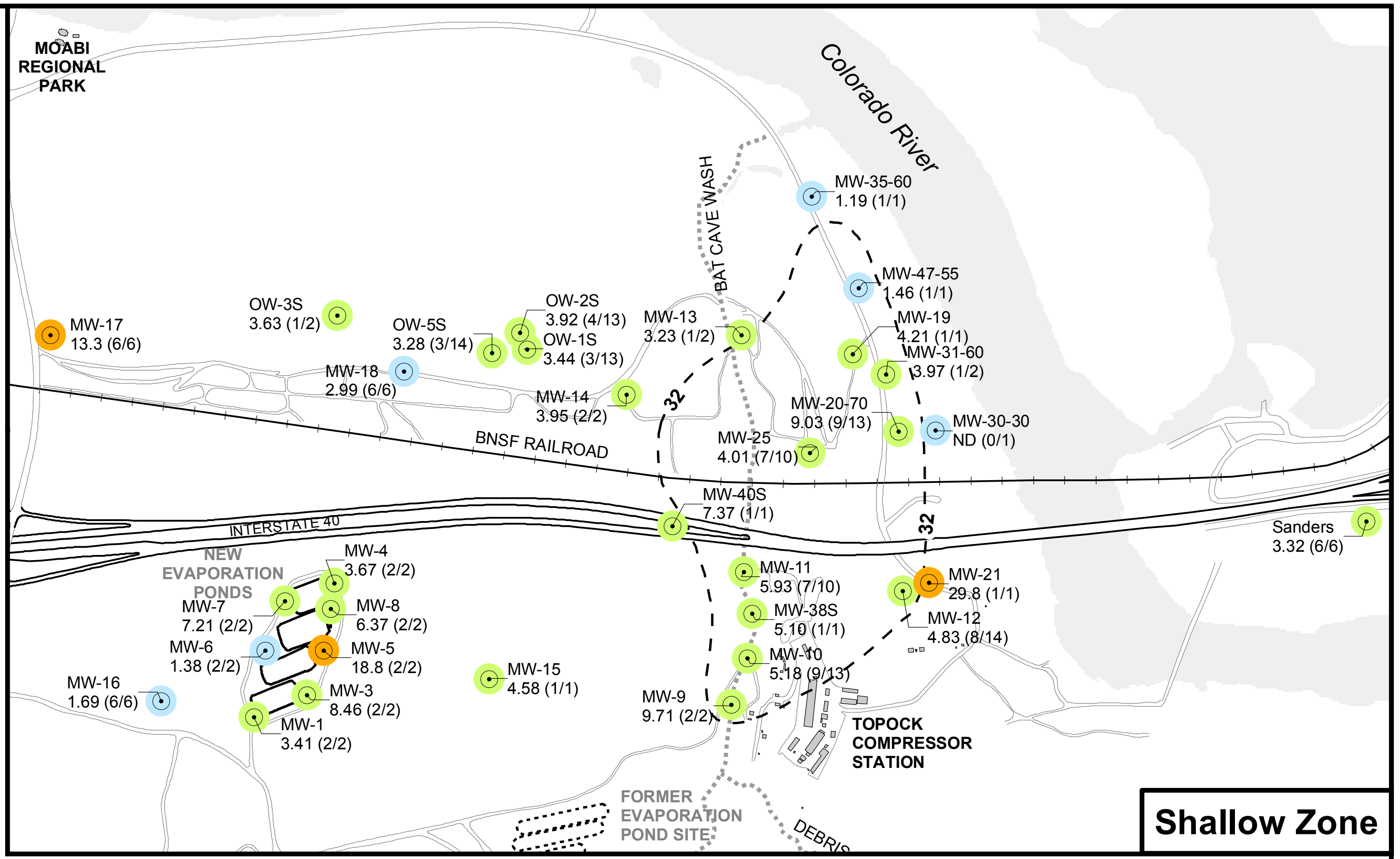
⊙ < 15 µg/L (or not detected [ND])
⊙ 15 - 36.3 µg/L
⊙ 36.4 - 70 µg/L
⊙ > 70 µg/L

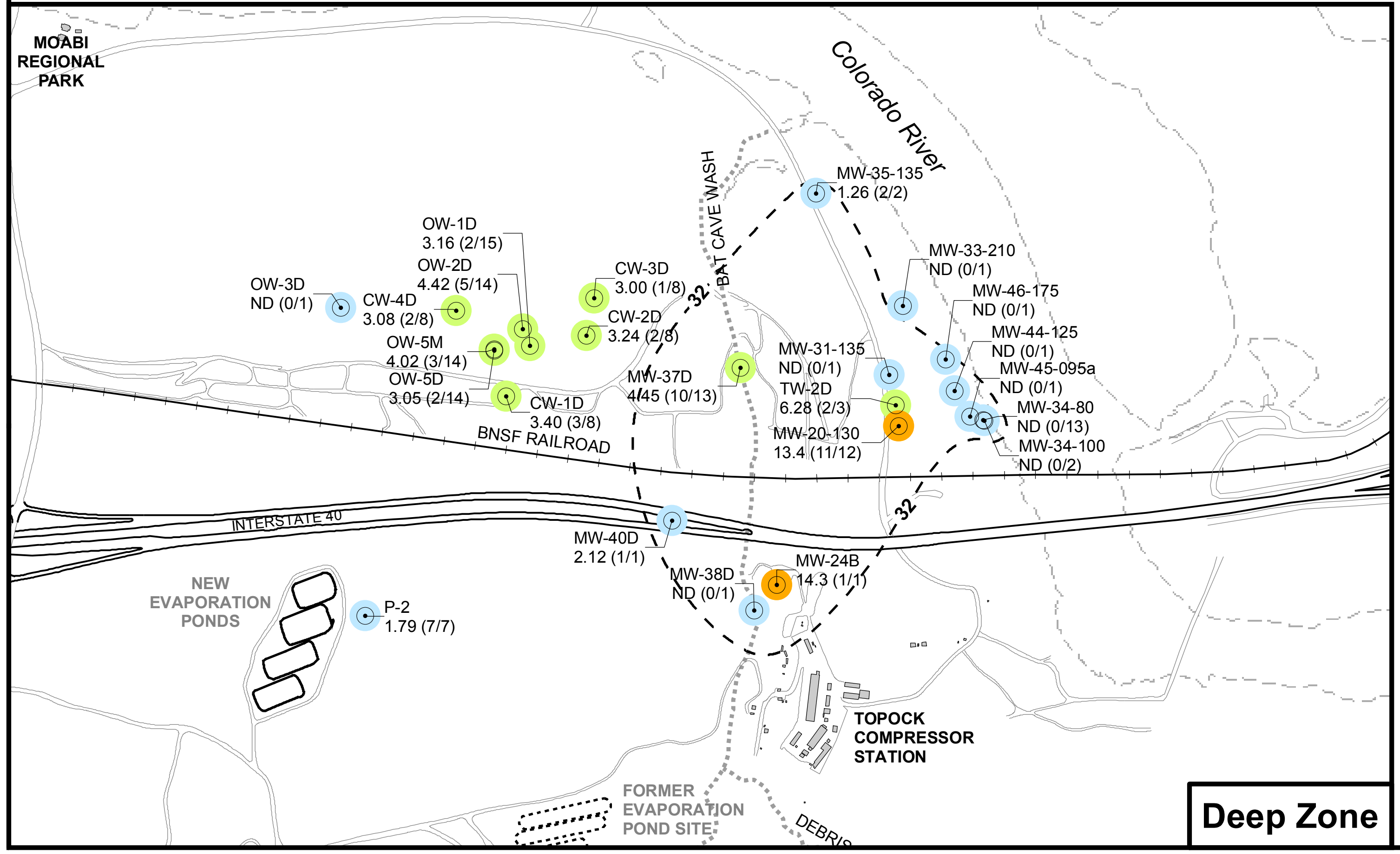
Molybdenum Background Study Upper Tolerance Limit (UTL) = 36.3 µg/L
See Table 6-8 for summary of sampling results

FIGURE 6-7
MOLYBDENUM CONCENTRATIONS IN GROUNDWATER, 1997-2007

RCRA FACILITY INVESTIGATION/REMEDIAL
INVESTIGATION REPORT (VOLUME 2)
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA







LEGEND

⊙ Groundwater Well completed in Alluvial Aquifer (Shallow, Mid-depth or Deep Zones)

Dissolved Selenium Average Concentrations

MW-17 ⟵ Well ID
5.8 (8/16) ⟵ (No. of detections / No. of samples)
↑ Average concentration, micrograms per liter (µg/L)
1997 - 2007 groundwater sampling

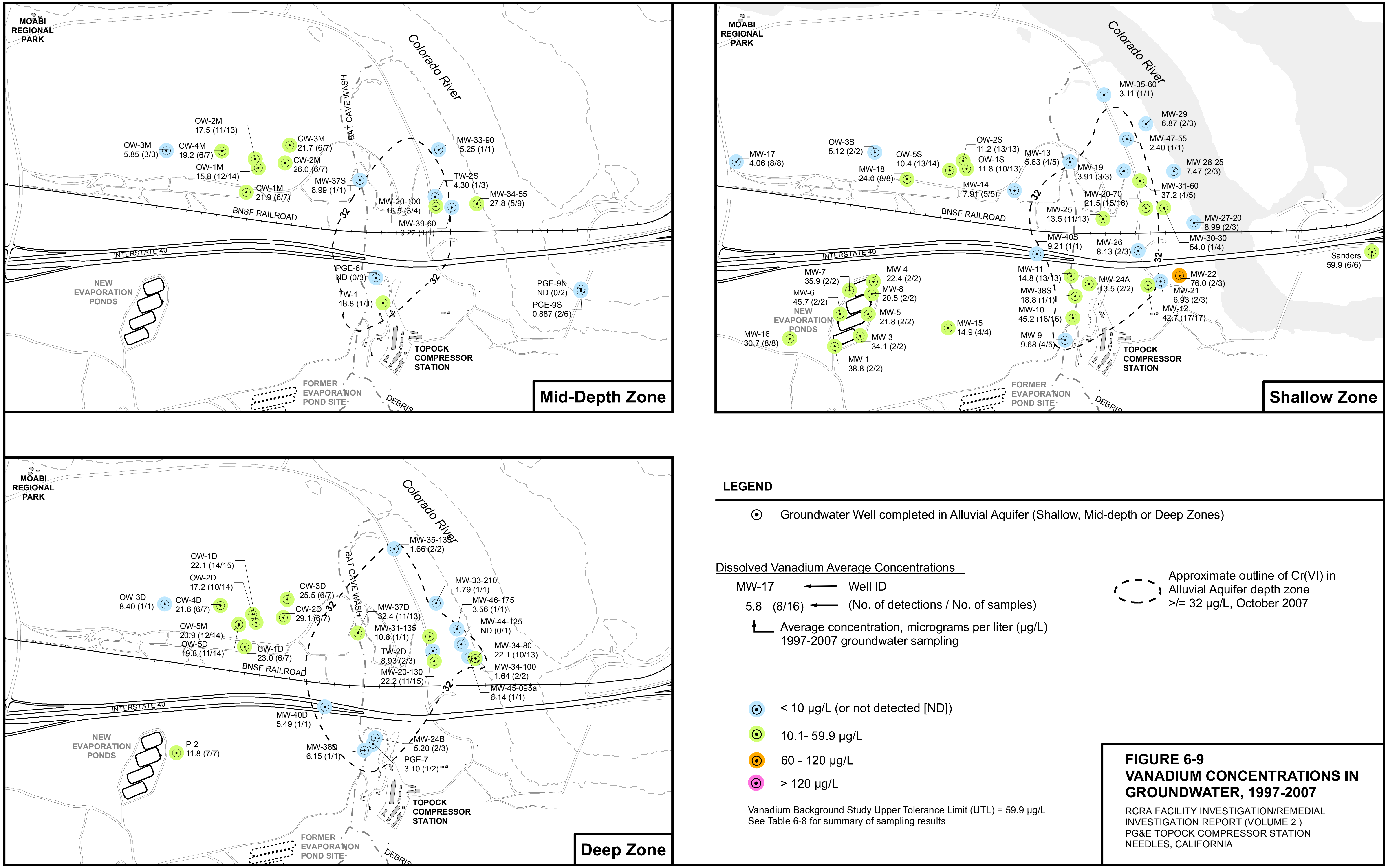
Approximate outline of Cr(VI) in Alluvial Aquifer depth zone >/= 32 µg/L, October 2007

⊙ < 3 µg/L (or not detected [ND])
⊙ 3 - 10.3 µg/L
⊙ 10.4 - 50 µg/L
⊙ > 50 µg/L

Selenium Background Study Upper Tolerance Level (UTL) = 10.3 µg/L
Selenium applicable or relevant and appropriate requirement (ARAR) = 50 µg/L
See Table 6-8 for summary of sampling results

FIGURE 6-8
SELENIUM CONCENTRATIONS IN GROUNDWATER, 1997-2007

RCRA FACILITY INVESTIGATION/REMEDIAL
INVESTIGATION REPORT (VOLUME 2)
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA



LEGEND

⊙ Groundwater Well completed in Alluvial Aquifer (Shallow, Mid-depth or Deep Zones)

Dissolved Vanadium Average Concentrations

MW-17 ← Well ID

5.8 (8/16) ← (No. of detections / No. of samples)

↑ Average concentration, micrograms per liter (µg/L) 1997-2007 groundwater sampling

Approximate outline of Cr(VI) in Alluvial Aquifer depth zone >/= 32 µg/L, October 2007

⊙ < 10 µg/L (or not detected [ND])

⊙ 10.1- 59.9 µg/L

⊙ 60 - 120 µg/L

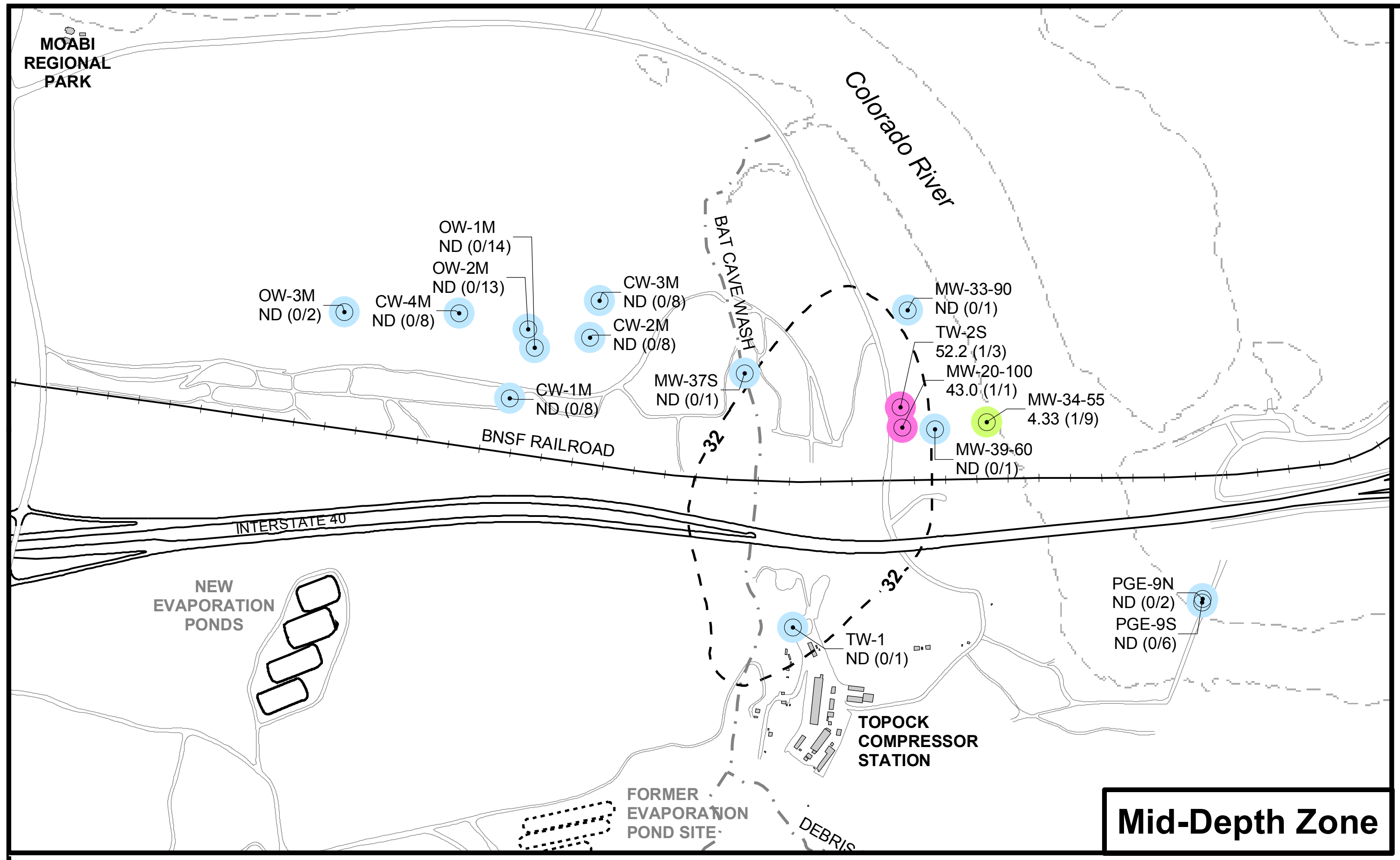
⊙ > 120 µg/L

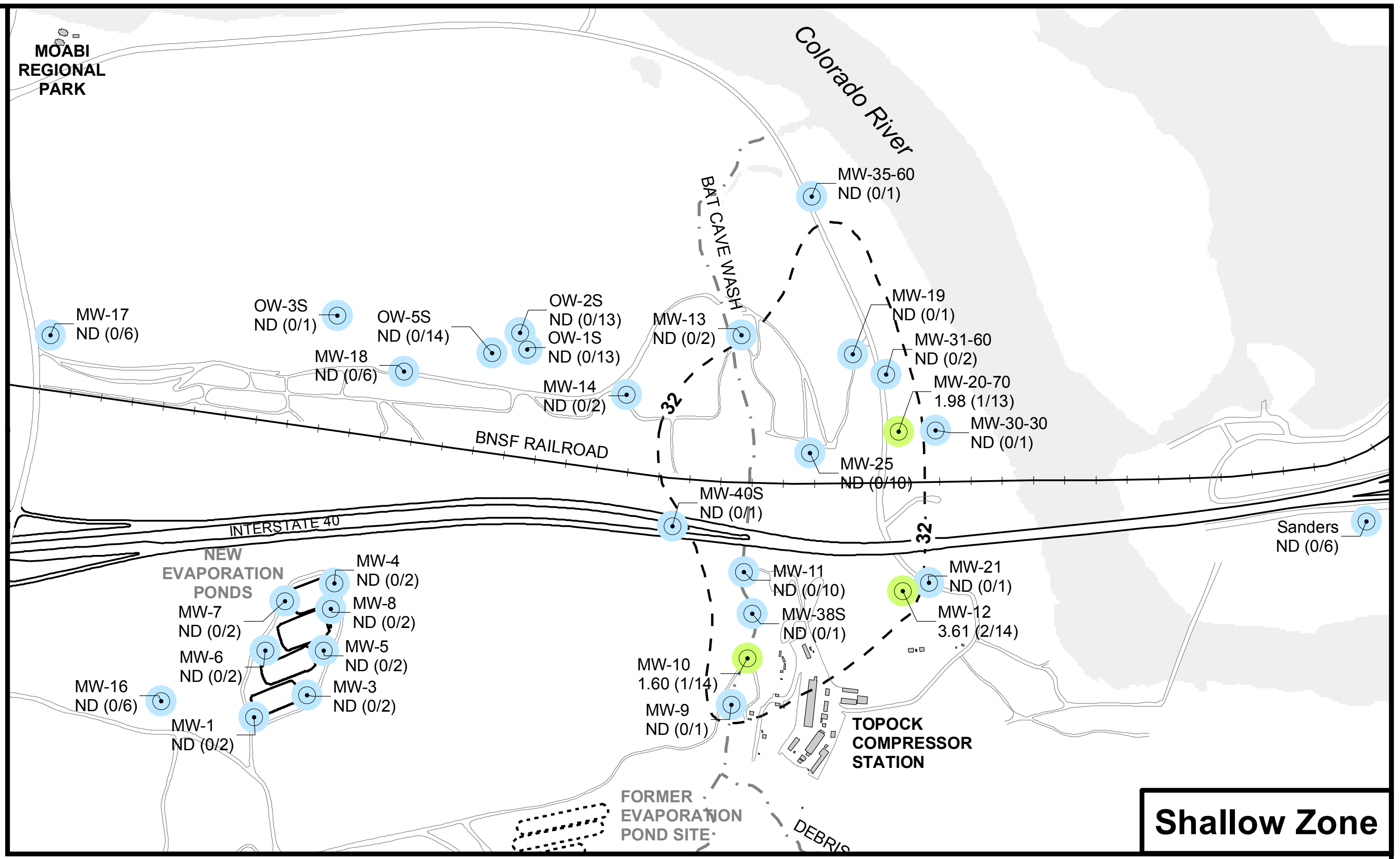
Vanadium Background Study Upper Tolerance Limit (UTL) = 59.9 µg/L
See Table 6-8 for summary of sampling results

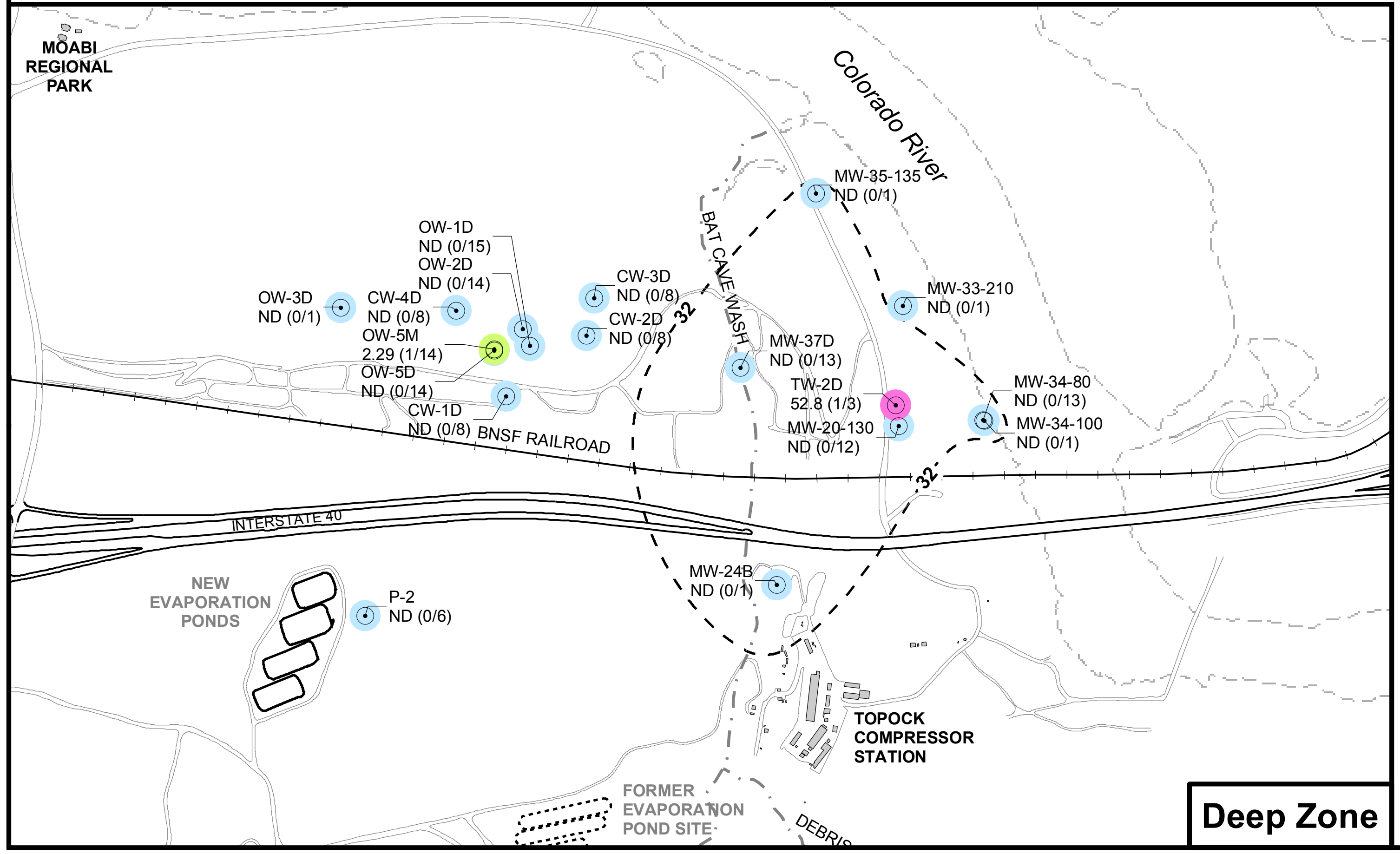
FIGURE 6-9
VANADIUM CONCENTRATIONS IN GROUNDWATER, 1997-2007

RCRA FACILITY INVESTIGATION/REMEDIAL INVESTIGATION REPORT (VOLUME 2)
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

BAO \\ZINFANDEL\PROJ\PACIFICGASELECTRICCO\TOPOCKPROGRAM\GIS\MAPFILES\2007\RFI\RFI_METALSDIST_VD.MXD 12/30/2008 09:42:30







LEGEND

⊙ Groundwater Well completed in Alluvial Aquifer (Shallow, Mid-depth or Deep Zones)

Dissolved Antimony Average Concentrations

MW-17 ← Well ID

5.8 (8/16) ← (No. of detections / No. of samples)

Average concentration, micrograms per liter (µg/L) 1997-2007 groundwater sampling

Approximate outline of Cr(VI) in Alluvial Aquifer depth zone >/= 32 µg/L, October 2007

⊙ < 1.22 µg/L (or not detected [ND])

⊙ 1.23 - 6µg/L

⊙ 6.1 - 40 µg/L

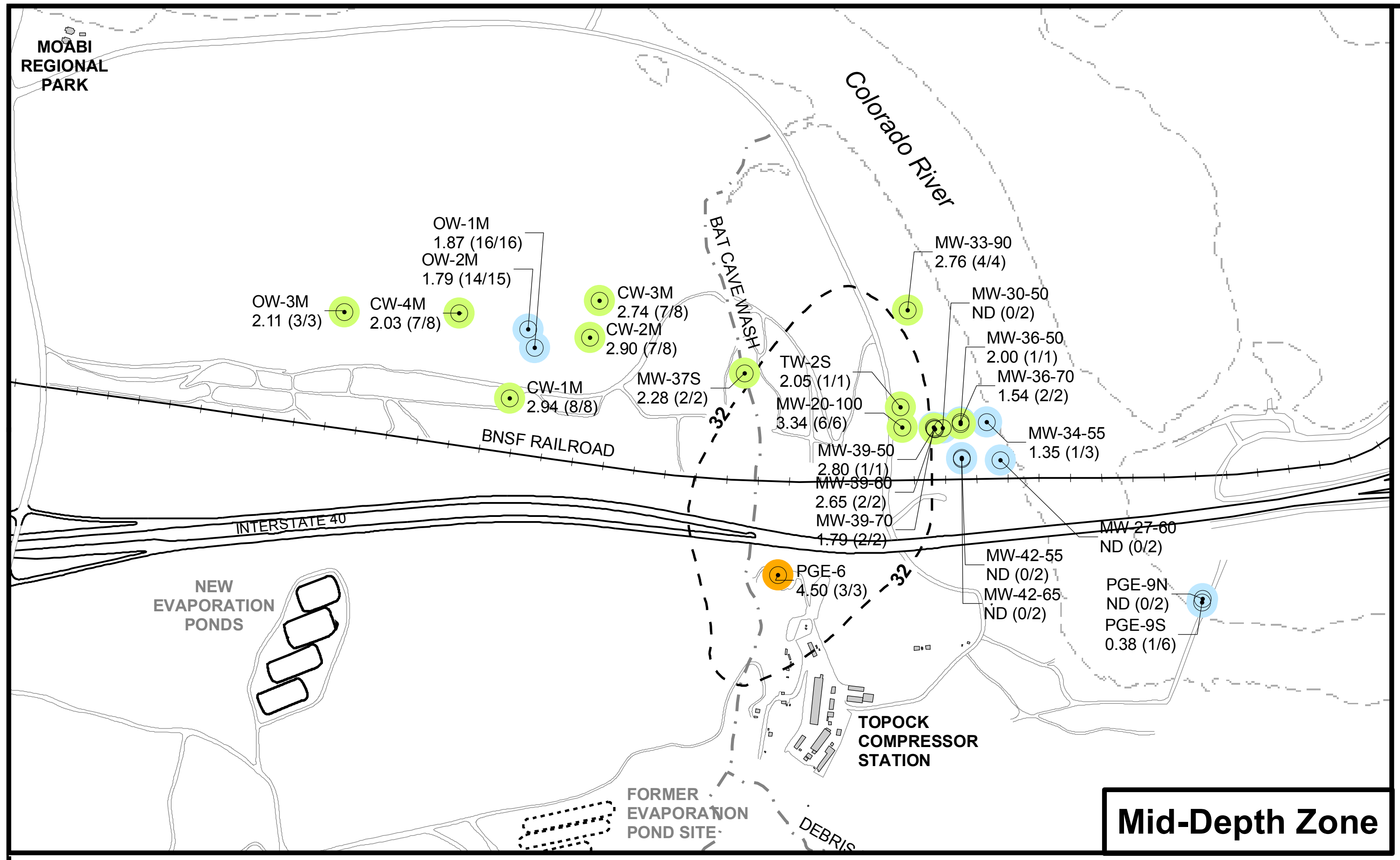
⊙ > 40 µg/L

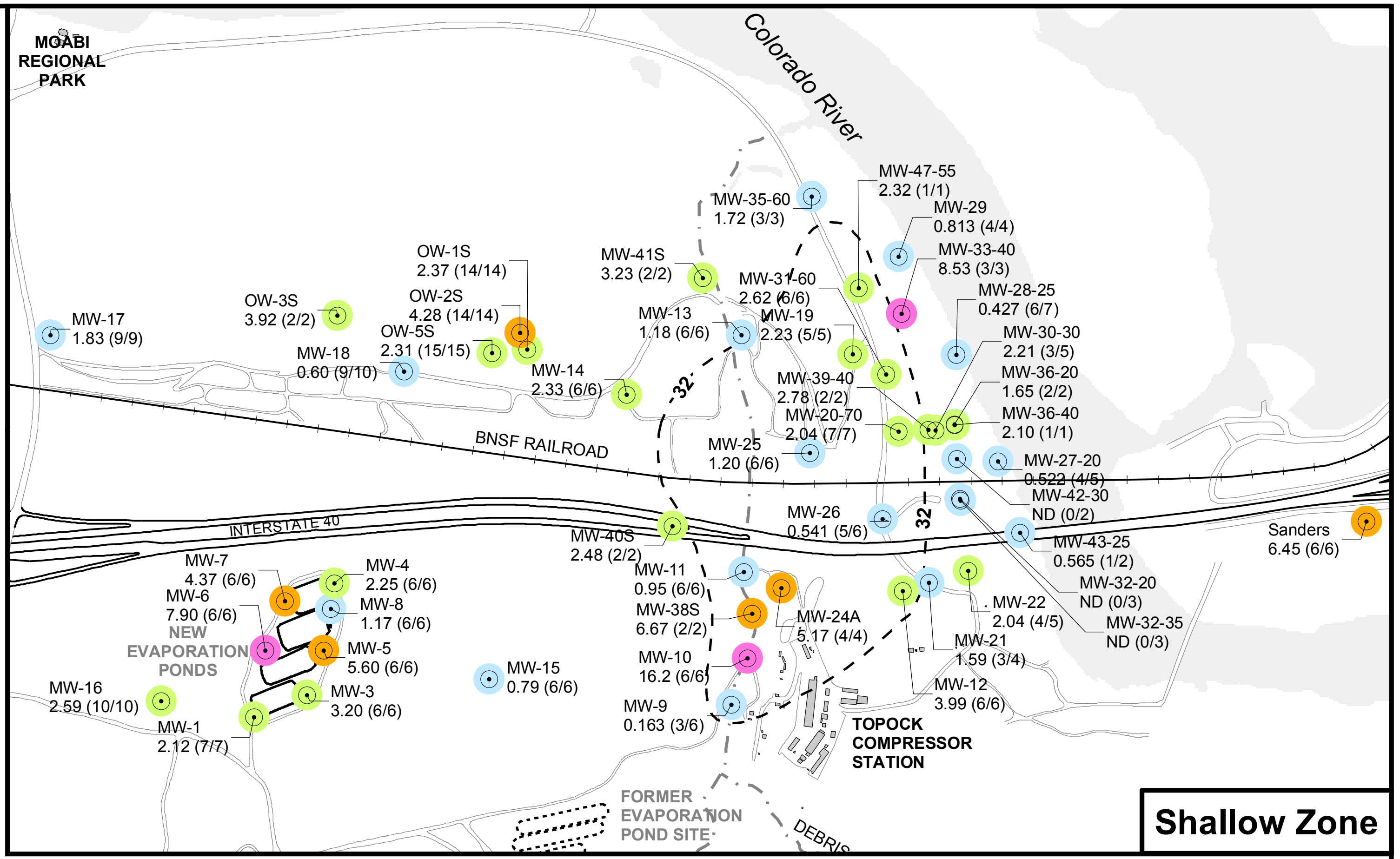
Antimony Background Study Upper Tolerance Limit (UTL) = 1.22 µg/L
Antimony applicable or relevant and appropriate requirement (ARAR) = 6 µg/L
See Table 6-8 for summary of sampling results

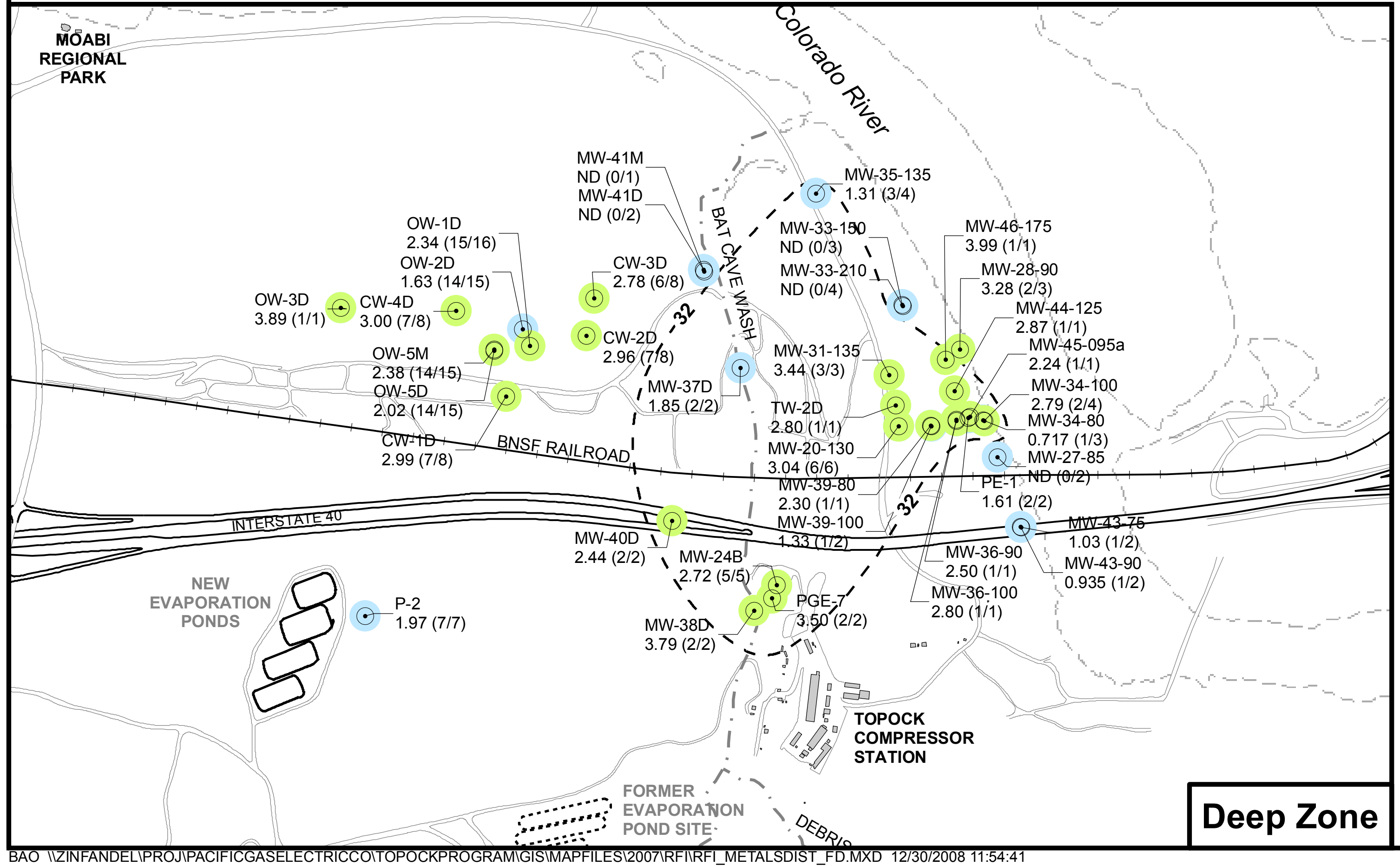
FIGURE 6-10
ANTIMONY CONCENTRATIONS IN GROUNDWATER, 1997-2007

RCRA FACILITY INVESTIGATION/REMEDIAL
INVESTIGATION REPORT (VOLUME 2)
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

BAO \\ZINFANDEL\PROJ\PACIFICGASELECTRICCO\TOPOCKPROGRAM\GIS\MAPFILES\2007\RFI\RFI_METALSDIST_SBD.MXD 12/31/2008 10:07:11







LEGEND

⊙ Groundwater Well completed in Alluvial Aquifer (Shallow, Mid-depth or Deep Zones)

Dissolved Fluoride Average Concentrations

MW-17 ← Well ID

5.8 (8/16) ← (No. of detections / No. of samples)

↑ Average concentration, milligrams per liter (mg/L) 1997-2007 groundwater sampling

( ) Approximate outline of Cr(VI) in Alluvial Aquifer depth zone >/= 32 μg/L, October 2007

⊙ < 2 mg/L

⊙ 2 - 4 mg/L

⊙ 4 - 7.1 mg/L

⊙ > 7.1 mg/L

Fluoride Calculated Upper Tolerance Limit (UTL) = 7.1 mg/L
Fluoride applicable or relevant and appropriate requirement (ARAR) = 2 mg/L

FIGURE 6-11
FLUORIDE CONCENTRATIONS IN GROUNDWATER, 1997-2007

RCRA FACILITY INVESTIGATION/REMEDIAL
INVESTIGATION REPORT (VOLUME 2)
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

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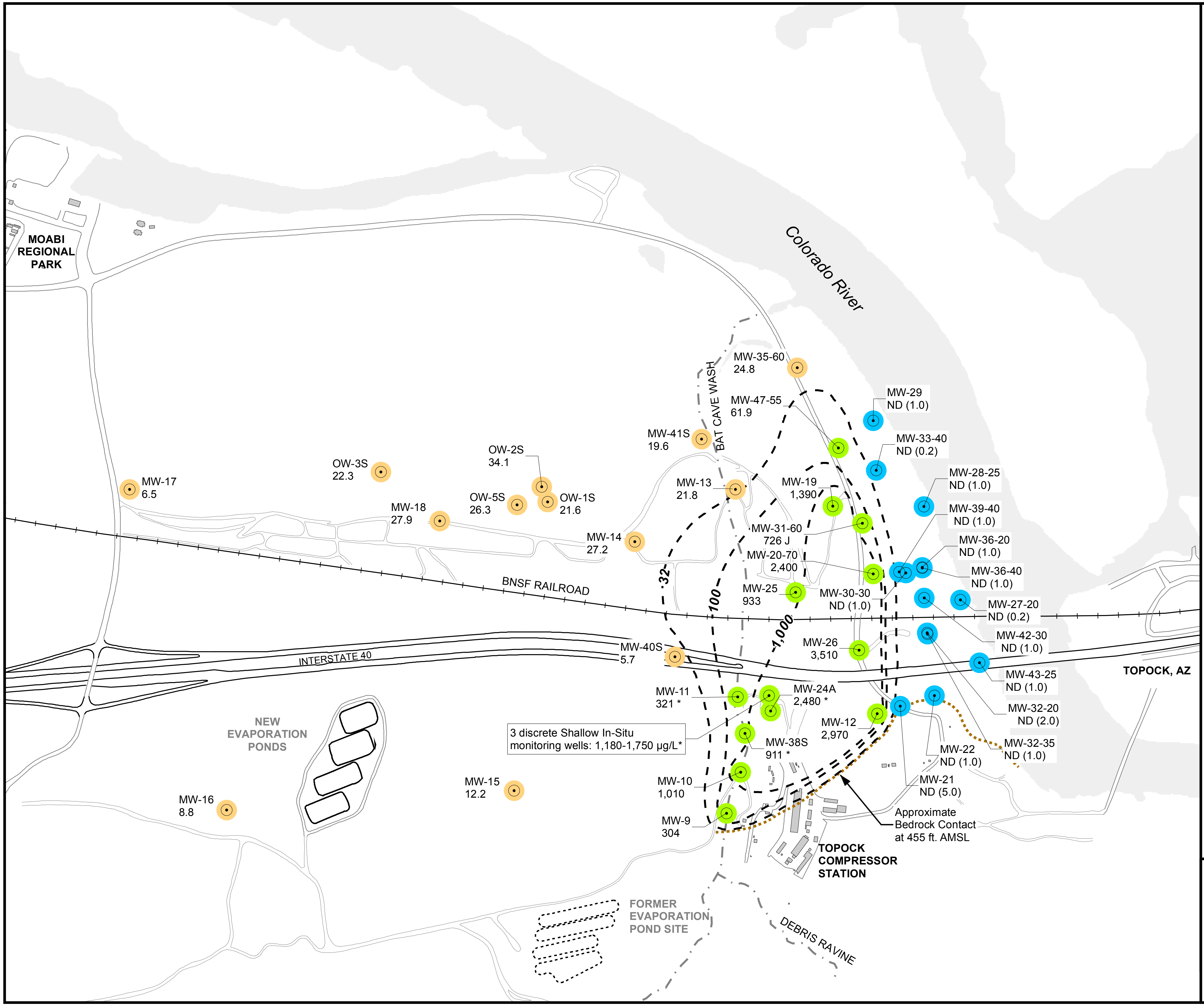

LEGEND

⊙ Monitoring, Test, or Supply Well

⊕ Extraction Well

6.48 Concentration of hexavalent chromium [Cr(VI)] in micrograms per liter (µg/L)

ND (0.2) Cr(VI) not detected at listed reporting limit

Results shown are maximum concentrations in primary and duplicate samples from wells completed in **Shallow zone** of Alluvial Aquifer, October 2007 sampling.

* Results from July 2007 (well not sampled October 2007)

······ Bedrock Contact

Cr(VI) Concentrations in Alluvial Aquifer

● Not detected at analytical reporting limit

● Concentration between reporting limit and 32 µg/L

● Concentration greater than 32 µg/L

32 Approximate Cr(VI) isoconcentration contour in Alluvial Aquifer, October 2007

N

0 750 1,500 Feet

FIGURE 6-12a
GROUNDWATER Cr(VI) RESULTS SHALLOW WELLS OF ALLUVIAL AQUIFER OCTOBER 2007

RCRA FACILITY INVESTIGATION/REMEDIAL INVESTIGATION REPORT (VOLUME 2)
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CH2MHILL

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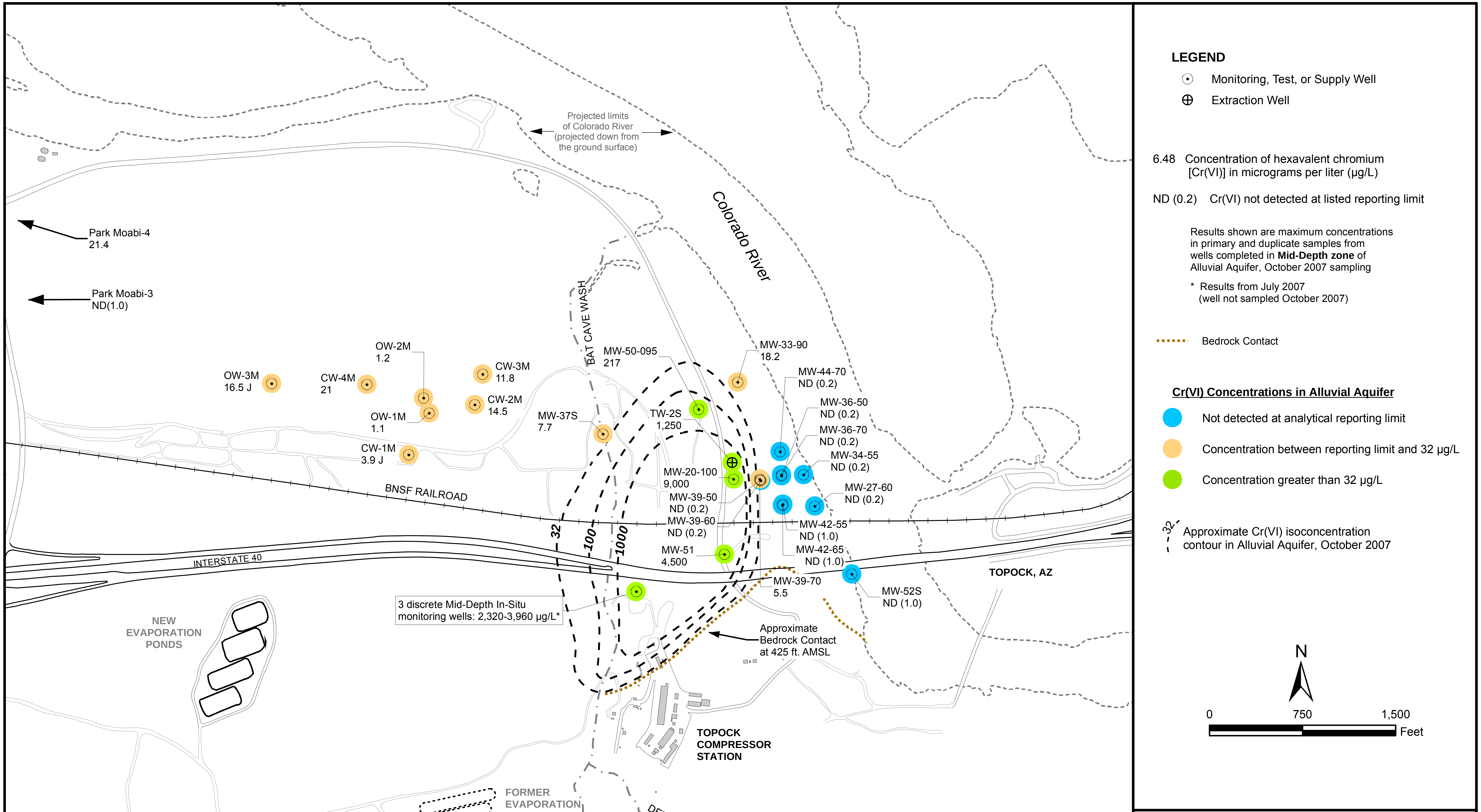

FIGURE 6-12b
GROUNDWATER Cr(VI) RESULTS
MID-DEPTH WELLS OF ALLUVIAL AQUIFER
OCTOBER 2007

RCRA FACILITY INVESTIGATION/REMEDIAL
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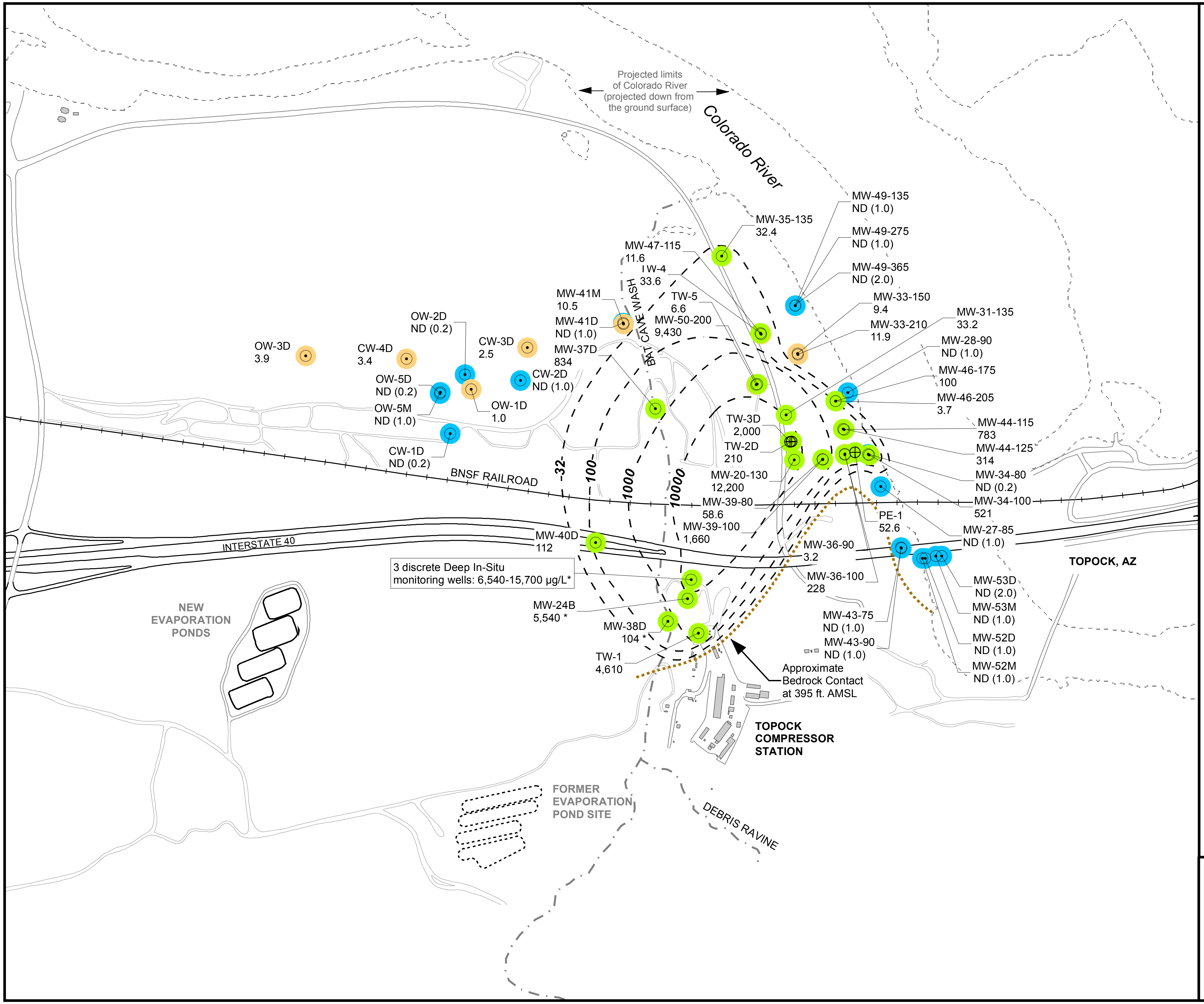
\\ZINFANDEL\PROJ\PACIFICGASELECTRICCO\TOPOCKPROGRAM\GIS\MAPFILES\2007\RFI\RFI_OCT07_CR6MAP_MZ.MXD RFI_OCT07_CR6MAP_MZ CARCHER 1/29/2009 13:56:38



LEGEND

⊙ Monitoring, Test, or Supply Well

⊕ Extraction Well

6.48 Concentration of hexavalent chromium [Cr(VI)] in micrograms per liter (µg/L)

ND (0.2) Cr(VI) not detected at listed reporting limit

Results shown are maximum concentrations in primary and duplicate samples from wells completed in **Deep zone** of Alluvial Aquifer, October 2007 sampling

* Results from July 2007 (well not sampled October 2007)

······ Bedrock Contact

Cr(VI) Concentrations in Alluvial Aquifer

● Not detected at analytical reporting limit

● Concentration between reporting limit and 32 µg/L

● Concentration greater than 32 µg/L

32 Approximate Cr(VI) isoconcentration contour in Alluvial Aquifer, October 2007

In the floodplain area, the 32 µg/L outline for Cr(VI) in Deep zone (80-90 feet below Colorado River) is estimated based on available groundwater sampling, hydrogeologic and geochemical data.There are no data confirming the existence of Cr(VI) under the Colorado River.

N

0 750 1,500 Feet

FIGURE 6-12c
GROUNDWATER Cr(VI) RESULTS DEEP WELLS IN ALLUVIAL AQUIFER OCTOBER 2007

RCRA FACILITY INVESTIGATION/REMEDIAL INVESTIGATION REPORT (VOLUME 2)
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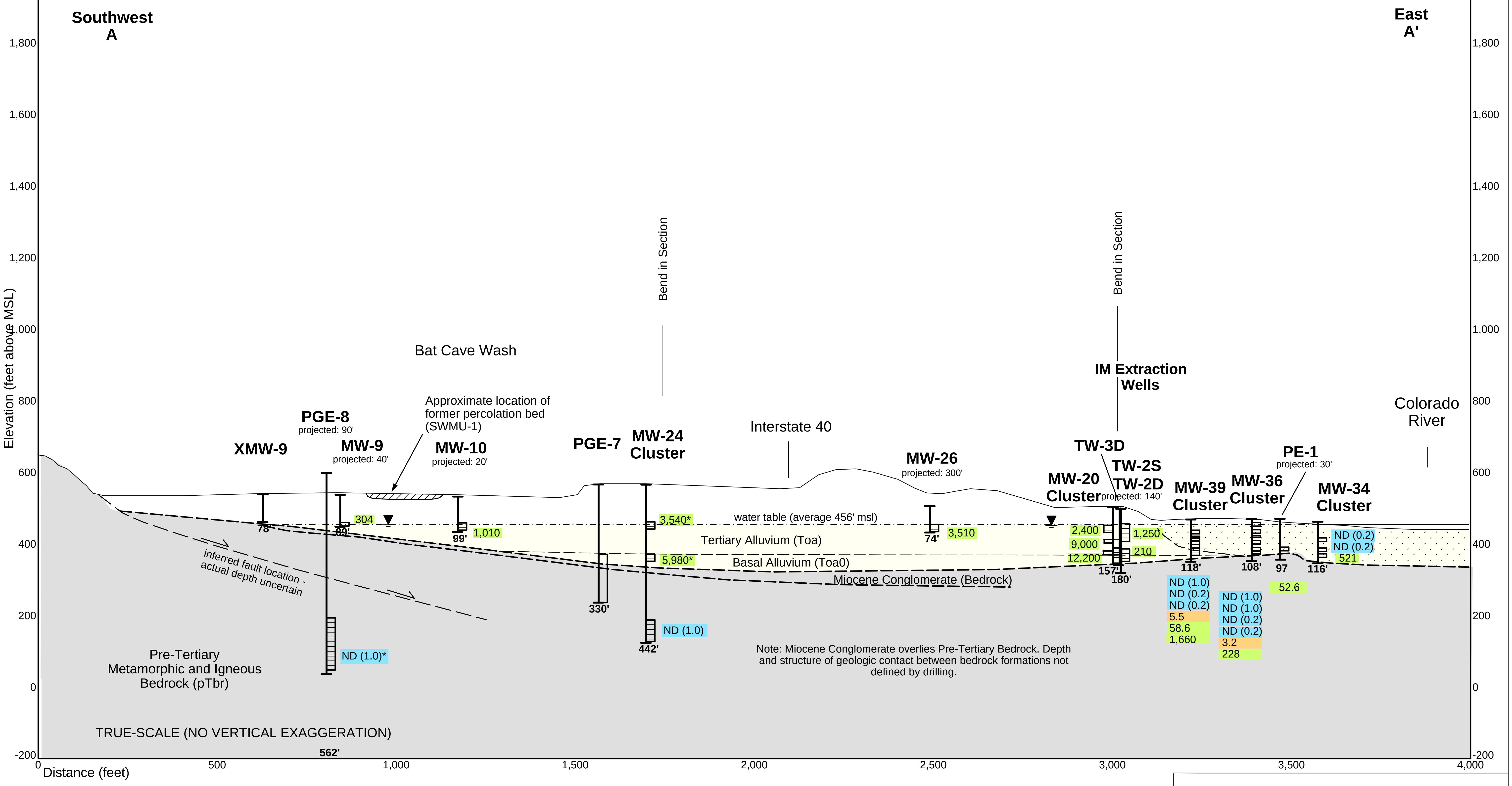
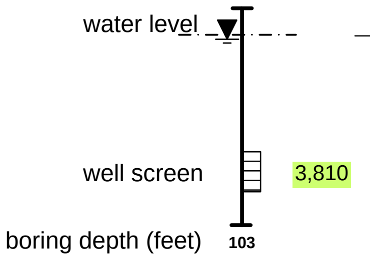


Notes:
* Indicates data from March or August, 2007.
Refer to Figure 5-1 for location of cross-section.



Hexavalent Chromium [Cr(VI)] Results, October 2007

Concentrations in micrograms per liter (µg/L)

ND (1)	Not detected at listed reporting limit
28	Less than 32 µg/L
3,810	Greater than 32 µg/L

12/8/08

FIGURE 6-13
Cr(VI) RESULTS, OCTOBER 2007 HYDROGEOLOGIC CROSS SECTION A-A' BAT CAVE WASH TO FLOODPLAIN

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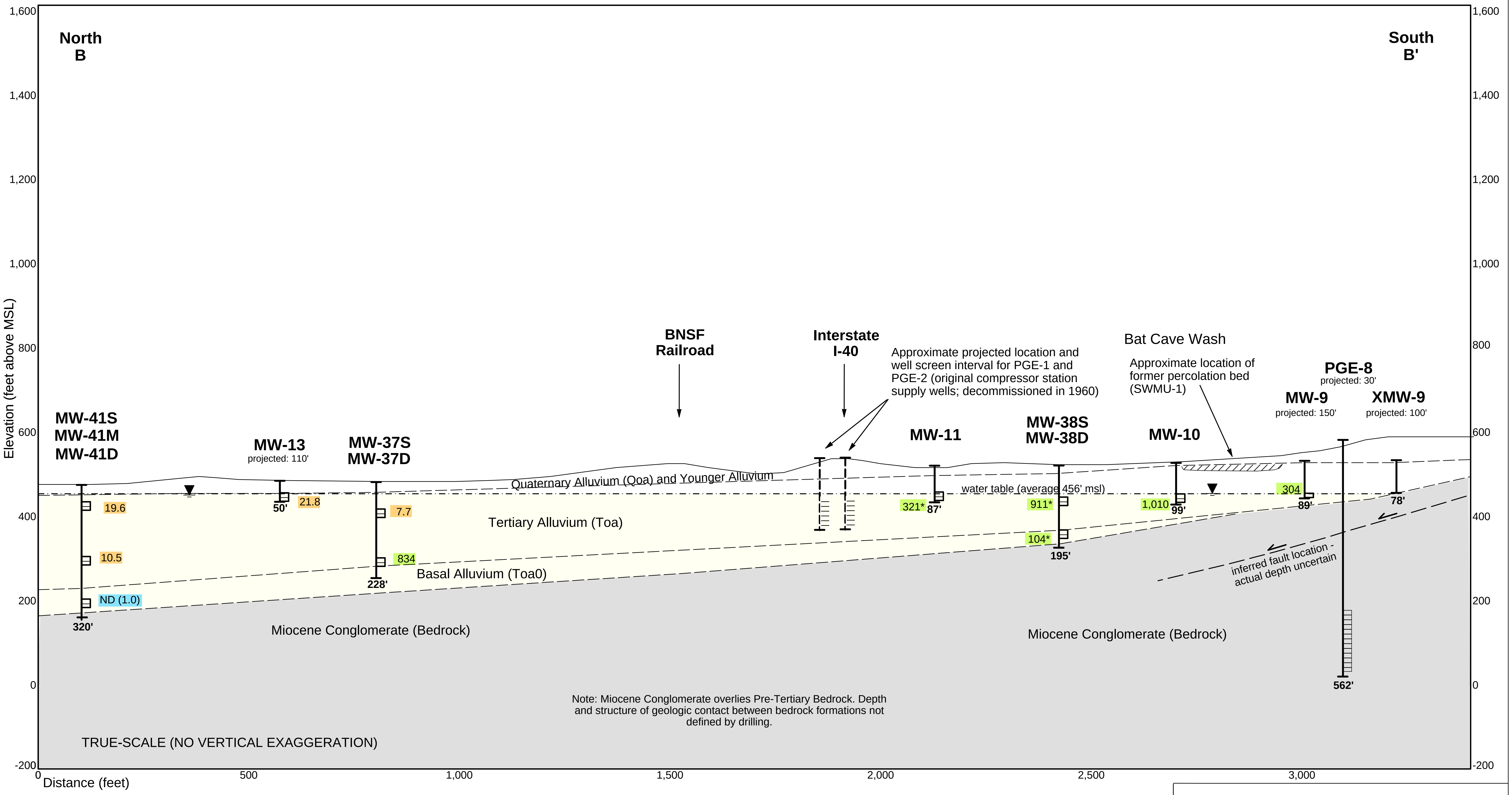
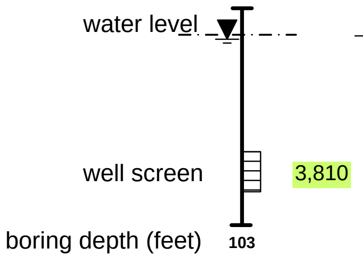
CH2MHILL



Notes:
Refer to Figure 5-1 for location of cross-section.
* Indicates data from July, 2007.



Hexavalent Chromium [Cr(VI)] Results, October 2007

Concentrations in micrograms per liter (µg/L)

ND (1)	Not detected at listed reporting limit (µg/L)
28	Less than 32 µg/L
3,810	Greater than 32 µg/L

12/8/08

FIGURE 6-14
Cr(VI) RESULTS, OCTOBER 2007
HYDROGEOLOGIC CROSS SECTION B-B'
BAT CAVE WASH

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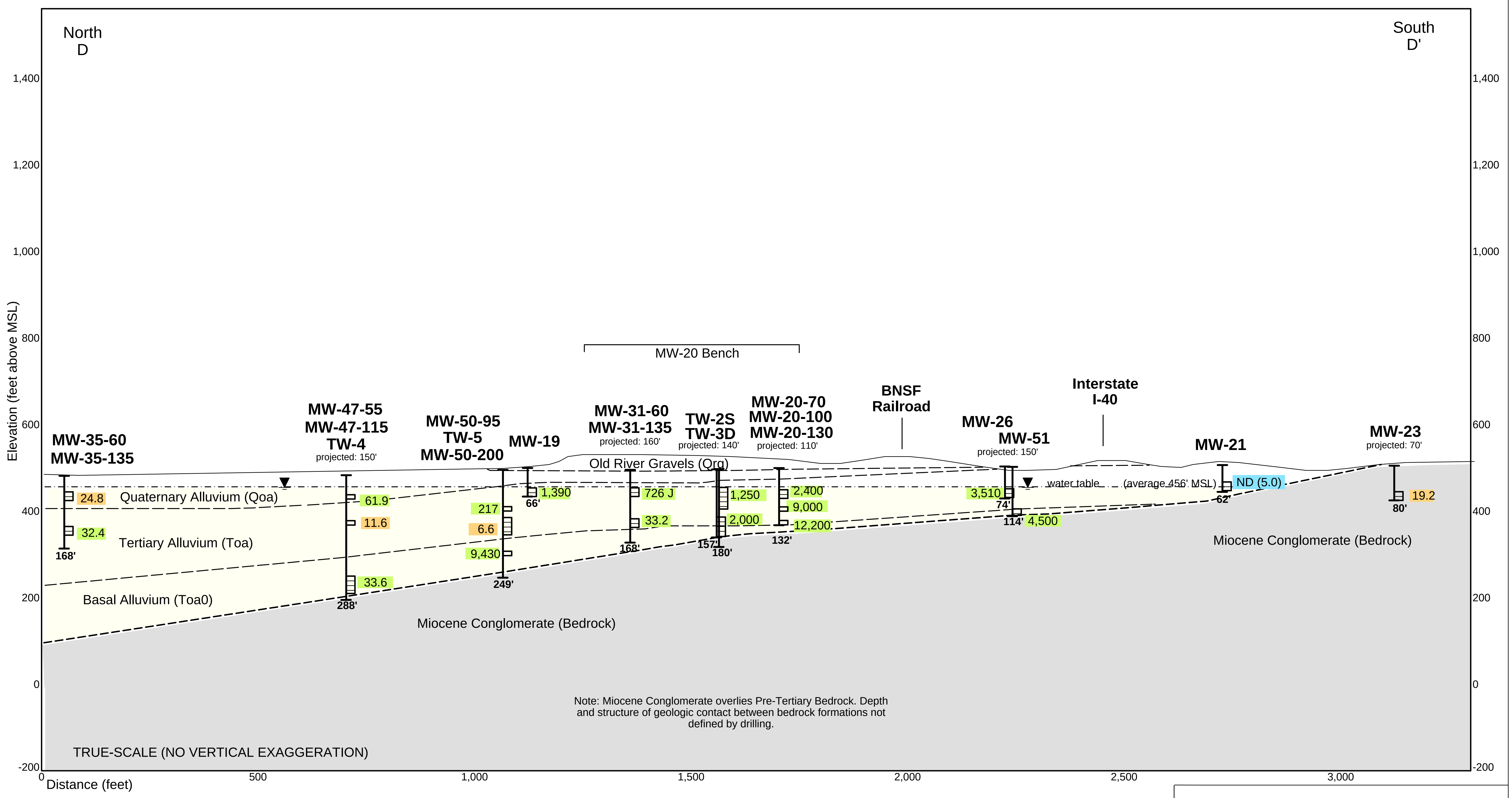

water level

well screen 3,810

boring depth (feet) 103

Hexavalent Chromium [Cr(VI)] Results, October 2007

Concentrations in micrograms per liter (µg/L)

ND (1)	Not detected at listed reporting limit (µg/L)
28	Less than 32 (µg/L)
3,810	Greater than 32 (µg/L)

Notes:
Refer to Figure 5-1 for location of cross-section.
MSL = mean sea level

12/8/08

FIGURE 6-15
Cr(VI) RESULTS, OCTOBER 2007
HYDROGEOLOGIC CROSS SECTION D-D'
PARK MOABI ROAD ALIGNMENT

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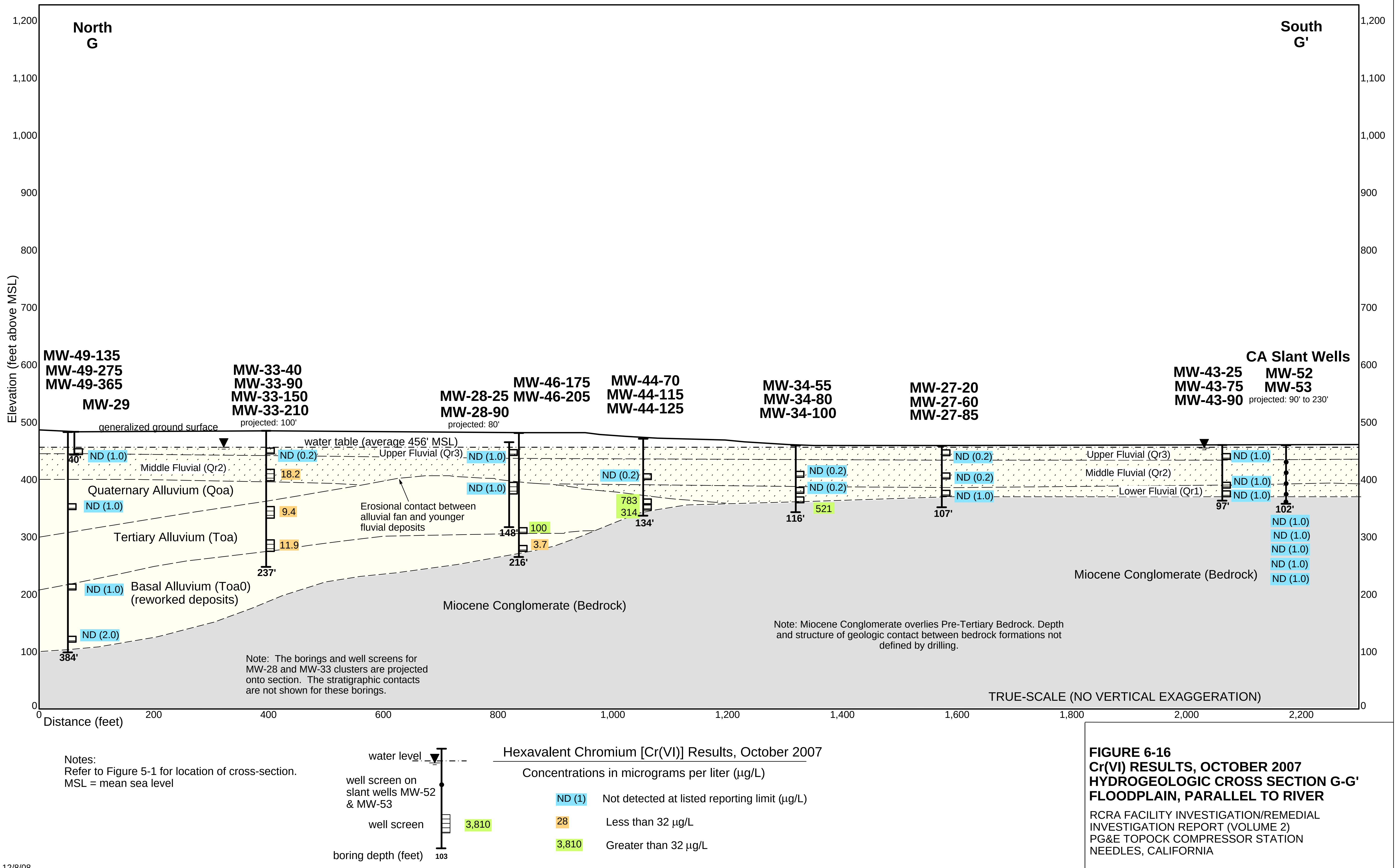

Notes:
Refer to Figure 5-1 for location of cross-section.
MSL = mean sea level

12/8/08

FIGURE 6-16
Cr(VI) RESULTS, OCTOBER 2007
HYDROGEOLOGIC CROSS SECTION G-G'
FLOODPLAIN, PARALLEL TO RIVER

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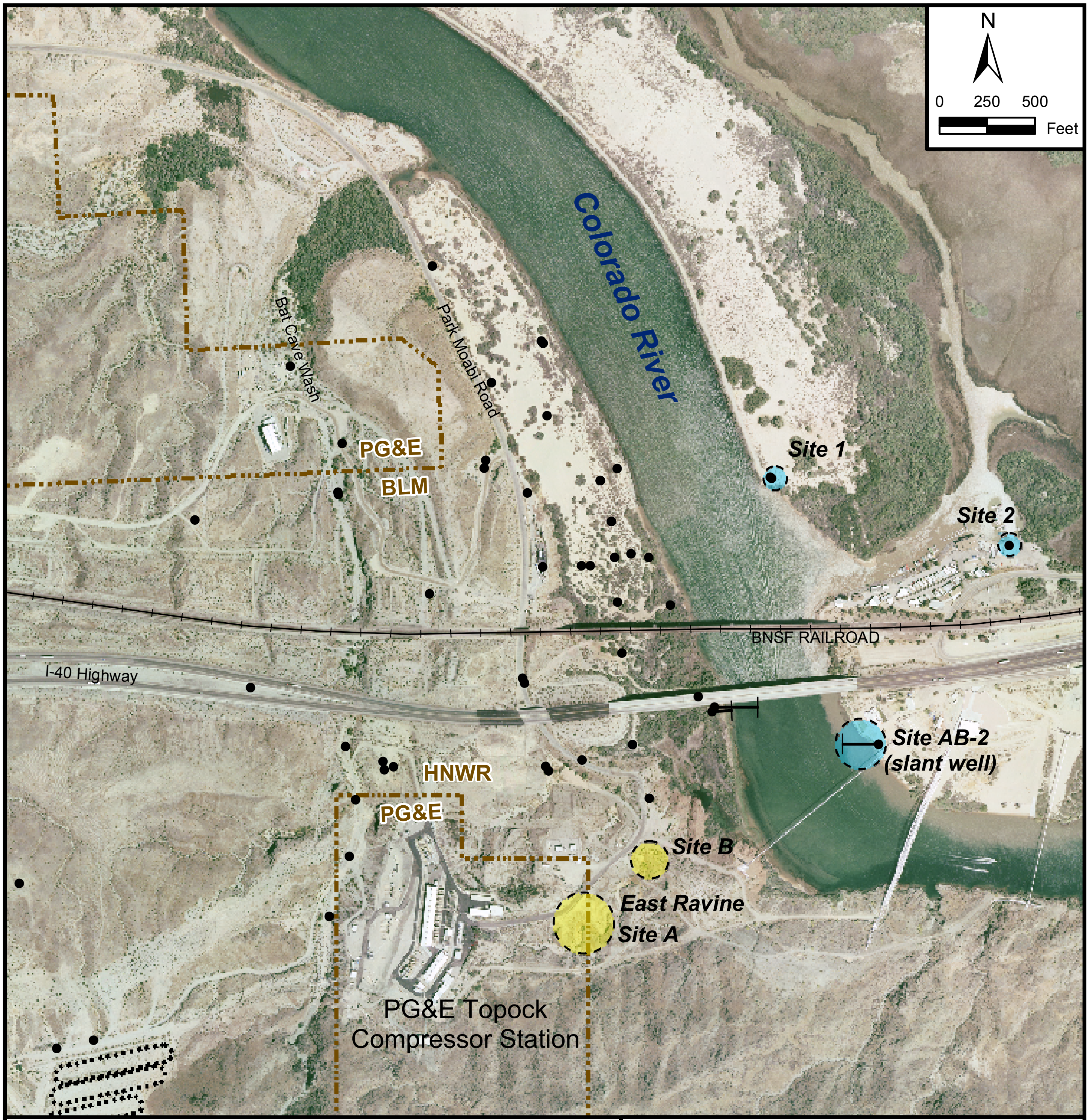

LEGEND

● Groundwater monitoring well (see Figure 4-2 for well identifications)

🔵 Drilling site for groundwater characterization in Arizona (primary drilling sites)

🟡 Drilling site for East Ravine groundwater investigation (general area for primary drilling sites)

Note: Additional groundwater investigation is planned for inside the Topock Compressor Station (not shown). The locations and number of wells proposed to assess potential on-site source areas during the Part B soils investigation have not been approved by the agencies.

FIGURE 6-17
LOCATIONS OF ADDITIONAL GROUNDWATER INVESTIGATIONS TO SUPPORT THE RFI/RI

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PG&E TOPOCK COMPRESSOR STATION
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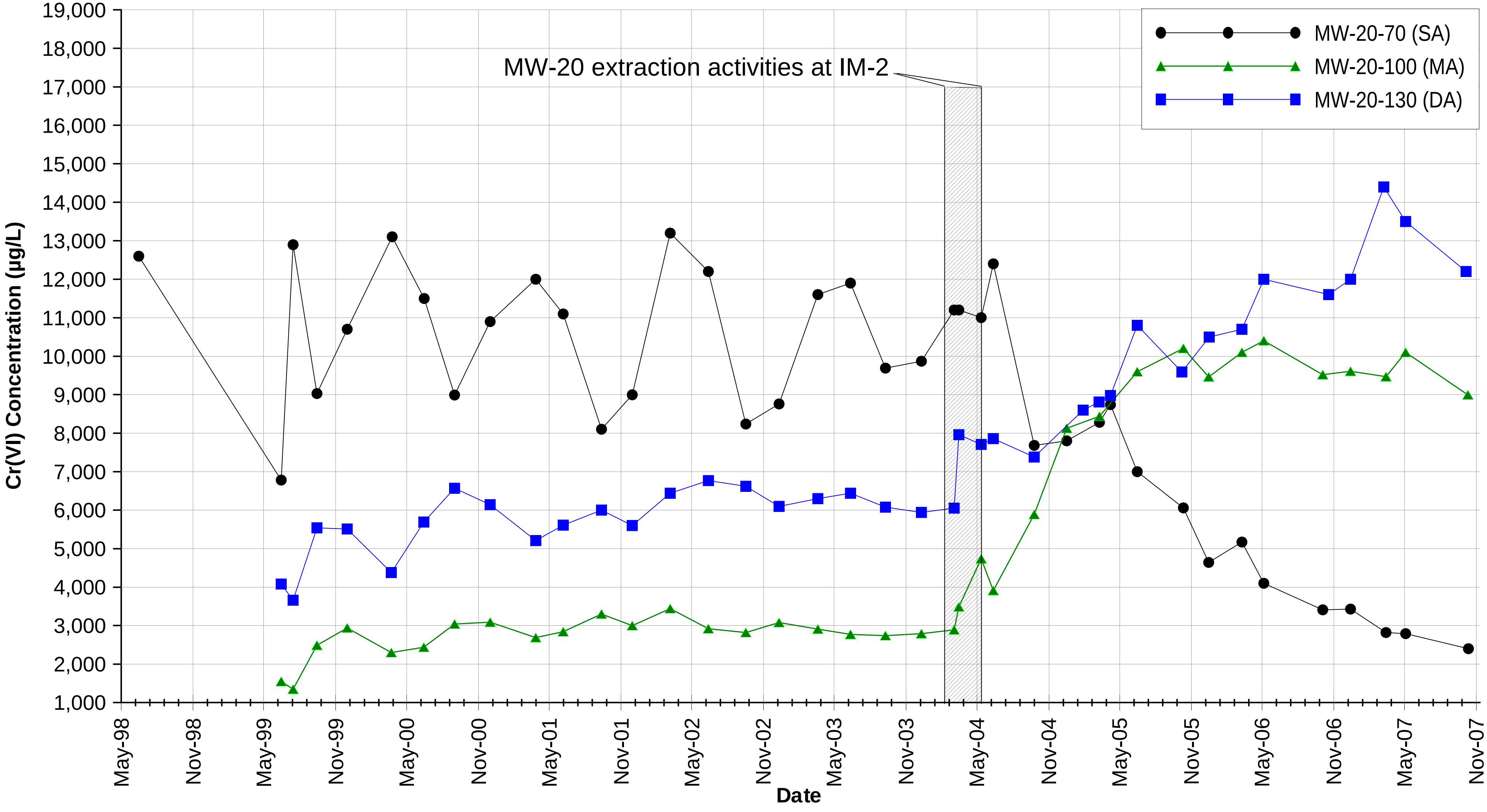

Notes:
1. Hexavalent Chromium [Cr(VI)] concentrations in micrograms per liter (ug/L)
2. Alluvial Aquifer monitoring zones for wells plotted: Shallow (SA), Mid-Depth (MA), Deep (DA)
3. Data from RFI/RI sampling June 1998 to October 2007

FIGURE 6-18
Cr(VI) GROUNDWATER CONCENTRATIONS
MW-20 WELL CLUSTER

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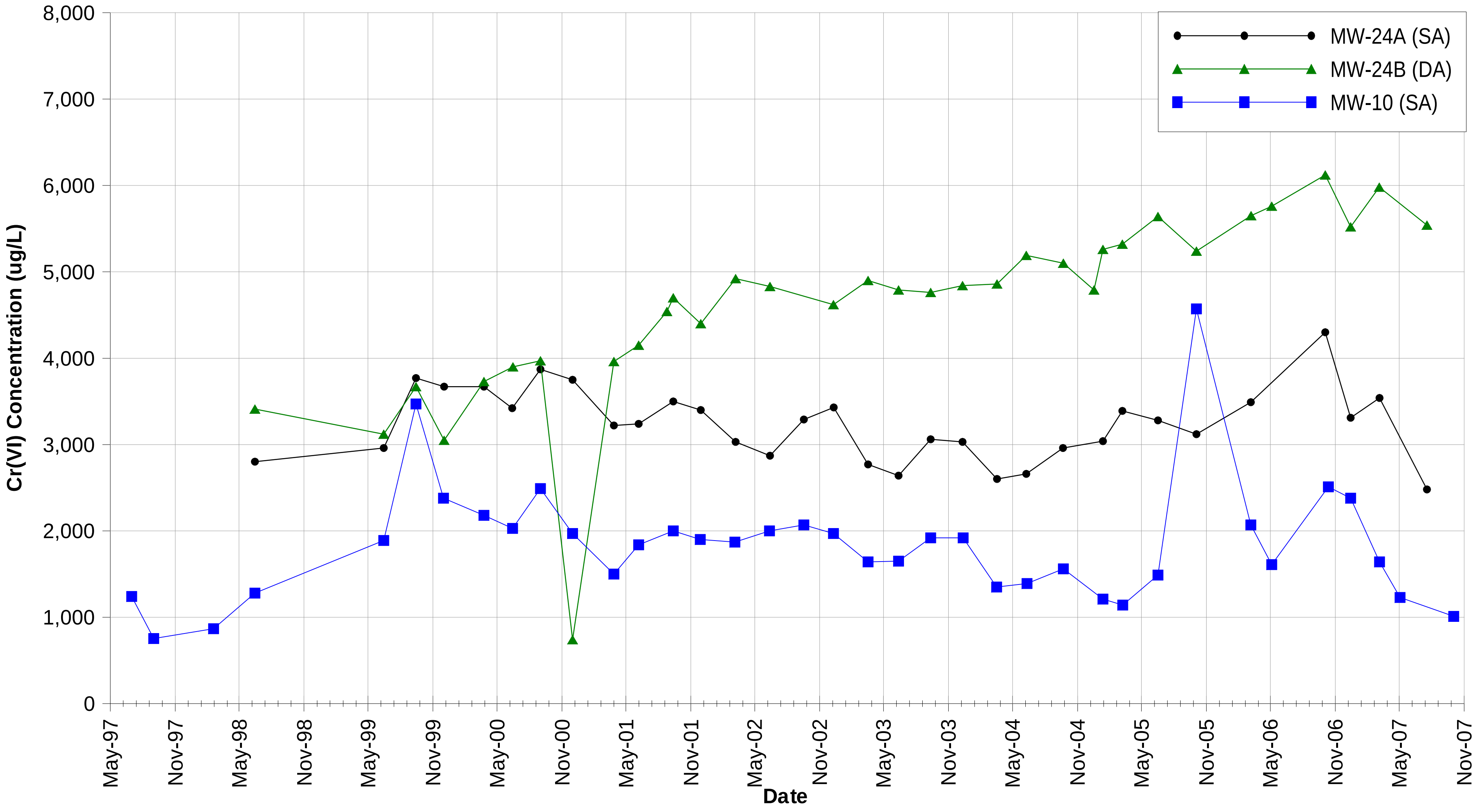

Notes:
1. Hexavalent Chromium [Cr(VI)] concentrations in micrograms per liter (ug/L)
2. Alluvial Aquifer monitoring zones for wells plotted: Shallow (SA), Mid-Depth (MA), Deep (DA)
3. Data from RFI/RI sampling July 1997 to October 2007

FIGURE 6-19
Cr(VI) GROUNDWATER CONCENTRATIONS
MW-24A, MW-24B AND MW-10

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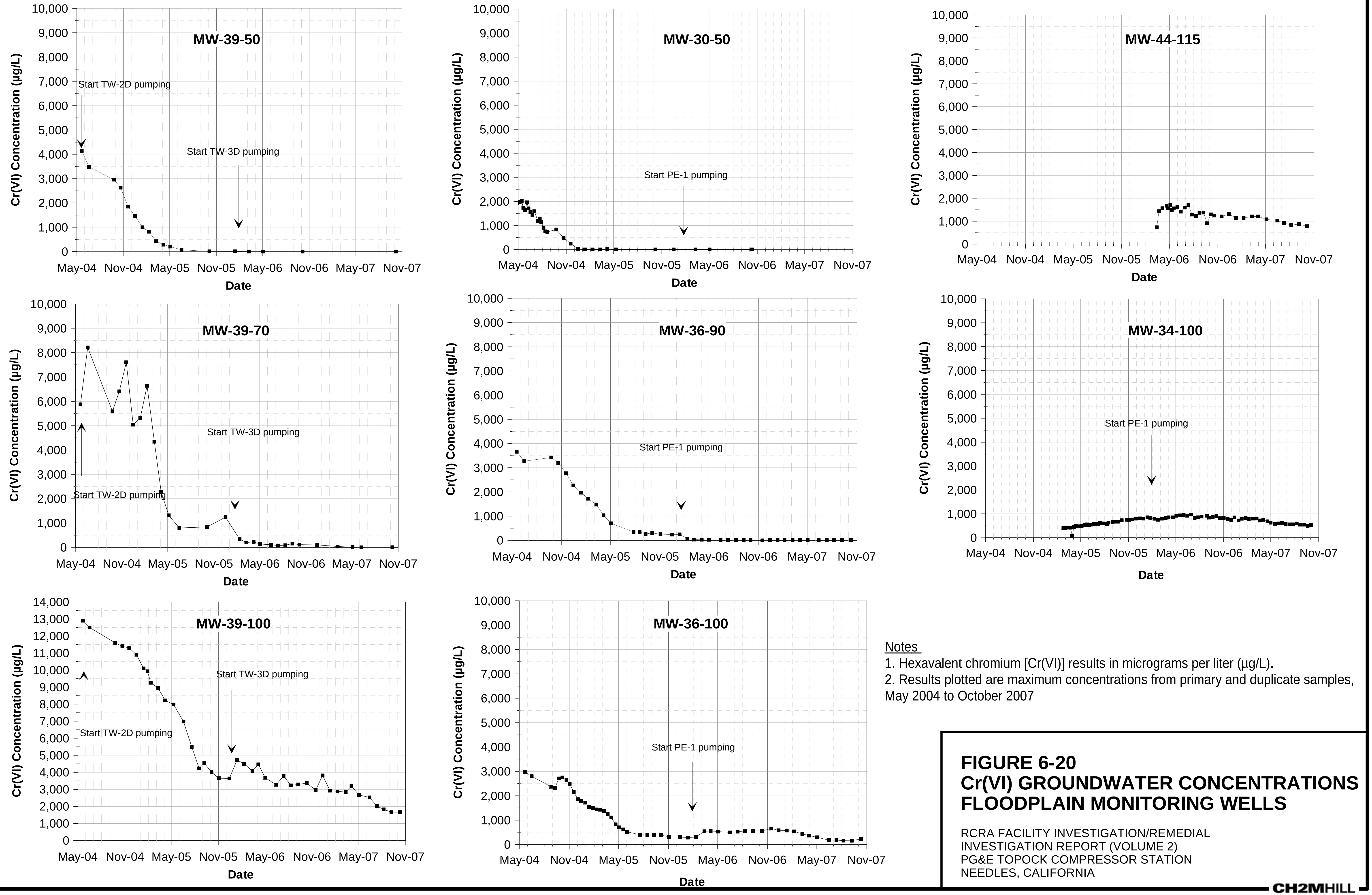

Notes

1. Hexavalent chromium [Cr(VI)] results in micrograms per liter (µg/L).
2. Results plotted are maximum concentrations from primary and duplicate samples, May 2004 to October 2007

FIGURE 6-20
Cr(VI) GROUNDWATER CONCENTRATIONS FLOODPLAIN MONITORING WELLS

RCRA FACILITY INVESTIGATION/REMEDIAL
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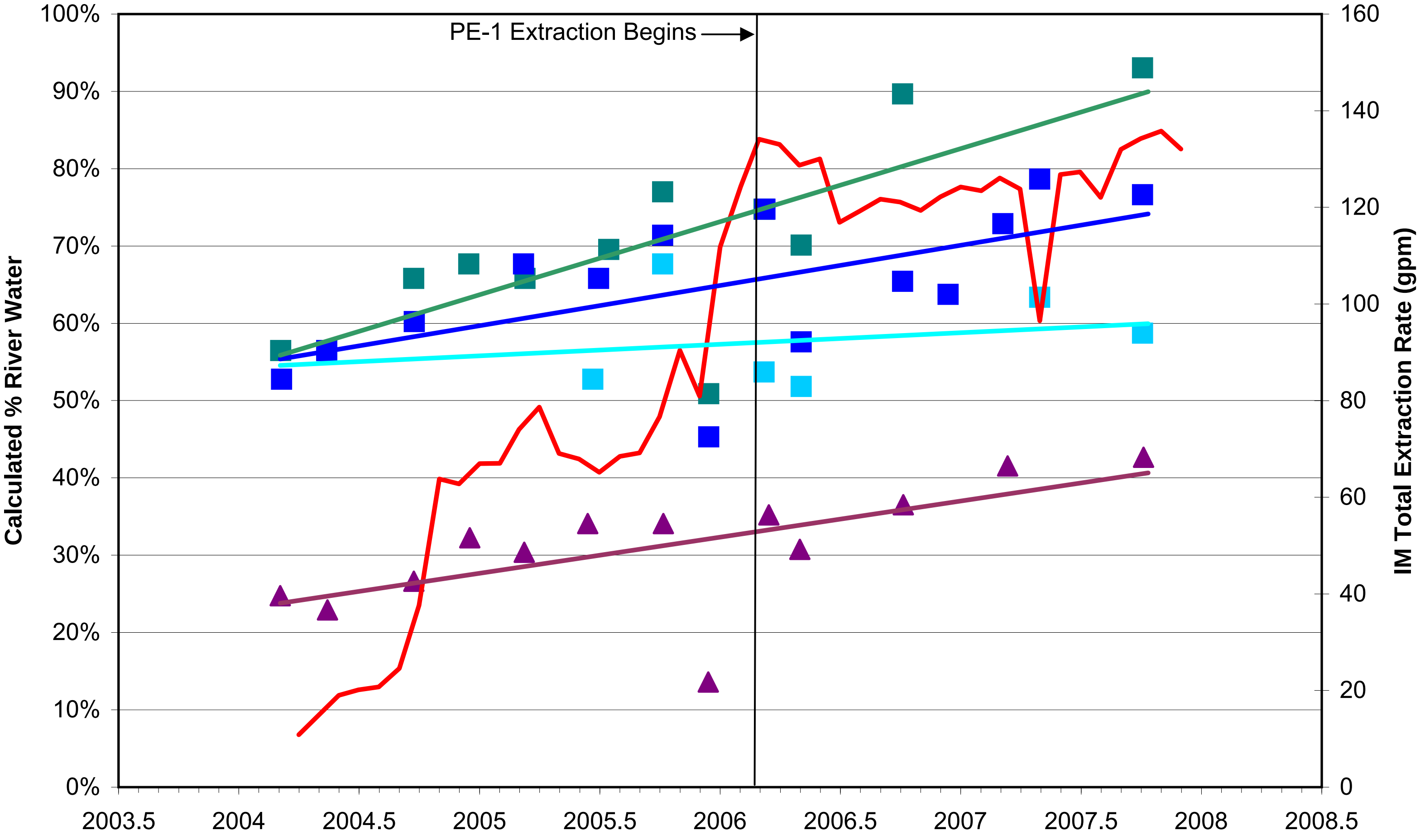

Note: River water percentage was calculated on the basis of an assumed river water δ2H value of -100.3 per mil, and an assumed industrial (plume) water δ2H value of -46.7 per mil (see text for further explanation).

FIGURE 6-21
DEUTERIUM-ESTIMATED RIVER WATER PERCENTAGES OVER TIME

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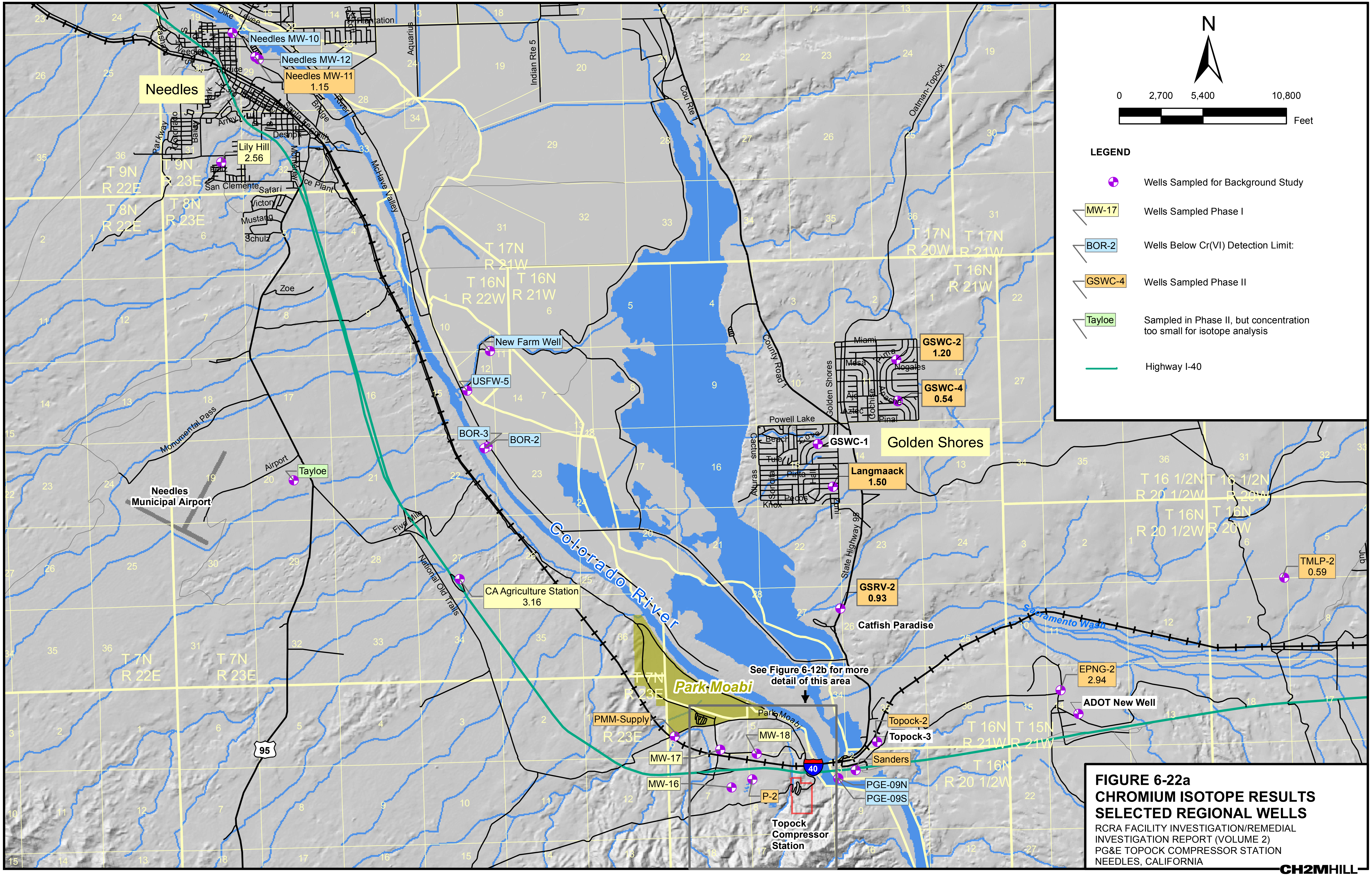

FIGURE 6-22a
CHROMIUM ISOTOPE RESULTS SELECTED REGIONAL WELLS

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PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

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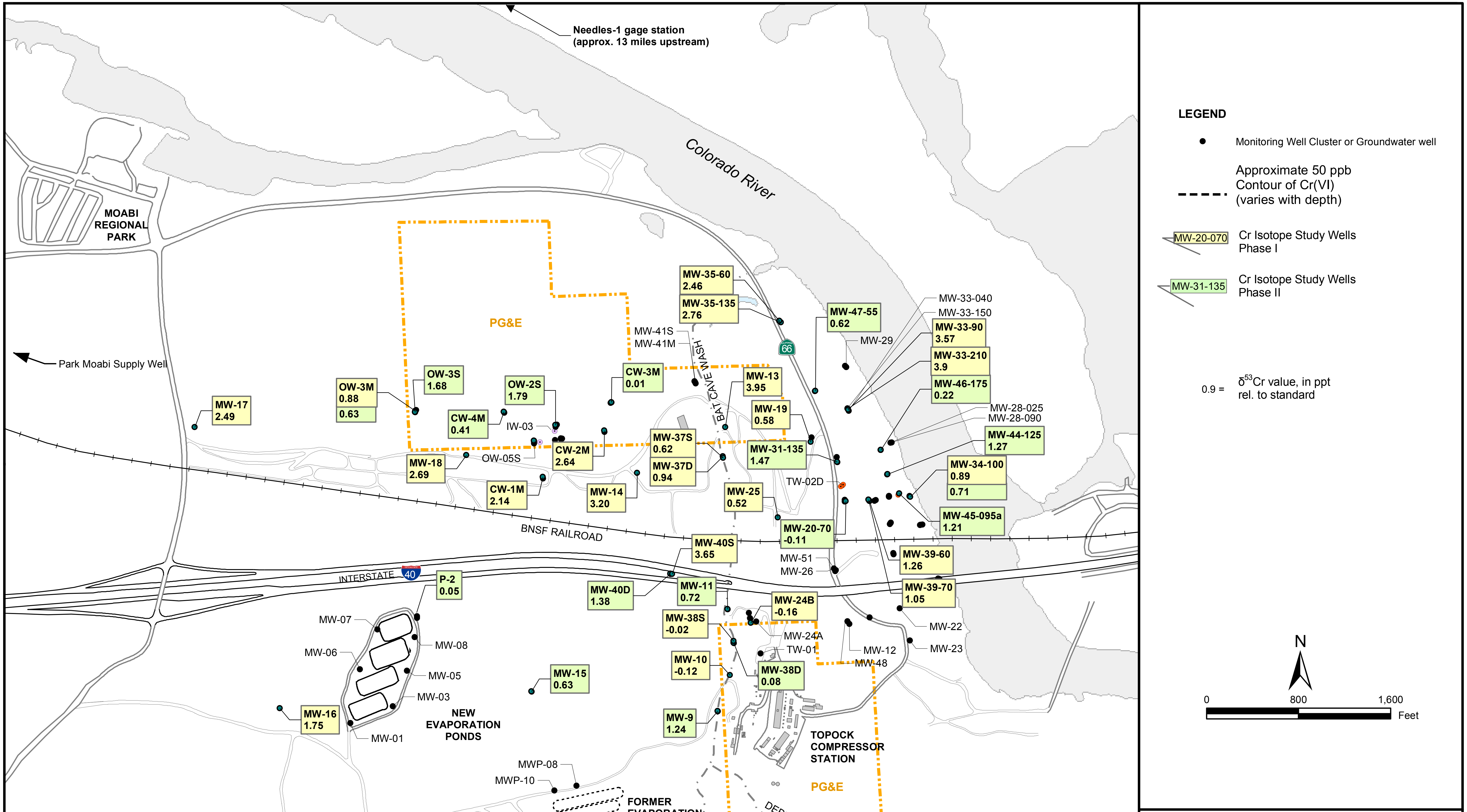

FIGURE 6-22b
CHROMIUM ISOTOPE RESULTS, SITE AREA WELLS

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INVESTIGATION REPORT (VOLUME 2)
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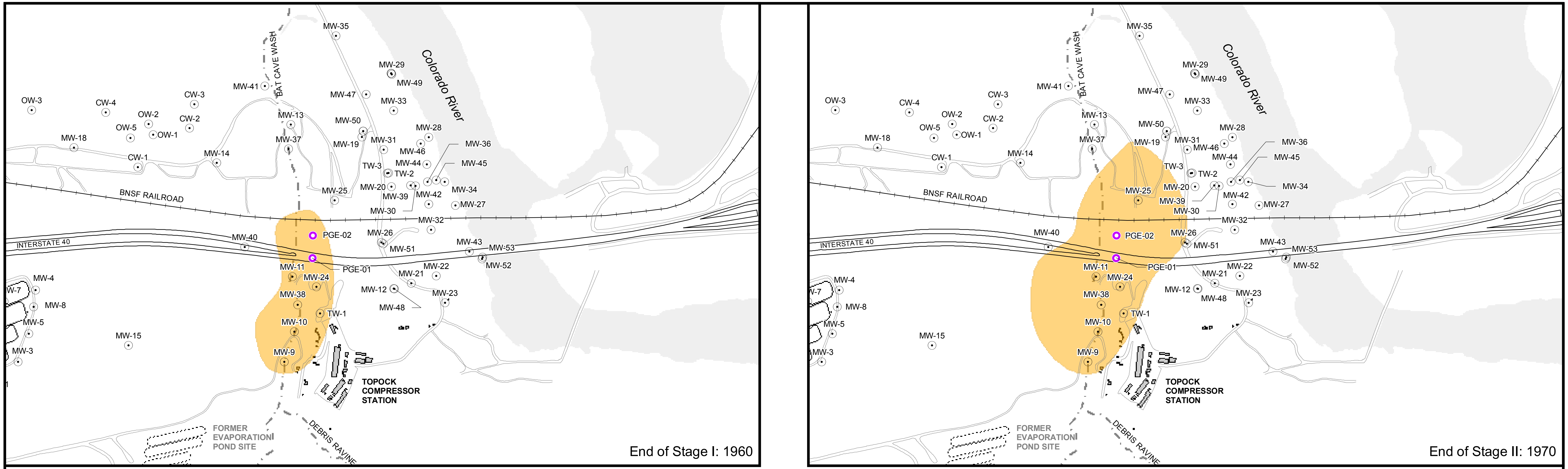
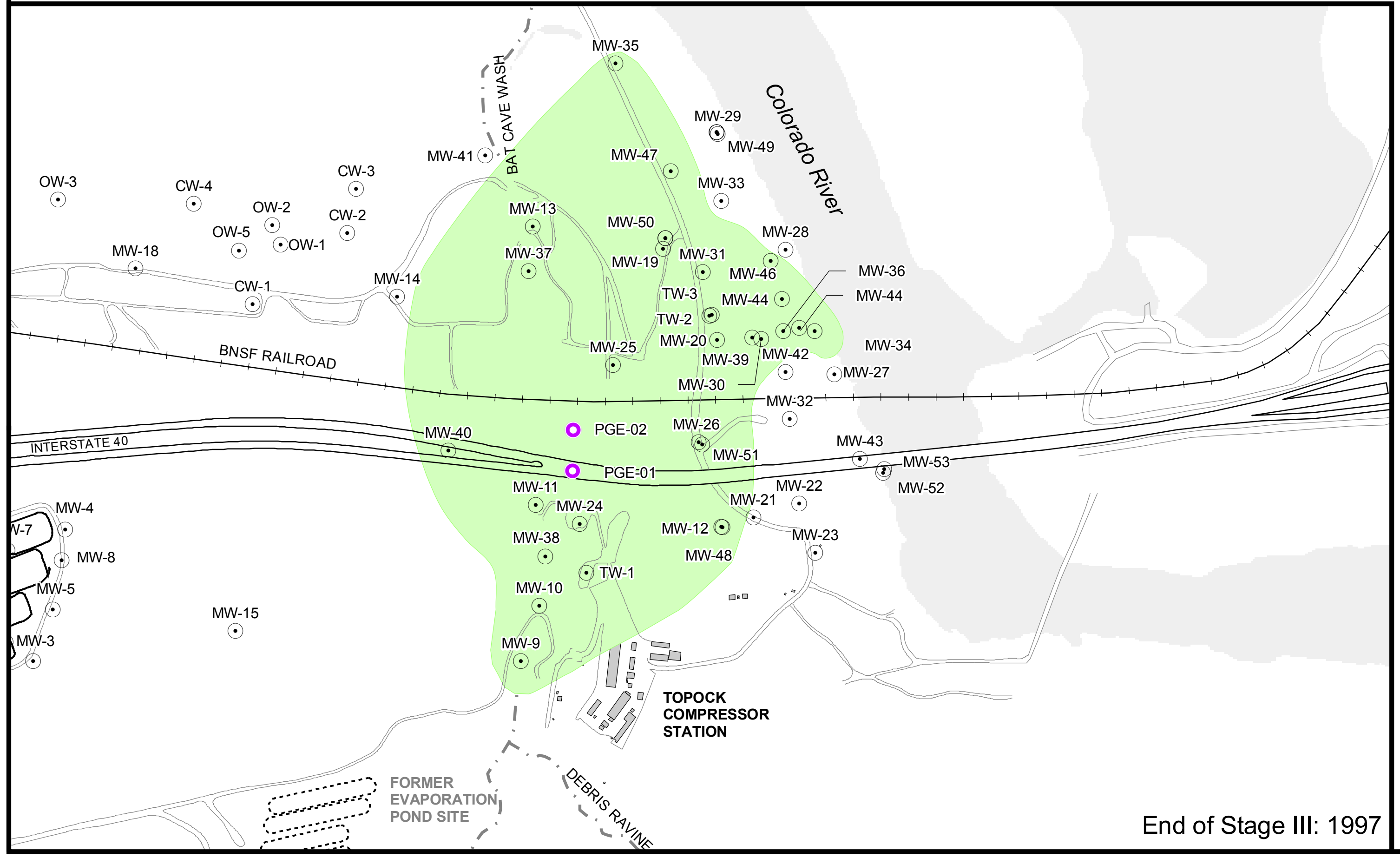


End of Stage I: 1960

End of Stage II: 1970



End of Stage III: 1997

LEGEND

⊙ Monitoring, Test, or Supply Well

○ Former Extraction Well

🟧 Simulated Flow of Historical Discharge in Groundwater

🟩 Present-day Plume, representing >32 μg/L Cr(VI)

Note:
Simulated discharge flow areas represent estimated groundwater flow and do not represent concentration estimates. Orange shaded areas represent the outlines of all simulated flowlines originating from (for Stage I) the original disposal area, and (for Stage II) the simulated Stage I flow area. Flowlines were run in each layer of the model corresponding to the Alluvial Aquifer. Historical groundwater concentrations greater than 32 μg/L would be expected to extend some distance from the simulated flow area boundaries in alluvial areas, whereas flowlines reaching the shallow floodplain and river would have Cr(VI) removed by reducing material (see text for further explanation).

FIGURE 6-23
MODELED STAGES OF PLUME DEVELOPMENT

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PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

BAO \\ZINFANDEL\PROJ\PACIFICGASELECTRICCO\TOPOCKPROGRAM\GIS\MAPFILES\2007\RFI\FIG6-13_STAGES_OF_PLUME_DEVELOPMENT.MXD FIG6-20_STAGES_OF_PLUME_DEVELOPMENT.MXD 12/30/2008 11:28:05

7.0 Surface Water Quality Characterization

This section presents the results and findings of the RFI/RI investigations to identify and characterize the nature and extent of COPCs in surface water at the site. Though no COPCs have been identified by the RFI/RI Volume 1 Report for surface water (CH2M HILL, 2007a), for the purposes of characterization, this section examines COPCs similar to those identified for groundwater associated with SWMU 1/AOC 1.

7.1 Surface Water Data and Regulatory Standards

7.1.1 Chemical Parameters and Data Sets for Characterization

As described in Section 4.2 and summarized in Table 4-5, the cumulative surface water sampling activities conducted for the RFI/RI and site monitoring programs have yielded an extensive chemical analytical dataset for characterizing surface water conditions. More than 700 surface water samples have been collected from July 1997 to October 2007 for the RFI/RI characterization. The surface water dataset includes analytical results for chromium, general chemistry parameters, trace metals, stable isotopes, and perchlorate. A database report listing of all the surface water analytical results collected under the RFI/RI are included in Appendix H4.

7.1.2 Regulatory Standards for Surface Water

Table 7-1 summarizes the chemical-specific ARARs for constituents in surface water. These ARARs are the Federal Water Pollution Control Act, California Toxics Rule and the drinking water MCLs as defined in the California and federal Safe Drinking Water Acts[5]. Appendix G includes a complete listing and citation of the ARARs that apply to this site as provided by DOI. The most stringent ARAR value was used for characterization purposes.

7.2 Surface Water Characterization Data

Table 4-5 summarizes the number of events in which surface water stations have been sampled for COPCs from July 1997 through October 2007 for the RFI/RI. Surface water samples have been collected from 18 shoreline locations along the Colorado River since the start of the RFI/RI sampling period in July 1997 (Figure 4-6). Surface water samples were collected from nine in-channel surface water stations at three depths each starting in July 2005. Table 5-4 presents the general chemistry results of Colorado River water, which is further discussed in Section 5.3.2. The surface water sampling results for chromium and other COPCs are discussed below. All surface water samples for metals are filtered prior to analyses, so reported metals results represent the dissolved metals fraction. Table 7-2 summarizes the sampling location results, both upstream and downstream of Bat Cave

---

[5] The June 2008 Preliminary Determination of Potential ARARs and TBCs provided by DOI deemed the Arizona surface water standards as not ARARs because “These standards are not more stringent than the equivalent federal standards.” These ARARs were not available at the time of the prior 2005 RFI/RI Report, which used different comparison values that included the Arizona surface water standards.

Wash, for Cr(VI), dissolved Cr(T), and other site COPCs. Table 7-3 presents the monitoring results for Cr(VI), Cr(T), pH, and specific conductance from surface water samples from October 2006 through October 2007. Unfiltered surface water data that was collected after the October 2007 cutoff date, which may be used to assess risk to human health in the groundwater risk assessment, is not discussed in this report.

7.2.1 Shoreline Surface Water Sampling (1996-2007)

Shoreline surface water samples from the Colorado River have been collected at 10 locations downstream of the mouth of Bat Cave Wash (R-19, R-19-B, R-19-C, R-20, R-20-B, R-20-C, R-22, R-27, R-28, and I-3) and five upstream locations (CON, NR-1, NR-2, NR-3, and Needles-1 gauge) (Figure 4-6). Additional surface water samples have been collected in Park Moabi slough (A-Dock), a shoreline inlet at the mouth of Bat Cave Wash (RRB), and an area immediately west of the bridge crossing at Bat Cave Wash. The A-Dock surface water location has a direct connection to the river through Park Moabi slough at all water levels. The RRB surface water location is directly connected to the river except at very low river stage. The area immediately west of the bridge crossing at Bat Cave Wash is only directly connected to the river during relatively high river stage. This area may also receive water from infrequent surface water flow in Bat Cave Wash.

Shoreline surface water samples have been collected using disposable bailers or lowering sample containers into the top foot of the Colorado River. Whenever possible since 2005, shoreline surface water samples have been collected during the same sampling events as the in-channel surface water locations. In these instances, dedicated Tygon® tubing has been lowered into the top foot of the river and water has collected with a peristaltic pump from a pontoon boat.

7.2.1.1 Chromium Sampling Results

Dissolved Cr(T) has been detected in shoreline surface water samples at four locations downstream of Bat Cave Wash (I-3, R-22, R-27, and R-28) with average concentrations ranging from 2.84 to 3.49 µg/L (Table 7-2). Dissolved Cr(T) has been detected at three upstream locations (CON, NR-1, and NR-2) with average concentrations ranging from 0.63 to 3.42 µg/L. As discussed in Section 6.2, given the solubility of Cr(T), these sporadic Cr(T) detections may be due to occasional colloidal breakthrough from sample collection of surface water rather than true dissolved concentrations. None of the average Cr(T) concentrations exceed the chemical-specific ARARs criteria of 50 µg/L.

Cr(VI) has not been detected in any shoreline surface water samples collected during the July 1997 through October 2007 monitoring period, except for one sampling event in June 2002. During June 2002 surface water sampling, Cr(VI) was reported at concentrations ranging from 15.9 to 25.7 µg/L in six samples collected from the Colorado River at locations both upstream and downstream of Bat Cave Wash. The June 2002 Cr(VI) results were inconsistent with prior and subsequent Cr(VI) analyses, including laboratory re-testing of the samples. Confirmation sampling at the same locations in August 2002 yielded non-detect results for Cr(VI) (see Appendix H for analytical results). According to the data quality review for the June 2002 monitoring (PG&E, 2002c), there was indication of false-positive results caused by unidentified interference for these samples. DTSC concurred no action should be taken or project decisions should be made based on the results (Appendix H2). As further confirmation of the false-positive assessment, the same interference issue was also found in samples collected from three floodplain monitoring wells during the same sampling event which resulted in similar detections at normally non-detect wells. All RFI/RI shoreline surface water samples collected from the Colorado River, other than the June 2002 event, have been non-detect for Cr(VI) at the analytical reporting limit. The false positive samples from the June 2002 event represent 6 samples out of 536 shoreline surface water samples collected under the RFI/RI. All of the Cr(VI) data that are of sufficient quality for decision making purposes are below the chemical-specific ARARs criteria of 11 µg/L.

7.2.1.2 Sampling Results for Copper, Nickel, Zinc, Lead, pH, and Specific Conductance

Table 7-2 summarizes the RFI/RI surface water sampling results for chromium and other COPCs: copper, nickel, zinc, lead, specific conductance, and pH. The table presents the frequency of detection and average concentrations of the parameters and the chemical-specific ARARs (Table 7-1). The analytical results for the non-chromium COPCs are summarized below.

Copper. Dissolved copper has been detected in shoreline surface water samples at six locations downstream of Bat Cave Wash (I-3, R-19-B, R-20-B, R-22, R-27, and R-28) at average concentrations ranging from 4.75 to 13.2 µg/L (Table 7-2). Dissolved copper has been detected in two upstream locations (A-Dock and CON) at average concentrations ranging from 5.42 to 5.85 µg/L. None of the average copper concentrations exceed the chemical-specific ARARs criteria of 23 µg/L[6].

Nickel. Dissolved nickel has been detected in shoreline surface water samples at five locations downstream of Bat Cave Wash (I-3, R-20-B, R-22, R-27, and R-28) at average concentrations ranging from 7.07 to 12.3 µg/L (Table 7-2). Dissolved nickel has been detected in an upstream location (CON) at an average concentration of 7.82 µg/L. None of the average nickel concentrations exceed the chemical-specific ARARs criteria of 132 µg/L [7].

Zinc. Dissolved zinc has been detected in shoreline surface water samples at seven locations downstream of Bat Cave Wash (I-3, R-19-C, R-20-B, R-20-C, R-22, R-27, and R-28) at average concentrations ranging from 3.05 to 96.4 µg/L (Table 7-2). Dissolved zinc concentrations have been detected in five upstream locations (A-Dock, CON, NR-1, NR-2, and NR-3) at average concentrations ranging from 9.25 to 166 µg/L. None of the average zinc concentrations exceed the chemical-specific ARAR criteria of 297 µg/L [8].

Lead. Dissolved lead has not been detected in shoreline surface water samples at locations downstream of Bat Cave Wash (Table 7-2). Dissolved lead has been detected in one

---

[6] The surface water quality criteria for copper of 23 µg/L is based on presumed hardness of 300 ppm and chronic exposure of freshwater aquatic life (Table 7-1). The 300 ppm hardness value is an approximate average of the hardness values from surface water analytical samples during the RFI/RI dataset period.

[7] The surface water quality criteria for nickel of 132 µg/L is based on presumed hardness of 300 ppm and chronic exposure of freshwater aquatic life (Table 7-1). The 300 ppm hardness value is an approximate average of the hardness values from surface water analytical samples during the RFI/RI dataset period.

[8] The surface water quality criteria for zinc of 297 µg/L is based on presumed hardness of 300 ppm and acute exposure of freshwater aquatic life (Table 7-1). The 300 ppm hardness value is an approximate average of the hardness values from surface water analytical samples during the RFI/RI dataset period.

upstream location (CON) at an average concentration of 2.33 µg/L. None of the average lead concentrations exceed the chemical-specific ARAR criteria of 8 µg/L[9].

Specific Conductance. The average specific conductance results in shoreline surface water samples collected downstream of Bat Cave Wash ranged from 888 to 1,020 µS/cm. Specific conductance results in upstream locations range from 944 to 1,130 µS/cm. At the mouth of Bat Cave Wash (RRB), the average specific conductance value was 1,100 µS/cm. The average specific conductance result was 4,800 µS/cm for the surface water samples collected from Seasonal Wetlands. The water in the Seasonal Wetlands is only intermittently replenished with river water during the highest river stages. The area is covered with a dense thicket of Tamarisk trees, which transpire large amounts of water and exude salts through their leaves. Evapotranspiration by the Tamarisk trees and infrequent flushing/replenishment of water from the river result in elevated salinity in the Seasonal Wetland. None of the average specific conductance values exceed the chemical-specific ARAR criteria of 1,600 µS/cm, with the exception of the Seasonal Wetlands location.

pH. The average pH readings for all shoreline surface water samples range from 7.43 to 8.22. The RFI/RI surface water sampling results indicate no discernable difference between specific conductance or pH results collected upstream and downstream of Bat Cave Wash. None of the average pH concentrations are outside of the ARAR criteria range of 6.5 to 8.5.

7.2.1.3 Sampling Results for Trace Metals and Other Parameters

Table 7-4 summarizes the RFI/RI surface water sampling results for other trace metals. The table presents the frequency of detection and average concentrations of the dissolved metals and the chemical-specific ARARs (Table 7-1). The analytical results for other trace metals are summarized below.

Barium. Dissolved barium has been detected in shoreline surface water samples at one location downstream of Bat Cave Wash (I-3) at an average concentration of 150 µg/L (Table 7-4). Dissolved barium concentrations have been detected in three upstream locations (A-Dock, CON, and NR-1) at average concentrations ranging from 110 to 143 µg/L. None of the average barium concentrations exceed the chemical-specific ARAR criteria of 1,000 µg/L.

Iron. Dissolved iron has not been detected in shoreline surface water samples at either upstream or downstream locations (Table 7-4).

Manganese. Dissolved manganese has been detected in shoreline surface water samples at one location downstream of Bat Cave Wash (I-3) at an average concentration of 54.1 µg/L (Table 7-4). Dissolved manganese concentrations have been detected at one upstream location (CON) at an average concentration of 65.0 µg/L. The average manganese concentrations exceed the chemical-specific ARAR criteria of 50 µg/L because of elevated reporting limits in one sample that was non-detect for manganese each for both locations I-3 and CON. The highest manganese concentration above the analytical reporting limit from the CON location was 5.5 µg/L. The highest manganese concentration above the analytical

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[9] The surface water quality criteria for lead of 8 µg/L is based on presumed hardness of 300 ppm and acute exposure of freshwater aquatic life (Table 7-1). The 300 ppm hardness value is an approximate average of the hardness values from surface water analytical samples during the RFI/RI dataset period.

reporting limit from the I-3 location was 10 µg/L. Both of these maximum detected values are below the chemical-specific ARAR criteria of 50 µg/L.

Molybdenum. Dissolved molybdenum has been detected in shoreline surface water samples at two locations downstream of Bat Cave Wash (I-3 and R-28) at average concentrations ranging from 4.73 to 5.4 µg/L (Table 7-4). Dissolved molybdenum concentrations have been detected in one upstream location (CON) at an average concentration of 4.93 µg/L. Molybdenum does not have a chemical-specific ARAR criteria.

Vanadium. Dissolved vanadium has been detected in shoreline surface water samples at two locations downstream of Bat Cave Wash (I-3 and R-28) at average concentrations ranging from 3.2 to 253 µg/L (Table 7-4). Dissolved vanadium concentrations have been detected in one upstream location (CON) at an average concentration of 3.47 µg/L. Vanadium does not have a chemical-specific ARAR criteria.

Perchlorate. At DTSC request, two shoreline surface water monitoring locations (CON and I-3) were sampled for perchlorate in June 2003 (Appendix H4). Perchlorate was not detected at the method detection limit of 4 µg/L in either sample.

7.2.2 In-channel, Depth-specific Surface Water Sampling (2005-2007)

Depth-specific surface water samples from the Colorado River have been collected at five in-channel stations downstream of the mouth of Bat Cave Wash (C-R27, C-R22, C-I-3, C-TAZ, and C-MAR) and four in-channel upstream stations (C-CON, C-NR1, C-NR3, and C-NR4) (Figure 4-6). Analytical suites have varied over time, and have included chromium and general chemistry parameters (Appendix H4). At each in-channel surface water station, samples were collected from 1 foot off the bottom of the river channel, at the mid-depth point in the water column, and within 1 foot of the water surface. Surface water samples were collected from an anchored boat by drawing water through dedicated polyethylene tubing with a peristaltic pump. Since July 2005, depth-specific surface water monitoring events have been conducted quarterly during most of the year and monthly during low-river stages (typically November through January). Although the C-MAR station in the Topock Marsh is directly connected to the Colorado River, this location gets very shallow so that not all depths of the water column could be sampled during low river stages. The in-channel surface water stations are located in the river approximately one-third to one-half of the river width from the California shoreline (Figure 4-6).

7.2.2.1 Chromium Sampling Results

Cr(VI) and dissolved Cr(T) have not been detected in any in-channel surface water samples at analytical reporting limits during the RFI/RI period, except for one occurrence (Table 7-2). During the September 2007 surface water sampling, Cr(VI) was reported at a trace concentration of 0.4 µg/L at one in-channel surface water location (C-R22-D). Subsequent investigation revealed that Cr(VI) was present at low levels in the buffer solutions used for both field preservation and laboratory analysis of the samples. The presence of Cr(VI) in the buffer solutions is thought to be responsible for the low-level Cr(VI) reported result at C-R22-D. Consistent with this conclusion, Cr(VI) was detected at low levels in both the laboratory blanks and a field blank preserved and analyzed with the same batch of buffer solution. Therefore, the C-R22-D detection was flagged with a “J” data qualifier, indicating that there is uncertainty regarding the reported concentration value. Resampling was conducted on the following day at the same location and at step-out locations 1 meter away from the original location in four directions. An additional round of samples was also collected from all river sampling stations. In total, there were three resampling rounds of all the surface water stations in September and October 2007. None of these additional verification samples had detections of Cr(VI) above analytical reporting limits. None of the Cr(VI) and Cr(T) concentrations from the RFI/RI in-channel samples exceed the chemical-specific ARARs criteria of 11 and 50 µg/L respectively.

7.2.2.2 Sampling Results for pH and Specific Conductance

Specific Conductance. The average specific conductance results for in-channel surface water samples collected downstream of Bat Cave Wash range from 993 to 1,110 µS/cm (Table 7-2). Specific conductance results in upstream locations range from 1,030 to 1,050 µS/cm. None of the average specific conductance values exceed the chemical-specific ARAR criteria of 1,600 µS/cm.

pH. The average pH readings for the in-channel surface water samples range from 7.97 to 8.34. The RFI/RI in-channel surface water sampling indicates no discernable difference between specific conductance or pH results collected upstream and downstream of the mouth of Bat Cave Wash. None of the average pH concentrations are outside of the ARAR criteria range of 6.5 to 8.5.

7.2.3 Pore Water Study Surface Water Sampling (2006)

Additional in-channel surface water samples were collected at 16 locations upstream and downstream of the Topock site during the pore water study in early 2006 (Figure 4-6). The analytical suite included chromium and general chemistry parameters (Appendix H4). One surface water sample was collected at the "B" station of each transect during the pore water sampling event at 1 foot above the bottom of the Colorado River. There were seven locations sampled upstream of the mouth of Bat Cave Wash (SW-1B, SW-2B, SW-3B, SW-4B, SW-5B, SW-6B, and SW-7B) and nine locations sampled downstream (SW-8B, SW-9B, SW-10B, SW-11B, SW-12B, SW-13B, SW-14B, SW-15B, and SW-16B). These locations were co-located and collected at the same time as the corresponding pore water samples. Surface water samples were collected from an anchored boat using dedicated polyethylene tubing attached to a weighted rope with a peristaltic pump. See Section 8.2 for details regarding the pore water study.

7.2.3.1 Chromium Sampling Results

Table 7-2 summarizes the monitoring results for Cr(VI), Cr(T), pH, and specific conductance for the surface water samples collected from the 2006 pore water study. Cr(VI) and dissolved Cr(T) were not detected in any surface water samples at the analytical reporting limits, and hence none of the samples exceed the chemical-specific ARARs criteria of 11 and 50 µg/L respectively.

7.2.3.2 Sampling Results for pH and Specific Conductance

Specific Conductance. The average specific conductance results in surface water samples from the pore water study collected downstream of Bat Cave Wash range from 980 to 1,000 µS/cm. Specific conductance results in upstream locations range from 995 to

1,010 µS/cm. None of the average specific conductance values exceed the chemical-specific ARAR criteria of 1,600 µS/cm.

pH. The average pH readings for all surface water samples from the pore water study range from 7.79 to 8.20. None of the average pH concentrations is outside of the ARAR criteria range of 6.5 to 8.5.

7.2.4 Evaluation of Surface Water Characterization Findings

None of the average concentrations for the samples from the shoreline, in-channel, and pore water study surface water locations exceeds the most stringent chemical-specific ARAR listed in Table 7-1. Parameters are detected upstream and downstream of the site at similar frequencies and similar concentrations. The one exception is the Cr(VI) shoreline samples collected in June 2002 that data quality review indicates were false positives, which are discussed in Section 7.2.1.1. None of the other COPCs had an average detected concentration that exceeded its respective ARAR. There was no discernable difference between COPC results in samples collected upstream or downstream of Bat Cave Wash in the Colorado River.

Based on data collected during the monitoring period of this RFI/RI, no site-related contamination of surface water was observed.

TABLE 7-1
Chemical-Specific ARARs for Surface Water
RCRA Facility Investigation/Remedial Investigation (Volume 2)
PG&E Topock Compressor Station, Needles, California

	California Surface Water Standards (b)			**Drinking Water Standards**	
	Ecological Receptors		**Human Receptors**		
Constituents (a)	**Freshwater Aquatic Life**		**Human Health (c)**	**California Safe Drinking Water Act (d)**	**Federal Safe Drinking Water Act (e)**
	μg/L	**μg/L**	**μg/L**	**μg/L**	**μg/L**
	Acute (f)	**Chronic (g)**			
Barium	NA	NA	NA	1,000	2,000
Hexavalent chromium	16 (i)	11 (i)	NA	NA	NA
Total chromium	NA	NA	NA	50	100
Copper	38 (h, i)	23 (h, i)	1,300	1,000 (j)	1,300 (k)
Iron	NA	NA	NA	300 (j)	300 (j)
Lead	209 (h, i)	8 (h, i)	NA	15 (k)	15 (k)
Manganese	NA	NA	NA	50 (j)	50 (j)
Molybdenum	NA	NA	NA	NA	NA
Nickel	1,186 (h, i)	132 (h, i)	610	100	NA
Vanadium	NA	NA	NA	NA	NA
Zinc	297 (h, i)	300 (h, i)	NA	5,000 (j)	5,000 (j)
Chloride	NA	NA	NA	250,000-500,000(j)	250,000 (j)
Fluoride	NA	NA	NA	2,000	4,000
Nitrate as Nitrogen	NA	NA	NA	45,000	10,000
Specific Conductance	NA	NA	NA	900-1,600	NA
Sulfate	NA	NA	NA	250,000-500,000(j)	250,000 (j)
Perchlorate	NA	NA	NA	6,000	NA
pH	NA	NA	NA	NA	6.5-8.5 (j)
Total Dissolved Solids	NA	NA	NA	500,000 - 1,000,000 (j)	500,000 (j)

Notes:
NA = Not Available
(a) Constituents detected in surface water samples, both upstream and downstream of Topock Compressor Station. General water quality parameters for which there are no ARARs are not included.
(b) Federal Water Pollution Control Act, 33 USC §§ 1251-1387, 40 CFR §133.38. Source: Appendix G.
(c) Protective of human health assuming ingestion of surface water and fish from the same surface water body at 1 x 10-6 cancer risk level.
(d) California Safe Drinking Water Act, Title 22, CCR, Div 4, Ch 15, §64431, §64444, §64449. Source: Appendix G.
(e) Federal Safe Drinking Water Act, 42 USC § 300 f, et seq., 40 CFR 141- Subpart F - Maximum Contaminant Level Goals (MCLGs), and 42 USC § 300 g-1, 40 CFR 141 - Subpart G - National Primary Drinking Water Regulations (MCLs). Source: Appendix G.
(f) Acute exposure criteria are not-to-exceed 1-hour maximum concentrations.
(g) Chronic exposure criteria are not-to-exceed 96 hour-average concentrations.
(h) Hardness dependent. Shown is criteria @ CaCO3 = 300 ppm.
(i) Dissolved concentration.
(j) Secondary MCL standard, where primary MCL not developed.
(k) Action level for copper and lead, if more than 10 percent of samples exceed action level.

TABLE 7-2

Summary of Surface Water Sampling Results - Chromium, Other Metals, Specific Conductance, and pH, July 1997 through October 2007

RCRA Facility Investigation/Remedial Investigation (Volume 2)

PG&E Topock Compressor Station, Needles, California

	Hexavalent Chromium (µg/L)		**Dissolved Total Chromium (µg/L)**		**Dissolved Copper (µg/L)**		**Dissolved Nickel (µg/L)**		**Dissolved Zinc (µg/L)**		**Dissolved Lead (µg/L)**		**Specific Conductance (µS/cm)**		**pH (pH Units)**	
Chemical-Specific ARAR[1]	11		50		23		132		297		8		900-1600		6.5-8.5	
Station ID[2]	**Frequency of Detection[3] (Number of Detects/Number of Samples) and Average Concentration[4]**															
Shoreline Surface Water Locations																
Needles Gauge	0 \ 2	ND	0 \ 2	ND	0 \ 0	---	0 \ 0	---	0 \ 0	---	0 \ 0	---	0 \ 0	---	0 \ 0	---
NR-3	0 \ 41	ND	0 \ 42	ND	0 \ 2	ND	0 \ 2	ND	1 \ 2	166	0 \ 0	---	15 \ 15	1000	14 \ 14	8.20
NR-2	0 \ 43	ND	1 \ 44	0.65	0 \ 2	ND	0 \ 2	ND	1 \ 2	54.7	0 \ 0	---	15 \ 15	1010	14 \ 14	8.22
NR-1	0 \ 43	ND	1 \ 44	0.627	0 \ 2	ND	0 \ 2	ND	1 \ 2	51.1	0 \ 0	---	15 \ 15	1020	14 \ 14	8.20
A-Dock	0 \ 6	ND	0 \ 6	ND	2 \ 4	5.42	0 \ 4	ND	4 \ 4	9.25	0 \ 1	ND	4 \ 4	944	4 \ 4	8.02
CON	0 \ 70^	ND	6 \ 71	3.42	12 \ 28	5.85	10 \ 28	7.82	22 \ 28	47.1	1 \ 3	2.33	38 \ 38	1130	37 \ 37	8.09
Seasonal Wetlands	0 \ 8	ND	0 \ 8	ND	5 \ 8	11.4	2 \ 8	23.8	5 \ 8	9.97	1 \ 1	2.60	8 \ 8	4800	8 \ 8	7.97
RRB	0 \ 57^	ND	8 \ 58	3.47	7 \ 22	5.85	11 \ 22	9.28	19 \ 22	102	1 \ 1	2.00	30 \ 30	1100	29 \ 29	8.06
R-19	0 \ 1	ND	0 \ 1	ND	0 \ 1	ND	0 \ 1	ND	0 \ 1	ND	0 \ 0	---	1 \ 1	888	1 \ 1	7.43
R-19-B	0 \ 2	ND	0 \ 2	ND	1 \ 2	4.75	0 \ 2	ND	0 \ 2	ND	0 \ 0	---	2 \ 2	896	2 \ 2	7.79
R-19-C	0 \ 2	ND	0 \ 2	ND	0 \ 2	ND	0 \ 2	ND	1 \ 2	3.20	0 \ 0	---	2 \ 2	892	2 \ 2	7.84
R-28	0 \ 62^	ND	7 \ 63	3.49	6 \ 22	5.38	11 \ 22	8.80	18 \ 22	96.4	0 \ 0	---	32 \ 32	1020	31 \ 31	8.20
R-20	0 \ 1	ND	0 \ 1	ND	0 \ 1	ND	0 \ 1	ND	0 \ 1	ND	0 \ 0	---	1 \ 1	902	1 \ 1	7.95
R-20-B	0 \ 2	ND	0 \ 2	ND	1 \ 2	5.65	1 \ 2	12.3	1 \ 2	5.90	0 \ 0	---	2 \ 2	893	2 \ 2	7.84
R-20-C	0 \ 2	ND	0 \ 2	ND	0 \ 2	ND	0 \ 2	ND	1 \ 2	3.05	0 \ 0	---	2 \ 2	891	2 \ 2	7.77
R-27	0 \ 65^	ND	6 \ 66	2.84	8 \ 22	5.95	9 \ 22	7.07	19 \ 22	57.2	0 \ 0	---	32 \ 32	958	31 \ 31	8.18
R-22	0 \ 64^	ND	7 \ 65	2.85	11 \ 22	13.2	11 \ 22	8.58	19 \ 22	54.0	0 \ 0	---	32 \ 32	972	32 \ 32	8.21
I-3	0 \ 65^	ND	7 \ 66	3.33	12 \ 26	5.47	7 \ 26	7.73	20 \ 26	38.3	0 \ 3	ND	37 \ 37	951	35 \ 35	8.18
In-Channel Surface Water Locations																
C-NR4	0 \ 52	ND	0 \ 52	ND	0 \ 0	---	0 \ 0	---	0 \ 0	---	0 \ 0	---	30 \ 30	1030	30 \ 30	8.34
C-NR3	0 \ 52	ND	0 \ 52	ND	0 \ 0	---	0 \ 0	---	0 \ 0	---	0 \ 0	---	30 \ 30	1030	30 \ 30	8.34
C-NR1	0 \ 52	ND	0 \ 52	ND	0 \ 0	---	0 \ 0	---	0 \ 0	---	0 \ 0	---	30 \ 30	1030	30 \ 30	8.34
C-CON	0 \ 52	ND	0 \ 52	ND	0 \ 0	---	0 \ 0	---	0 \ 0	---	0 \ 0	---	30 \ 30	1050	30 \ 30	8.15
C-MAR	0 \ 26	ND	0 \ 26	ND	0 \ 0	---	0 \ 0	---	0 \ 0	---	0 \ 0	---	13 \ 13	1110	13 \ 13	7.97
C-R27	0 \ 47	ND	0 \ 47	ND	0 \ 0	---	0 \ 0	---	0 \ 0	---	0 \ 0	---	26 \ 26	1000	26 \ 26	8.19
C-R22	1 \ 59	0.119	0 \ 59	ND	0 \ 0	---	0 \ 0	---	0 \ 0	---	0 \ 0	---	30 \ 30	999	30 \ 30	8.19
C-I-3	0 \ 52	ND	0 \ 52	ND	0 \ 0	---	0 \ 0	---	0 \ 0	---	0 \ 0	---	30 \ 30	995	30 \ 30	8.19
C-TAZ	0 \ 49	ND	0 \ 52	ND	0 \ 0	---	0 \ 0	---	0 \ 0	---	0 \ 0	---	30 \ 30	993	30 \ 30	8.20
Pore Water Study Surface Water Locations																
SW-1B	0 \ 1	ND	0 \ 1	ND	0 \ 0	---	0 \ 0	---	0 \ 0	---	0 \ 0	---	1 \ 1	1000	1 \ 1	8.15
SW-2B	0 \ 1	ND	0 \ 1	ND	0 \ 0	---	0 \ 0	---	0 \ 0	---	0 \ 0	---	1 \ 1	999	1 \ 1	8.16

TABLE 7-2

Summary of Surface Water Sampling Results - Chromium, Other Metals, Specific Conductance, and pH, July 1997 through October 2007

RCRA Facility Investigation/Remedial Investigation (Volume 2)

PG&E Topock Compressor Station, Needles, California

	Hexavalent Chromium (µg/L)		**Dissolved Total Chromium (µg/L)**		**Dissolved Copper (µg/L)**		**Dissolved Nickel (µg/L)**		**Dissolved Zinc (µg/L)**		**Dissolved Lead (µg/L)**		**Specific Conductance (µS/cm)**		**pH (pH Units)**	
Chemical-Specific ARAR[1]	11		50		23		132		297		8		900-1600		6.5-8.5	
Station ID[2]	**Frequency of Detection[3] (Number of Detects/Number of Samples) and Average Concentration [4]**															
Pore Water Study Surface Water Locations																
SW-3B	0 \ 1	ND	0 \ 1	ND	0 \ 0	---	0 \ 0	---	0 \ 0	---	0 \ 0	---	1 \ 1	980	1 \ 1	8.12
SW-4B	0 \ 1	ND	0 \ 1	ND	0 \ 0	---	0 \ 0	---	0 \ 0	---	0 \ 0	---	1 \ 1	1000	1 \ 1	8.10
SW-5B	0 \ 1	ND	0 \ 1	ND	0 \ 0	---	0 \ 0	---	0 \ 0	---	0 \ 0	---	1 \ 1	998	1 \ 1	8.14
SW-6B	0 \ 1	ND	0 \ 1	ND	0 \ 0	---	0 \ 0	---	0 \ 0	---	0 \ 0	---	1 \ 1	992	1 \ 1	8.11
SW-7B	0 \ 1	ND	0 \ 1	ND	0 \ 0	---	0 \ 0	---	0 \ 0	---	0 \ 0	---	1 \ 1	1000	1 \ 1	7.96
SW-8B	0 \ 1	ND	0 \ 1	ND	0 \ 0	---	0 \ 0	---	0 \ 0	---	0 \ 0	---	1 \ 1	995	1 \ 1	8.20
SW-9B	0 \ 1	ND	0 \ 1	ND	0 \ 0	---	0 \ 0	---	0 \ 0	---	0 \ 0	---	1 \ 1	1010	1 \ 1	8.11
SW-10B	0 \ 1	ND	0 \ 1	ND	0 \ 0	---	0 \ 0	---	0 \ 0	---	0 \ 0	---	1 \ 1	1010	1 \ 1	8.06
SW-11B	0 \ 1	ND	0 \ 1	ND	0 \ 0	---	0 \ 0	---	0 \ 0	---	0 \ 0	---	1 \ 1	1000	1 \ 1	8.13
SW-12B	0 \ 1	ND	0 \ 1	ND	0 \ 0	---	0 \ 0	---	0 \ 0	---	0 \ 0	---	1 \ 1	999	1 \ 1	8.16
SW-13B	0 \ 1	ND	0 \ 1	ND	0 \ 0	---	0 \ 0	---	0 \ 0	---	0 \ 0	---	1 \ 1	1000	1 \ 1	8.09
SW-14B	0 \ 1	ND	0 \ 1	ND	0 \ 0	---	0 \ 0	---	0 \ 0	---	0 \ 0	---	1 \ 1	998	1 \ 1	8.16
SW-15B	0 \ 1	ND	0 \ 1	ND	0 \ 0	---	0 \ 0	---	0 \ 0	---	0 \ 0	---	1 \ 1	1000	1 \ 1	8.14
SW-16B	0 \ 1	ND	0 \ 1	ND	0 \ 0	---	0 \ 0	---	0 \ 0	---	0 \ 0	---	1 \ 1	1010	1 \ 1	7.79

Notes:

ND	not detected
^	According to the data quality review for the June 2002 monitoring, the results were determined to be false positive due to unidentified interference for these samples, and no action should be taken or project decisions made based on the results. These results were not included in the statistical analyses.
µS/cm	microsiemens per centimeter
µg/L	micrograms per liter
---	not analyzed

At each of the river channel surface water locations, depth specific samples were collected at shallow (1 foot from water surface), middle, and deep depths (1 foot from river bottom). Results for each location summarize the samples collected at depth.

At locations R-19B, R-19C and R-20B, multiple samples were collected at surface, 5-foot, and 10-foot depths and locations. Results for each location summarized the samples collected at depth.

Refer to Appendix H for complete analytical data for surface water sampling.

[1] Surface water chemical-specific ARARs. See Table 7-1.
[2] Surface water locations are listed in order of their position on the river, from north to south.
[3] Results listed for number of detections for primary samples collected during RFI, July 1997 through October 2007.
[4] Average concentrations of all results (including estimated concentrations) in micrograms per liter, with half the reporting limit used for non detects. Detected results are the maximum concentrations from primary or duplicate samples.

TABLE 7-3

Surface Water Sampling Results - October 2006 through October 2007

RCRA Facility Investigation/Remedial Investigation (Volume 2)

PG&E Topock Compressor Station, Needles, California

Station ID	Sample Date	Hexavalent Chromium (µg/L)	Dissolved Chromium (µg/L)	Specific Conductance (µS/cm)	pH (pH units)
Shoreline Surface Water Locations					
CON	10/04/2006	ND (0.2)	ND (1.0)	1010	8.01 R
CON	11/15/2006	ND (0.2)	ND (1.0)	---	---
CON	12/20/2006	ND (0.2)	ND (1.0)	927	8.17
CON	01/22/2007	ND (0.2)	ND (1.0)	---	---
CON	03/14/2007	ND (0.2)	ND (1.0)	949	8.25
CON	05/09/2007	ND (0.2)	ND (1.0)	949	8.23
CON	09/12/2007	ND (0.2)	ND (1.0)	1400	8.17 J
CON	09/14/2007	ND (0.2)	ND (1.0)	---	---
CON	09/26/2007	ND (0.2)	ND (1.0)	---	---
CON	10/03/2007	ND (0.2)	ND (1.0)	---	---
I-3	10/04/2006	ND (0.2)	ND (1.0)	1040	8.37 R
I-3	11/15/2006	ND (0.2)	ND (1.0)	---	---
I-3	12/20/2006	ND (0.2)	ND (1.0)	987	8.28
I-3	01/22/2007	ND (0.2)	ND (1.0)	---	---
I-3	03/13/2007	ND (0.2)	ND (1.0)	908	8.34
I-3	05/08/2007	ND (0.2)	ND (1.0)	957	8.29
I-3	09/11/2007	ND (0.2)	ND (1.0)	943	8.25 J
I-3	09/13/2007	ND (0.2)	ND (1.0)	---	---
I-3	09/25/2007	ND (0.2)	ND (1.0)	---	---
I-3	10/02/2007	ND (0.2)	ND (1.0)	---	---
NR-1	10/04/2006	ND (0.2)	ND (1.0)	1020	7.79 R
NR-1	11/15/2006	ND (0.2)	ND (1.0)	---	---
NR-1	12/20/2006	ND (0.2)	ND (1.0)	947	8.18
NR-1	01/22/2007	ND (0.2)	ND (1.0)	---	---
NR-1	03/14/2007	ND (0.2)	ND (1.0)	958	8.33
NR-1	05/09/2007	ND (0.2)	ND (1.0)	952	8.32
NR-1	09/12/2007	ND (0.2)	ND (1.0)	1330	8.08 J
NR-1	09/14/2007	ND (0.2)	ND (1.0)	---	---
NR-1	09/26/2007	ND (0.2)	ND (1.0)	---	---
NR-1	10/03/2007	ND (0.2)	ND (1.0)	---	---
NR-2	10/04/2006	ND (0.2)	ND (1.0)	1020	8.03 R
NR-2	11/15/2006	ND (0.2)	ND (1.0)	---	---
NR-2	12/20/2006	ND (0.2)	ND (1.0)	922	8.36
NR-2	01/22/2007	ND (0.2)	ND (1.0)	---	---
NR-2	03/14/2007	ND (0.2)	ND (1.0)	945	8.30
NR-2	05/09/2007	ND (0.2)	ND (1.0)	952	8.29
NR-2	09/12/2007	ND (0.2)	ND (1.0)	1390	8.07 J
NR-2	09/14/2007	ND (0.2)	ND (1.0)	---	---
NR-2	09/26/2007	ND (0.2)	ND (1.0)	---	---

Station ID	Sample Date	Hexavalent Chromium (µg/L)	Dissolved Chromium (µg/L)	Specific Conductance (µS/cm)	pH (pH units)
Shoreline Surface Water Locations					
NR-2	10/03/2007	ND (0.2)	ND (1.0)	---	---
NR-3	10/04/2006	ND (0.2)	ND (1.0)	1020	8.11 R
NR-3	11/15/2006	ND (0.2)	ND (1.0)	---	---
NR-3	12/20/2006	ND (0.2)	ND (1.0)	925	8.35
NR-3	01/22/2007	ND (0.2)	ND (1.0)	---	---
NR-3	03/14/2007	ND (0.2)	ND (1.0)	942	8.30
NR-3	05/09/2007	ND (0.2)	ND (1.0)	950	8.27
NR-3	09/12/2007	ND (0.2)	ND (1.0)	1320	8.02 J
NR-3	09/14/2007	ND (0.2)	ND (1.0)	---	---
NR-3	09/26/2007	ND (0.2)	ND (1.0)	---	---
NR-3	10/03/2007	ND (0.2)	ND (1.0)	---	---
R-22	10/04/2006	ND (1.0)	ND (1.0)	1020	7.68
R-22	11/15/2006	ND (0.2)	ND (1.0)	---	---
R-22	12/20/2006	ND (0.2)	ND (1.0)	928	8.19
R-22	01/22/2007	ND (0.2)	ND (1.0)	---	---
R-22	03/13/2007	ND (0.2)	ND (1.0)	928	8.30
R-22	05/08/2007	ND (0.2)	ND (1.0)	958	8.30
R-22	09/11/2007	ND (0.2)	ND (1.0)	938	8.27 J
R-22	09/13/2007	ND (0.2)	ND (1.0)	---	---
R-22	09/25/2007	ND (0.2)	ND (1.0)	---	---
R-22	10/02/2007	ND (0.2)	ND (1.0)	---	---
R-27	10/04/2006	ND (0.2)	ND (1.0)	1020	8.45 R
R-27	11/15/2006	ND (0.2)	ND (1.0)	---	---
R-27	12/20/2006	ND (0.2)	ND (1.0)	911	8.21
R-27	01/22/2007	ND (0.2)	ND (1.0)	---	---
R-27	03/13/2007	ND (0.2)	ND (1.0)	956	8.31
R-27	05/08/2007	ND (1.0)	ND (1.0)	967	8.28
R-27	09/11/2007	ND (0.2)	ND (1.0)	934	8.30 J
R-27	09/13/2007	ND (0.2)	ND (1.0)	---	---
R-27	09/26/2007	ND (0.2)	ND (1.0)	---	---
R-27	10/02/2007	ND (0.2)	ND (1.0)	---	---
R-28	10/04/2006	ND (0.2)	ND (1.0)	1010	8.25 R
R-28	11/15/2006	ND (0.2)	ND (1.0)	---	---
R-28	12/20/2006	ND (0.2)	ND (1.0)	896	8.16
R-28	01/22/2007	ND (0.2)	ND (1.0)	---	---
R-28	03/14/2007	ND (0.2)	ND (1.0)	914	8.16
R-28	05/09/2007	ND (0.2)	ND (1.0)	951	8.27
R-28	09/12/2007	ND (0.2)	ND (1.0)	1240	8.20 J

Station ID	Sample Date	Hexavalent Chromium (µg/L)	Dissolved Chromium (µg/L)	Specific Conductance (µS/cm)	pH (pH units)
Shoreline Surface Water Locations					
R-28	09/13/2007	ND (0.2)	ND (1.0)	---	---
R-28	09/26/2007	ND (0.2)	ND (1.0)	---	---
R-28	10/03/2007	ND (0.2)	ND (1.0)	---	---
RRB	10/04/2006	ND (0.2)	ND (1.0)	1070	7.90 R
RRB	11/15/2006	ND (0.2)	ND (1.0)	---	---
RRB	12/20/2006	ND (1.0)	ND (1.0)	3870	7.73
RRB	01/22/2007	ND (0.2)	ND (1.0)	---	---
RRB	03/14/2007	ND (0.2)	ND (1.0)	929	8.18
RRB	05/09/2007	ND (0.2)	ND (1.0)	947	8.13
RRB	09/12/2007	ND (0.2)	ND (1.0)	1310	7.92 J
RRB	09/14/2007	ND (0.2)	ND (1.0)	---	---
RRB	09/26/2007	ND (0.2)	ND (1.0)	---	---
RRB	10/03/2007	ND (0.2)	ND (1.0)	---	---
In-Channel Surface Water Locations					
C-CON-S	10/03/2006	ND (0.2)	ND (1.0)	955	8.00
C-CON-M	10/03/2006	ND (0.2)	ND (1.0)	953	8.02
C-CON-D	10/03/2006	ND (0.2)	ND (1.0)	956	8.04
C-CON-S	11/16/2006	ND (0.2)	ND (1.0)	---	---
C-CON-M	11/16/2006	ND (0.2)	ND (1.0)	---	---
C-CON-D	11/16/2006	ND (0.2)	ND (1.0)	---	---
C-CON-S	12/19/2006	ND (0.2)	ND (1.0)	912	8.14
C-CON-M	12/19/2006	ND (0.2)	ND (1.0)	903	8.24
C-CON-D	12/19/2006	ND (0.2)	ND (1.0)	892	8.14
C-CON-S	01/22/2007	ND (0.2)	ND (1.0)	---	---
C-CON-M	01/22/2007	ND (0.2)	ND (1.0)	---	---
C-CON-D	01/22/2007	ND (0.2)	ND (1.0)	---	---
C-CON-D	02/20/2007	ND (0.2)	ND (1.0)	---	---
C-CON-S	03/14/2007	ND (0.2)	ND (1.0)	932	8.28
C-CON-M	03/14/2007	ND (0.2)	ND (1.0)	930	8.30
C-CON-D	03/14/2007	ND (0.2)	ND (1.0)	939	8.26
C-CON-S	05/09/2007	ND (0.2)	ND (1.0)	948	8.25
C-CON-M	05/09/2007	ND (0.2)	ND (1.0)	951	8.27
C-CON-D	05/09/2007	ND (0.2)	ND (1.0)	949	8.25
C-CON-S	09/12/2007	ND (0.2)	ND (1.0)	1370	8.09 J
C-CON-M	09/12/2007	ND (0.2)	ND (1.0)	1350	8.10 J
C-CON-D	09/12/2007	ND (0.2)	ND (1.0)	1610	8.07 J
C-CON-S	09/14/2007	ND (0.2)	ND (1.0)	---	---
C-CON-M	09/14/2007	ND (0.2)	ND (1.0)	---	---

Station ID	Sample Date	Hexavalent Chromium (µg/L)	Dissolved Chromium (µg/L)	Specific Conductance (µS/cm)	pH (pH units)
In-Channel Surface Water Locations					
C-CON-D	09/14/2007	ND (0.2)	ND (1.0)	---	---
C-CON-S	09/26/2007	ND (0.2)	ND (1.0)	---	---
C-CON-M	09/26/2007	ND (0.2)	ND (1.0)	---	---
C-CON-D	09/26/2007	ND (0.2)	ND (1.0)	---	---
C-CON-S	10/03/2007	ND (0.2)	ND (1.0)	---	---
C-CON-M	10/03/2007	ND (0.2)	ND (1.0)	---	---
C-CON-D	10/03/2007	ND (0.2)	ND (1.0)	---	---
C-I-3-S	10/03/2006	ND (0.2)	ND (1.0)	962	8.11
C-I-3-M	10/03/2006	ND (0.2)	ND (1.0)	953	8.12
C-I-3-D	10/03/2006	ND (0.2)	ND (1.0)	943	8.12
C-I-3-S	11/15/2006	ND (0.2)	ND (1.0)	---	---
C-I-3-M	11/15/2006	ND (0.2)	ND (1.0)	---	---
C-I-3-D	11/15/2006	ND (0.2)	ND (1.0)	---	---
C-I-3-S	12/19/2006	ND (0.2)	ND (1.0)	942	8.22
C-I-3-M	12/19/2006	ND (0.2)	ND (1.0)	905	8.29
C-I-3-D	12/19/2006	ND (0.2)	ND (1.0)	901	8.23
C-I-3-S	01/23/2007	ND (0.2)	ND (1.0)	---	---
C-I-3-M	01/23/2007	ND (0.2)	ND (1.0)	---	---
C-I-3-D	01/23/2007	ND (0.2)	ND (1.0)	---	---
C-I-3-D	02/20/2007	ND (0.2)	ND (1.0)	---	---
C-I-3-S	03/13/2007	ND (0.2)	ND (1.0)	945	8.29
C-I-3-M	03/13/2007	ND (0.2)	ND (1.0)	931	8.30
C-I-3-D	03/13/2007	ND (0.2)	ND (1.0)	920	8.25
C-I-3-S	05/08/2007	ND (0.2)	ND (1.0)	953	8.28
C-I-3-M	05/08/2007	ND (0.2)	ND (1.0)	952	8.24
C-I-3-D	05/08/2007	ND (0.2)	ND (1.0)	950	8.32
C-I-3-S	09/11/2007	ND (0.2)	ND (1.0)	948	8.19 J
C-I-3-M	09/11/2007	ND (0.2)	ND (1.0)	945	8.18 J
C-I-3-D	09/11/2007	ND (0.2)	ND (1.0)	936	8.14 J
C-I-3-S	09/13/2007	ND (0.2)	ND (1.0)	---	---
C-I-3-M	09/13/2007	ND (0.2)	ND (1.0)	---	---
C-I-3-D	09/13/2007	ND (0.2)	ND (1.0)	---	---
C-I-3-S	09/25/2007	ND (0.2)	ND (1.0)	---	---
C-I-3-M	09/25/2007	ND (0.2)	ND (1.0)	---	---
C-I-3-D	09/25/2007	ND (0.2)	ND (1.0)	---	---
C-I-3-S	10/02/2007	ND (0.2)	ND (1.0)	---	---
C-I-3-M	10/02/2007	ND (0.2)	ND (1.0)	---	---
C-I-3-D	10/02/2007	ND (0.2)	ND (1.0)	---	---
C-MAR-M	10/03/2006	ND (0.2)	ND (1.0)	985	7.84

TABLE 7-3

Surface Water Sampling Results - October 2006 through October 2007

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Station ID	Sample Date	Hexavalent Chromium (µg/L)	Dissolved Chromium (µg/L)	Specific Conductance (µS/cm)	pH (pH units)
In-Channel Surface Water Locations					
C-MAR-M	11/16/2006	ND (0.2)	ND (1.0)	---	---
C-MAR-M	12/19/2006	ND (0.2)	ND (1.0)	1830	7.85
C-MAR-D	01/23/2007	ND (0.2)	ND (1.0)	---	---
C-MAR-D	02/20/2007	ND (0.2)	ND (1.0)	---	---
C-MAR-S	03/13/2007	ND (0.2)	ND (1.0)	1030	8.04
C-MAR-D	03/13/2007	ND (0.2)	ND (1.0)	1030	8.06
C-MAR-S	05/09/2007	ND (0.2)	ND (1.0)	951	8.24
C-MAR-D	05/09/2007	ND (0.2)	ND (1.0)	929	8.08
C-MAR-S	09/11/2007	ND (0.2)	ND (1.0)	1010	7.81 J
C-MAR-D	09/11/2007	ND (0.2)	ND (1.0)	1000	7.88 J
C-MAR-S	09/13/2007	ND (0.2)	ND (1.0)	---	---
C-MAR-D	09/13/2007	ND (0.2)	ND (1.0)	---	---
C-MAR-S	09/26/2007	ND (0.2)	ND (1.0)	---	---
C-MAR-D	09/26/2007	ND (0.2)	ND (1.0)	---	---
C-MAR-S	10/02/2007	ND (0.2)	ND (1.0)	---	---
C-MAR-D	10/02/2007	ND (0.2)	ND (1.0)	---	---
C-NR1-S	10/04/2006	ND (0.2)	ND (1.0)	1000	8.20
C-NR1-M	10/04/2006	ND (0.2)	ND (1.0)	995	8.18
C-NR1-D	10/04/2006	ND (0.2)	ND (1.0)	986	8.19
C-NR1-S	11/16/2006	ND (0.2)	ND (1.0)	---	---
C-NR1-M	11/16/2006	ND (0.2)	ND (1.0)	---	---
C-NR1-D	11/16/2006	ND (0.2)	ND (1.0)	---	---
C-NR1-S	12/19/2006	ND (0.2)	ND (1.0)	909	8.04
C-NR1-M	12/19/2006	ND (0.2)	ND (1.0)	911	8.24
C-NR1-D	12/19/2006	ND (0.2)	ND (1.0)	923	8.20
C-NR1-S	01/22/2007	ND (0.2)	ND (1.0)	---	---
C-NR1-M	01/22/2007	ND (0.2)	ND (1.0)	---	---
C-NR1-D	01/22/2007	ND (0.2)	ND (1.0)	---	---
C-NR1-D	02/20/2007	ND (0.2)	ND (1.0)	---	---
C-NR1-S	03/14/2007	ND (0.2)	ND (1.0)	935	8.27
C-NR1-M	03/14/2007	ND (0.2)	ND (1.0)	934	8.22
C-NR1-D	03/14/2007	ND (0.2)	ND (1.0)	942	8.30
C-NR1-S	05/09/2007	ND (0.2)	ND (1.0)	957	8.32
C-NR1-M	05/09/2007	ND (0.2)	ND (1.0)	952	8.31
C-NR1-D	05/09/2007	ND (0.2)	ND (1.0)	951	8.29
C-NR1-S	09/12/2007	ND (0.2)	ND (1.0)	1280	8.15 J
C-NR1-M	09/12/2007	ND (0.2)	ND (1.0)	1300	8.12 J
C-NR1-D	09/12/2007	ND (0.2)	ND (1.0)	1230	8.14 J
C-NR1-S	09/14/2007	ND (0.2)	ND (1.0)	---	---

TABLE 7-3
Surface Water Sampling Results - October 2006 through October 2007
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PG&E Topock Compressor Station, Needles, California

Station ID	Sample Date	Hexavalent Chromium (µg/L)	Dissolved Chromium (µg/L)	Specific Conductance (µS/cm)	pH (pH units)
In-Channel Surface Water Locations					
C-NR1-M	09/14/2007	ND (0.2)	ND (1.0)	---	---
C-NR1-D	09/14/2007	ND (0.2)	ND (1.0)	---	---
C-NR1-S	09/26/2007	ND (0.2)	ND (1.0)	---	---
C-NR1-M	09/26/2007	ND (0.2)	ND (1.0)	---	---
C-NR1-D	09/26/2007	ND (0.2)	ND (1.0)	---	---
C-NR1-S	10/03/2007	ND (0.2)	ND (1.0)	---	---
C-NR1-M	10/03/2007	ND (0.2)	ND (1.0)	---	---
C-NR1-D	10/03/2007	ND (0.2)	ND (1.0)	---	---
C-NR3-S	10/04/2006	ND (0.2)	ND (1.0)	975	8.17
C-NR3-M	10/04/2006	ND (0.2)	ND (1.0)	981	8.19
C-NR3-D	10/04/2006	ND (0.2)	ND (1.0)	987	8.16
C-NR3-S	11/16/2006	ND (0.2)	ND (1.0)	---	---
C-NR3-M	11/16/2006	ND (0.2)	ND (1.0)	---	---
C-NR3-D	11/16/2006	ND (0.2)	ND (1.0)	---	---
C-NR3-S	12/19/2006	ND (0.2)	ND (1.0)	935	8.03
C-NR3-M	12/19/2006	ND (0.2)	ND (1.0)	906	8.08
C-NR3-D	12/19/2006	ND (0.2)	ND (1.0)	901	8.15
C-NR3-S	01/22/2007	ND (0.2)	ND (1.0)	---	---
C-NR3-M	01/22/2007	ND (0.2)	ND (1.0)	---	---
C-NR3-D	01/22/2007	ND (0.2)	ND (1.0)	---	---
C-NR3-D	02/20/2007	ND (0.2)	ND (1.0)	---	---
C-NR3-S	03/14/2007	ND (0.2)	ND (1.0)	931	8.31
C-NR3-M	03/14/2007	ND (0.2)	ND (1.0)	944	8.30
C-NR3-D	03/14/2007	ND (0.2)	ND (1.0)	945	8.27
C-NR3-S	05/09/2007	ND (0.2)	ND (1.0)	957	8.27
C-NR3-M	05/09/2007	ND (0.2)	ND (1.0)	955	8.31
C-NR3-D	05/09/2007	ND (0.2)	ND (1.0)	952	8.28
C-NR3-S	09/12/2007	ND (0.2)	ND (1.0)	1310	8.16 J
C-NR3-M	09/12/2007	ND (0.2)	ND (1.0)	1340	7.86 J
C-NR3-D	09/12/2007	ND (0.2)	ND (1.0)	1260	8.00 J
C-NR3-S	09/14/2007	ND (0.2)	ND (1.0)	---	---
C-NR3-M	09/14/2007	ND (0.2)	ND (1.0)	---	---
C-NR3-D	09/14/2007	ND (0.2)	ND (1.0)	---	---
C-NR3-S	09/26/2007	ND (0.2)	ND (1.0)	---	---
C-NR3-M	09/26/2007	ND (0.2)	ND (1.0)	---	---
C-NR3-D	09/26/2007	ND (0.2)	ND (1.0)	---	---
C-NR3-S	10/03/2007	ND (0.2)	ND (1.0)	---	---
C-NR3-M	10/03/2007	ND (0.2)	ND (1.0)	---	---
C-NR3-D	10/03/2007	ND (0.2)	ND (1.0)	---	---

TABLE 7-3
Surface Water Sampling Results - October 2006 through October 2007
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PG&E Topock Compressor Station, Needles, California

Station ID	Sample Date	Hexavalent Chromium (µg/L)	Dissolved Chromium (µg/L)	Specific Conductance (µS/cm)	pH (pH units)
In-Channel Surface Water Locations					
C-NR4-S	10/04/2006	ND (0.2)	ND (1.0)	995	8.09
C-NR4-M	10/04/2006	ND (0.2)	ND (1.0)	983	8.16
C-NR4-D	10/04/2006	ND (0.2)	ND (1.0)	970	8.17
C-NR4-S	11/16/2006	ND (0.2)	ND (1.0)	---	---
C-NR4-M	11/16/2006	ND (0.2)	ND (1.0)	---	---
C-NR4-D	11/16/2006	ND (0.2)	ND (1.0)	---	---
C-NR4-S	12/20/2006	ND (0.2)	ND (1.0)	915	8.29
C-NR4-M	12/20/2006	ND (0.2)	ND (1.0)	915	8.25
C-NR4-D	12/20/2006	ND (0.2)	ND (1.0)	922	8.15
C-NR4-S	01/22/2007	ND (0.2)	ND (1.0)	---	---
C-NR4-M	01/22/2007	ND (0.2)	ND (1.0)	---	---
C-NR4-D	01/22/2007	ND (0.2)	ND (1.0)	---	---
C-NR4-D	02/20/2007	ND (0.2)	ND (1.0)	---	---
C-NR4-S	03/14/2007	ND (0.2)	ND (1.0)	943	8.28
C-NR4-S FD	03/14/2007	ND (0.2)	ND (1.0)	941	8.24
C-NR4-M	03/14/2007	ND (0.2)	ND (1.0)	947	8.31
C-NR4-D	03/14/2007	ND (0.2)	ND (1.0)	946	8.30
C-NR4-S	05/09/2007	ND (0.2)	ND (1.0)	954	8.22
C-NR4-M	05/09/2007	ND (0.2)	ND (1.0)	950	8.21
C-NR4-D	05/09/2007	ND (0.2)	ND (1.0)	957	8.25
C-NR4-S	09/12/2007	ND (0.2)	ND (1.0)	1250	8.17 J
C-NR4-M	09/12/2007	ND (0.2)	ND (1.0)	1250	8.14 J
C-NR4-D	09/12/2007	ND (0.2)	ND (1.0)	1280	8.09 J
C-NR4-S	09/14/2007	ND (0.2)	ND (1.0)	---	---
C-NR4-M	09/14/2007	ND (0.2)	ND (1.0)	---	---
C-NR4-D	09/14/2007	ND (0.2)	ND (1.0)	---	---
C-NR4-S	09/26/2007	ND (0.2)	ND (1.0)	---	---
C-NR4-M	09/26/2007	ND (0.2)	ND (1.0)	---	---
C-NR4-D	09/26/2007	ND (0.2)	ND (1.0)	---	---
C-NR4-S	10/03/2007	ND (0.2)	ND (1.0)	---	---
C-NR4-M	10/03/2007	ND (0.2)	ND (1.0)	---	---
C-NR4-D	10/03/2007	ND (0.2)	ND (1.0)	---	---
C-R22-S	10/03/2006	ND (0.2)	ND (1.0)	946	8.16
C-R22-M	10/03/2006	ND (0.2)	ND (1.0)	975	8.16
C-R22-D	10/03/2006	ND (0.2)	ND (1.0)	964	8.15
C-R22-S	11/15/2006	ND (0.2)	ND (1.0)	---	---
C-R22-M	11/15/2006	ND (0.2)	ND (1.0)	---	---
C-R22-D	11/15/2006	ND (0.2)	ND (1.0)	---	---
C-R22-S	12/19/2006	ND (0.2)	ND (1.0)	940	8.15

Station ID	Sample Date	Hexavalent Chromium (µg/L)	Dissolved Chromium (µg/L)	Specific Conductance (µS/cm)	pH (pH units)
In-Channel Surface Water Locations					
C-R22-M	12/19/2006	ND (0.2)	ND (1.0)	892	8.03
C-R22-D	12/19/2006	ND (0.2)	ND (1.0)	927	8.31
C-R22-S	01/23/2007	ND (0.2)	ND (1.0)	---	---
C-R22-M	01/23/2007	ND (0.2)	ND (1.0)	---	---
C-R22-D	01/23/2007	ND (0.2)	ND (1.0)	---	---
C-R22-D	02/20/2007	ND (0.2)	ND (1.0)	---	---
C-R22-S	03/13/2007	ND (0.2)	ND (1.0)	937	8.18
C-R22-M	03/13/2007	ND (0.2)	ND (1.0)	934	8.30
C-R22-D	03/13/2007	ND (0.2)	ND (1.0)	941	8.25
C-R22-S	05/08/2007	ND (0.2)	ND (1.0)	963	8.29
C-R22-M	05/08/2007	ND (0.2)	ND (1.0)	960	8.28
C-R22-D	05/08/2007	ND (0.2)	ND (1.0)	960	8.30
C-R22-S	09/11/2007	ND (0.2)	ND (1.0)	936	8.17 J
C-R22-M	09/11/2007	ND (0.2)	ND (1.0)	932	8.20 J
C-R22-D	09/11/2007	0.40 J	ND (1.0)	941	8.22 J
C-R22-S	09/12/2007	ND (1.0)	ND (1.0)	---	---
C-R22-M	09/12/2007	ND (0.2)	ND (1.0)	---	---
C-R22-D	09/12/2007	ND (0.2)	ND (1.0)	---	---
C-R22-D-East	09/12/2007	ND (0.2)	ND (1.0)	---	---
C-R22-D-North	09/12/2007	ND (0.2)	ND (1.0)	---	---
C-R22-D-South	09/12/2007	ND (0.2)	ND (1.0)	---	---
C-R22-D-West	09/12/2007	ND (1.0)	ND (1.0)	---	---
C-R22-S	09/13/2007	ND (0.2)	ND (1.0)	---	---
C-R22-M	09/13/2007	ND (0.2)	ND (1.0)	---	---
C-R22-D	09/13/2007	ND (0.2)	ND (1.0)	---	---
C-R22-S	09/25/2007	ND (0.2)	ND (1.0)	---	---
C-R22-M	09/25/2007	ND (0.2)	ND (1.0)	---	---
C-R22-D	09/25/2007	ND (0.2)	ND (1.0)	---	---
C-R22-S	10/02/2007	ND (0.2)	ND (1.0)	---	---
C-R22-M	10/02/2007	ND (0.2)	ND (1.0)	---	---
C-R22-D	10/02/2007	ND (0.2)	ND (1.0)	---	---
C-R27-S	10/03/2006	ND (0.2)	ND (1.0)	931	8.10
C-R27-M	10/03/2006	ND (0.2)	ND (1.0)	944	8.11
C-R27-D	10/03/2006	ND (0.2)	ND (1.0)	946	8.11
C-R27-S	11/16/2006	ND (0.2)	ND (1.0)	---	---
C-R27-D	11/16/2006	ND (0.2)	ND (1.0)	---	---
C-R27-M	12/19/2006	ND (0.2)	ND (1.0)	873	8.25
C-R27-S	01/23/2007	ND (0.2)	ND (1.0)	---	---
C-R27-M	01/23/2007	ND (0.2)	ND (1.0)	---	---

Station ID	Sample Date	Hexavalent Chromium (µg/L)	Dissolved Chromium (µg/L)	Specific Conductance (µS/cm)	pH (pH units)
In-Channel Surface Water Locations					
C-R27-D	01/23/2007	ND (0.2)	ND (1.0)	---	---
C-R27-D	02/20/2007	ND (0.2)	ND (1.0)	---	---
C-R27-S	03/13/2007	ND (0.2)	ND (1.0)	949	8.31
C-R27-M	03/13/2007	ND (0.2)	ND (1.0)	953	8.34
C-R27-D	03/13/2007	ND (0.2)	ND (1.0)	948	8.33
C-R27-S	05/08/2007	ND (1.0)	ND (1.0)	962	8.27
C-R27-M	05/08/2007	ND (1.0)	ND (1.0)	960	8.26
C-R27-D	05/08/2007	ND (0.2)	ND (1.0)	963	8.25
C-R27-S	09/11/2007	ND (0.2)	ND (1.0)	944	8.21 J
C-R27-M	09/11/2007	ND (0.2)	ND (1.0)	942	8.19 J
C-R27-D	09/11/2007	ND (0.2)	ND (1.0)	934	8.18 J
C-R27-S	09/13/2007	ND (0.2)	ND (1.0)	---	---
C-R27-M	09/13/2007	ND (0.2)	ND (1.0)	---	---
C-R27-D	09/13/2007	ND (0.2)	ND (1.0)	---	---
C-R27-S	09/25/2007	ND (0.2)	ND (1.0)	---	---
C-R27-M	09/25/2007	ND (0.2)	ND (1.0)	---	---
C-R27-D	09/25/2007	ND (0.2)	ND (1.0)	---	---
C-R27-S	10/02/2007	ND (0.2)	ND (1.0)	---	---
C-R27-M	10/02/2007	ND (0.2)	ND (1.0)	---	---
C-R27-D	10/02/2007	ND (0.2)	ND (1.0)	---	---
C-TAZ-S	10/03/2006	ND (0.2)	ND (1.0)	956	8.14
C-TAZ-M	10/03/2006	ND (0.2)	ND (1.0)	955	8.15
C-TAZ-D	10/03/2006	ND (0.2)	ND (1.0)	926	8.15
C-TAZ-S	11/15/2006	ND (0.2)	ND (1.0)	---	---
C-TAZ-M	11/15/2006	ND (0.2)	ND (1.0)	---	---
C-TAZ-D	11/15/2006	ND (0.2)	ND (1.0)	---	---
C-TAZ-S	12/19/2006	ND (0.2)	ND (1.0)	897	8.30
C-TAZ-M	12/19/2006	ND (0.2)	ND (1.0)	886	8.24
C-TAZ-D	12/19/2006	ND (0.2)	ND (1.0)	920	8.13
C-TAZ-S	01/23/2007	ND (0.2)	ND (1.0)	---	---
C-TAZ-M	01/23/2007	ND (0.2)	ND (1.0)	---	---
C-TAZ-D	01/23/2007	ND (0.2)	ND (1.0)	---	---
C-TAZ-D	02/20/2007	ND (0.2)	ND (1.0)	---	---
C-TAZ-S	03/13/2007	ND (0.2)	ND (1.0)	922	8.31
C-TAZ-M	03/13/2007	ND (0.2)	ND (1.0)	941	8.35
C-TAZ-D	03/13/2007	ND (0.2)	ND (1.0)	936	8.33
C-TAZ-S	05/08/2007	ND (0.2)	ND (1.0)	950	8.31
C-TAZ-M	05/08/2007	ND (0.2)	ND (1.0)	951	8.32
C-TAZ-D	05/08/2007	ND (0.2)	ND (1.0)	947	8.30

TABLE 7-3

Surface Water Sampling Results - October 2006 through October 2007

RCRA Facility Investigation/Remedial Investigation (Volume 2)

PG&E Topock Compressor Station, Needles, California

Station ID	Sample Date	Hexavalent Chromium (µg/L)	Dissolved Chromium (µg/L)	Specific Conductance (µS/cm)	pH (pH units)
In-Channel Surface Water Locations					
C-TAZ-S	09/11/2007	ND (0.2)	ND (1.0)	938	8.12 J
C-TAZ-M	09/11/2007	ND (0.2)	ND (1.0)	941	8.09 J
C-TAZ-D	09/11/2007	ND (0.2)	ND (1.0)	935	8.06 J
C-TAZ-S	09/13/2007	ND (0.2)	ND (1.0)	---	---
C-TAZ-M	09/13/2007	ND (0.2)	ND (1.0)	---	---
C-TAZ-D	09/13/2007	ND (0.2)	ND (1.0)	---	---
C-TAZ-S	09/25/2007	ND (0.2)	ND (1.0)	---	---
C-TAZ-M	09/25/2007	ND (0.2)	ND (1.0)	---	---
C-TAZ-D	09/25/2007	ND (0.2)	ND (1.0)	---	---
C-TAZ-S	10/02/2007	ND (0.2)	ND (1.0)	---	---
C-TAZ-M	10/02/2007	ND (0.2)	ND (1.0)	---	---
C-TAZ-D	10/02/2007	ND (0.2)	ND (1.0)	---	---

Notes:

ND	not detected at listed reporting limit
J	concentration or reporting limit estimated by laboratory or data validation
R	result exceeded analytical criteria for precision and accuracy; should not be used for project decision-making
µS/cm	microsiemens per centimeter
µg/L	micrograms per liter
(---)	data not collected or available
FD	Field duplicate

Refer to Appendix H for complete analytical data for surface water sampling.

TABLE 7-4

Summary of Surface Water Sampling Results - Additional Trace Metals, July 1997 through October 2007

RCRA Facility Investigation/Remedial Investigation (Volume 2)
PG&E Topock Compressor Station, Needles, California

	Barium (µg/L)		Iron (µg/L)		Manganese (µg/L)		Molybdenum (µg/L)		Vanadium (µg/L)	
Chemical-Specific ARAR[1]	1,000		300		50		NA		NA	
Station ID [2]	**Frequency of Detection[3] (Number of Detects/Number of Samples) and Average Concentration[4]**									
Shoreline Surface Water Locations										
Needles Gauge	0 \ 0	---	0 \ 0	---	0 \ 0	---	0 \ 0	---	0 \ 0	---
NR-3	0 \ 0	---	0 \ 0	---	0 \ 0	---	0 \ 0	---	0 \ 0	---
NR-2	0 \ 0	---	0 \ 0	---	0 \ 0	---	0 \ 0	---	0 \ 0	---
NR-1	1 \ 1	140	0 \ 1	ND	0 \ 1	ND	0 \ 0	---	0 \ 0	---
A-Dock	1 \ 1	110	0 \ 0	---	0 \ 1	ND	0 \ 1	ND	0 \ 1	ND
CON	3 \ 4	143	0 \ 1	ND	2 \ 4	65.0	2 \ 3	4.93	2 \ 3	3.47
Seasonal Wetlands	1 \ 1	120	0 \ 0	---	1 \ 1	8.00	1 \ 1	5.00	0 \ 1	ND
RRB	1 \ 1	120	0 \ 0	---	1 \ 1	5.00	1 \ 1	7.00	0 \ 1	ND
R-19	0 \ 0	---	0 \ 0	---	0 \ 0	---	0 \ 0	---	0 \ 0	---
R-19-B	0 \ 0	---	0 \ 0	---	0 \ 0	---	0 \ 0	---	0 \ 0	---
R-19-C	0 \ 0	---	0 \ 0	---	0 \ 0	---	0 \ 0	---	0 \ 0	---
R-28	0 \ 1	ND	0 \ 3	ND	0 \ 3	ND	1 \ 1	5.40	1 \ 1	253
R-20	0 \ 0	---	0 \ 0	---	0 \ 0	---	0 \ 0	---	0 \ 0	---
R-20-B	0 \ 0	---	0 \ 0	---	0 \ 0	---	0 \ 0	---	0 \ 0	---
R-20-C	0 \ 0	---	0 \ 0	---	0 \ 0	---	0 \ 0	---	0 \ 0	---
R-27	0 \ 1	ND	0 \ 3	ND	0 \ 3	ND	0 \ 0	---	0 \ 0	---
R-22	0 \ 0	---	0 \ 0	---	0 \ 0	---	0 \ 0	---	0 \ 0	---
I-3	4 \ 5	150	0 \ 2	ND	3 \ 5	54.1	3 \ 3	4.73	2 \ 3	3.20

Notes:

ND	not detected
µg/L	micrograms per liter
---	not analyzed

At locations R-19B, R-19C and R-20B, multiple samples were collected at surface, 5-foot, and 10-foot depths and locations. Results for each location summarized the samples collected at depth.

Refer to Appendix H for complete analytical data for surface water sampling.

[1] Surface water chemical-specific ARARs. See Table 7-1.
[2] Surface water locations are listed in order of their position on the river, from north to south.
[3] Results listed for number of detections for primary samples collected during RFI, July 1997 through October 2007.
[4] Average concentrations of all results (including estimated concentrations) in micrograms per liter, with half the reporting limit used for non detects. Detected results are the maximum concentrations from primary or duplicate samples.

8.0 Pore Water Investigation

This section presents the results and findings of the pore water investigations and characterization completed for this RFI/RI in February 2003 and January 2006. This section also summarizes the river bottom temperature survey conducted for the 2006 pore water study (CH2M HILL, 2006p).

8.1 River Bottom Temperature Survey

A river bottom temperature survey was conducted prior to the collection of samples for the 2006 pore water study to determine the depth of influence from diurnal river level fluctuation and select pore water sampling depths. Shallow river sediment temperatures were measured with small, self-contained, temperature-recording devices that were buried in the river bottom to record the temperature in the pore water over approximately 1 week. Temperature fluctuations were expected to be a sensitive indicator of groundwater/surface water interchange because of the large temperature contrast between groundwater and river water at the Topock site.

Strings of the temperature recorders were jetted to at least 7 feet below the river bottom at 10 locations (three upgradient and seven downgradient): PS-3B, PS-5B, PS-7B, PS-8B, PS-9B, PS-11B, PS-12B, PS-13B, PS-14B, and PS-15B, shown on Figure 4-8. The temperature recorders were positioned at depths of 0, 1, 3, and 6 feet on each string below the river bottom. Results from the temperature data indicated that a sample depth of 6 feet below the river bottom was sufficient to sample pore water that is not influenced by diurnal fluctuations from the Colorado River. Figure 8-1 shows an example plot of the results of the temperature survey.

Data collected from temperature recorders on the surface of the river bottom showed the most variation in temperature. There was a general trend of falling temperature over the duration of the test that corresponds with a general trend of rising river levels. Temperature recorders installed at 1- and 3-foot depths generally recorded a falling trend in temperature over the period of deployment but did not record diurnal fluctuations. The deepest temperature recorders, installed 6 feet below the river bottom, showed the least change in temperature after their initial equilibration period. At some locations, temperature equilibration after installation was rapid, whereas other locations took up to 2 days to equilibrate. The delay in temperature equilibration is a result of the cold river water that was introduced into the river bottom sediments during the jetting operation to place the temperature recorders.

The temperature survey indicated that, at a depth of 6 feet below the river bottom, the river influenced fluctuations were effectively damped out to magnitudes below the resolution of the temperature recorders (0.6° at 70°F). From these results, it was recommended that the 2006 pore water samples be collected from depths of 6 feet below the river bottom, below the depth of significant diurnal changes in the flow regime.

8.2 Pore Water Sampling

Though no COPCs have been identified for pore water, for the purposes of characterization, the RFI/RI examined COPCs similar to those identified for SWMU 1/AOC 1.

8.2.1 Pore Water Sampling (February 2003)

Pore water samples were collected from six locations in February 2003 from piezometers driven approximately 2 to 3 feet into the river sediments. Samples were analyzed for chromium and general chemistry and redox parameters (Appendix H). Two locations were upstream of the mouth of Bat Cave Wash in the Moabi Regional Park slough (W-1 and W-2), and one location was at the mouth of Bat Cave Wash (W-4) (Figure 4-7). Three locations were downstream of the mouth of Bat Cave Wash (W-27, W-28 and W-29) along the Colorado River shoreline near monitoring wells (clusters) MW-27, MW-28 and MW–29. A summary of the 2003 pore water results are presented in Table 8-1. Complete analytical results of the pore samples are presented in Appendix H.

8.2.1.1 Chromium Sampling Results

Cr(VI) was not detected in any of the 2003 pore samples (Table 8-1) at the analytical reporting limit. Note the samples were not analyzed within the holding time for the method, and the results were J-flagged. Cr(T) was detected in pore water samples from three locations at trace concentrations around 1 µg/L, well below the California surface water quality criteria of 50 µg/L. A similar trace concentration of Cr(T) was also detected in the rinse blank of 1.1 µg/L (Table 8-1, Appendix H); therefore, it is possible that the trace detections in the pore water samples were from external contamination.

8.2.1.2 Sampling Results for Trace Metals

Table 8-1 summarizes the RFI/RI pore water sampling results for chromium and other COPCs: copper, nickel, zinc, specific conductance, and pH. The analytical results for the non-chromium COPC trace metals from the 2003 pore water samples are summarized below.

Copper. Dissolved copper has not been detected in pore water samples at locations downstream of the mouth of Bat Cave Wash or adjacent to the mouth during February 2003. Dissolved copper was detected in one pore water sample from a location upstream of the mouth of Bat Cave Wash (W-2) (Table 8-1).

Nickel. Dissolved nickel has not been detected in pore samples from any of the locations sampled during February 2003 (Table 8-1).

Zinc. Dissolved zinc has been detected in pore water samples at two locations downstream of the mouth of Bat Cave Wash (W-27 and W-29 field duplicate) at 5.26 µg/L and 10.0 µg/L. Dissolved zinc was also detected in one pore water sample from a location upstream of the mouth of Bat Cave Wash (W-2) at 1.14 µg/L. Dissolved zinc was not detected in pore water samples from the remaining locations sampled during February 2003 (Table 8-1). A similar concentration of dissolved zinc was also detected in the rinse blank at 13 µg/L (Table 8-1, Appendix H); therefore, it is possible that the trace detections in the pore water samples were from external contamination.

8.2.2 Pore Water Study (January 2006)

A pore water study was conducted in January 2006 to assess chromium concentrations at multiple locations both upgradient and downgradient of the mouth of Bat Cave Wash and to assess whether geochemical conditions in shallow sediments below the Colorado River favor chromium reduction. Pore water samples were collected from 64 locations along 16 transects in January 2006 from modified GeoProbe® rods driven approximately 6 feet below the Colorado River bottom. Seven of the transects were located upstream of the mouth of Bat Cave Wash (PW-1 through PW-7), and nine of the of the transects were downstream of the mouth of Bat Cave Wash (PW-8 through PW-16) (Figure 4-7). Samples were collected during the seasonal low river stand and were analyzed for chromium and general chemistry parameters. A summary of the 2006 pore water study results are presented in Table 8-1. Complete analytical results of the pore samples are presented in Appendix H.

Surface water samples were also collected concurrently with the pore water samples at each transect, 1 foot from the river bottom. A summary of these results is provided in Section 7.2.3. Ten river sediment samples were collected from 0.5 feet to 2.5 feet below the river bottom, concurrent with the pore water samples. A summary of these results is provided in Section 9.2.2.

8.2.2.1 Chromium Sampling Results

Both Cr(VI) and Cr(T) were not detected in any of the 2006 pore water samples collected from 64 locations both upstream and downstream of the Topock site. Reporting limits for these analyses were 0.2 and 1.0 µg/L, respectively.

8.2.2.2 Sampling Results for pH and Specific Conductance

Table 8-1 summarizes the RFI/RI pore water sampling results for chromium and other COPCs: copper, nickel, zinc, lead, specific conductance, and pH. The analytical results for the non-chromium COPCs from the 2006 pore water samples are summarized below.

Specific Conductance. The average specific conductance results in pore water samples collected downstream of Bat Cave Wash ranged from 991 to 7,610 µS/cm. Specific conductance results in upstream locations range from 726 to 2,020 µS/cm. Specific conductance at particular downstream locations are believed to be slightly higher than the upstream locations due to a couple of factors. The elevated specific conductance in surface water associated with the marshy area at the mouth of Bat Cave Wash could account for elevated pore water values at PW-8A (see Section 7.2.1.2 and Figure 4-7). Subsurface hydrogeologic conditions on the Arizona side of the river may account for the elevated specific conductance detected in D-series pore water samples (PW-9D, 11D, 12D, 13D, 14D, 15D, and 16D). These elevated pore water samples are consistent with groundwater supply wells PGE-9N and PGE-9S on the Arizona side which have specific conductance ranges of 8,680 to 14,900 µS/cm and 11,700 to 17,600 µS/cm (Appendix H2).

pH. The average pH readings for all pore water samples range from 6.70 to 8.96 (all average pH data are within the water quality standards).

8.2.2.3 Other Geochemistry Results

Additional parameters were analyzed from samples collected at 10 pore water locations to assess whether geochemical conditions in shallow sediments below the Colorado River favored chromium reduction. Table 8-2 presents the results of the extended analytical suite. Higher chloride concentrations and alkalinity values from samples downstream of Bat Cave Wash (samples PW-8B through PW-15B) account for the higher specific conductance values. Pore water samples from locations PW-3B and PW-5B show higher sulfate concentrations than the others, reflecting the less reducing conditions of the upstream locations. In the more strongly-reducing conditions downstream, it is likely that some of the sulfate has become reduced to sulfide, which is mostly precipitated out of solution. The acid volatile sulfide reporting limit was too high to detect sulfate in the sediment samples. Other geochemical indicators for reducing conditions are the presence of reduced aquatic species, including iron, manganese, and ammonia. Conditions that favor the existence of these species also favor the reduction of Cr(VI). As shown on Table 8-2, all three of these species were found in nearly all 10 of the pore water samples that were analyzed for the extended suite parameters. Dissolved organic carbon, which could potentially be metabolized by microorganisms that catalyze reduction reactions, was detected in all 10 of the pore water samples.

8.2.2.4 Geochemistry of Site Pore Water

ORP was measured as a field parameter during the 2006 pore water study. All ORP values at the pore water locations were negative, ranging from -46 to -231 mV and with an overall average of -162 mV. These results, combined with the lack of detections for Cr(VI) and other pore water geochemical parameters (Table 8-2) demonstrate geochemical conditions that readily reduce Cr(VI) to Cr(III). Historical data from site monitoring wells show that ORP values below (i.e., more negative than) -90 mV are indicative of geochemical conditions in which Cr(VI) is not present. These reducing conditions probably exist in large part due to the presence of microbial communities, which are supported by the organic carbon in the sediments and create the reducing conditions (see Section 9.2.2). The fact that significant dissolved organic carbon was found in all river pore water samples demonstrates that there are sufficient nutrients present to support microbes. Stronger reducing conditions appear to be more prevalent downstream of the intersection with Park Moabi Slough (Transect PW-7 onward). Organic material is likely more abundant here than in the upstream areas (Transect PW-3 and PW-5) due to inputs from the slough and the marshy area at the mouth of Bat Cave Wash.

The combination of (a) lack of detections of chromium in any of the pore water and associated surface water samples, (b) the consistency of reducing condition indicators in pore water samples along with slant well groundwater samples below the river bottom, and (c) anaerobic core sample laboratory testing, provide compelling evidence for the presence of a naturally-occurring geochemical zone that would reduce or eliminate Cr(VI) in groundwater migrating towards the river, assuming no IM-3 extraction were occurring. Note that uncertainties remain regarding the extent to which reducing conditions in fluvial deposits provide a pervasive and permanent barrier to Cr(VI) contaminant migration to the river. Based on the results of the anaerobic core study and supported by published literature, reducing material found in core samples collected near and beneath the river rapidly reduce Cr(VI) to Cr(III), which is removed from solution by mineral precipitation and adsorption reactions. The reducing capacity and aquifer matrix concentration of the reducing material is variable, so quantification of the amount of Cr(VI) that may be reduced is currently an estimate, based on laboratory testing of a limited number of core samples from localized boreholes.

TABLE 8-1

Pore Water Sampling Results - Chromium, Other Metals, Specific Conductance, ORP, and pH, February 2003 and January 2006

RCRA Facility Investigation/Remedial Investigation (Volume 2)

PG&E Topock Compressor Station, Needles, California

Station ID	Sample Date	Hexavalent Chromium (µg/L)	Dissolved Total Chromium (µg/L)	Specific Conductance (µS/cm)	pH pH Units	ORP[†] mV	Dissolved Copper (µg/L)	Dissolved Nickel (µg/L)	Dissolved Zinc (µg/L)
Other Pore Water Locations									
W-1	02/01/2003	ND (10) J	ND (10) *	---	---	---	ND (20) *	ND (20) *	ND (10) *
W-2	02/01/2003	ND (10) J	1.13 J*	---	---	---	1.14 J*	ND (20) *	6.41 J*
W-4	02/01/2003	ND (10) J	ND (10) *	---	---	---	ND (20) *	ND (20) *	ND (10) *
W-27	02/01/2003	ND (10) J	1.23 *	---	---	---	ND (20) *	ND (20) *	5.26 J*
W-28	02/01/2003	ND (10) J	ND (10) *	---	---	---	ND (20) *	ND (20) *	ND (10) *
W-29	02/01/2003	ND (10) J	1.01 *	---	---	---	ND (20) *	ND (20) *	ND (6.1) *
W-29 FD	02/01/2003	ND (10) J	ND (10) *	---	---	---	ND (20) *	ND (20) *	10.0 J*
Pore Water Study Locations									
PW-1A	01/04/2006	ND (0.2)	ND (1.0)	976	8.00	-193	---	---	---
PW-1B	01/04/2006	ND (0.2)	ND (1.0)	991	7.87	-169	---	---	---
PW-1C	01/04/2006	ND (0.2)	ND (1.0)	997	7.75	-184	---	---	---
PW-1D	01/04/2006	ND (0.2)	ND (1.0)	1000	7.61	-165	---	---	---
PW-2A	01/04/2006	ND (0.2)	ND (1.0)	1000	7.62	-142	---	---	---
PW-2B	01/04/2006	ND (0.2)	ND (1.0)	988	7.78	-188	---	---	---
PW-2C	01/05/2006	ND (0.2)	ND (1.0)	726	7.15	-158	---	---	---
PW-2D	01/05/2006	ND (0.2)	ND (1.0)	983	7.64	-166	---	---	---
PW-3A	01/05/2006	ND (0.2)	ND (1.0)	1010	7.47	-46	---	---	---
PW-3B	01/05/2006	ND (0.2)	ND (1.0)	981	7.65	-168	---	---	---
PW-3B FD	01/05/2006	ND (0.2)	ND (1.0)	982	7.67	FD	---	---	---
PW-3C	01/05/2006	ND (0.2)	ND (1.0)	1000	7.64	-178	---	---	---
PW-3D	01/05/2006	ND (0.2)	ND (1.0)	980	7.81	-202	---	---	---
PW-4A	01/05/2006	ND (0.2)	ND (1.0)	1000	7.49	-89	---	---	---
PW-4B	01/05/2006	ND (0.2)	ND (1.0)	975	7.56	-172	---	---	---
PW-4C	01/05/2006	ND (0.2)	ND (1.0)	947	7.50	-173	---	---	---
PW-4D	01/05/2006	ND (0.2)	ND (1.0)	982	7.56	-170	---	---	---
PW-5A	01/06/2006	ND (0.2)	ND (1.0)	974	7.42	-176	---	---	---
PW-5B	01/06/2006	ND (0.2)	ND (1.0)	987	7.88	-231	---	---	---
PW-5C	01/06/2006	ND (0.2)	ND (1.0)	843	7.83	-215	---	---	---
PW-5D	01/06/2006	ND (0.2)	ND (1.0)	947	7.36	-188	---	---	---
PW-5D FD	01/06/2006	ND (0.2)	ND (1.0)	942	7.29	FD	---	---	---
PW-6A	01/06/2006	ND (0.2)	ND (1.0)	2020	7.57	-201	---	---	---
PW-6B	01/06/2006	ND (0.2)	ND (1.0)	1170	7.14	-170	---	---	---
PW-6C	01/06/2006	ND (0.2)	ND (1.0)	1070	7.49	-182	---	---	---
PW-6D	01/06/2006	ND (0.2)	ND (1.0)	957	7.57	-175	---	---	---
PW-7A	01/06/2006	ND (0.2)	ND (1.0)	1740	7.44	-167	---	---	---
PW-7B	01/06/2006	ND (0.2)	ND (1.0)	1080	7.52	-173	---	---	---
PW-7C	01/06/2006	ND (0.2)	ND (1.0)	918	7.37	-163	---	---	---
PW-7D	01/06/2006	ND (0.2)	ND (1.0)	863	7.59	-179	---	---	---
PW-8A	01/07/2006	ND (0.2)	ND (1.0)	5310	7.32	-153	---	---	---
PW-8A FD	01/07/2006	ND (0.2)	ND (1.0)	5320	7.37	FD	---	---	---
PW-8B	01/07/2006	ND (0.2)	ND (1.0)	1870	7.11	-190	---	---	---
PW-8C	01/07/2006	ND (0.2)	ND (1.0)	1310	7.10	-159	---	---	---

TABLE 8-1

Pore Water Sampling Results - Chromium, Other Metals, Specific Conductance, ORP, and pH, February 2003 and January 2006

RCRA Facility Investigation/Remedial Investigation (Volume 2)

PG&E Topock Compressor Station, Needles, California

Station ID	Sample Date	Hexavalent Chromium (µg/L)	Dissolved Total Chromium (µg/L)	Specific Conductance (µS/cm)	pH pH Units	ORP[†] mV	Dissolved Copper (µg/L)	Dissolved Nickel (µg/L)	Dissolved Zinc (µg/L)
Pore Water Study Locations									
PW-8D	01/07/2006	ND (0.2)	ND (1.0)	1180	7.46	-173	---	---	---
PW-9A	01/04/2006	ND (0.2) J	ND (1.0)	2070	8.96	-88	---	---	---
PW-9B	01/04/2006	ND (0.2)	ND (1.0)	1010	7.48	-178	---	---	---
PW-9C	01/04/2006	ND (0.2) J	ND (1.0)	2360	6.70	-121	---	---	---
PW-9D	01/04/2006	ND (0.2)	ND (1.0)	7610	7.97	-215	---	---	---
PW-10A	01/05/2006	ND (0.2)	ND (1.0)	1020	7.48	-176	---	---	---
PW-10A FD	01/05/2006	ND (0.2)	ND (1.0)	1030	7.50	FD	---	---	---
PW-10B	01/05/2006	ND (0.2)	ND (1.0)	999	7.66	-161	---	---	---
PW-10C	01/04/2006	ND (0.2)	ND (1.0)	2400	7.35	-159	---	---	---
PW-10D	01/04/2006	ND (0.2)	ND (1.0)	1580	7.47	-152	---	---	---
PW-11A	01/06/2006	ND (0.2)	ND (1.0)	1810	6.88	-114	---	---	---
PW-11B	01/05/2006	ND (0.2)	ND (1.0)	1170	7.13	-89	---	---	---
PW-11C	01/05/2006	ND (0.2)	ND (1.0)	1020	7.67	-173	---	---	---
PW-11D	01/05/2006	ND (0.2)	ND (1.0)	3960	7.14	-130	---	---	---
PW-12A	01/06/2006	ND (0.2)	ND (1.0)	1380	7.15	-167	---	---	---
PW-12B	01/06/2006	ND (0.2)	ND (1.0)	1060	7.32	-140	---	---	---
PW-12C	01/06/2006	ND (0.2)	ND (1.0)	1160	7.43	-158	---	---	---
PW-12C FD	01/06/2006	ND (0.2)	ND (1.0)	1160	7.42	FD	---	---	---
PW-12D	01/06/2006	ND (0.2)	ND (1.0)	2560	7.13	-157	---	---	---
PW-13A	01/06/2006	ND (0.2)	ND (1.0)	1450	7.53	-164	---	---	---
PW-13B	01/06/2006	ND (0.2)	ND (1.0)	1680	7.53	-170	---	---	---
PW-13C	01/06/2006	ND (0.2)	ND (1.0)	1680	6.95	-134	---	---	---
PW-13D	01/06/2006	ND (0.2)	ND (1.0)	2840	7.27	-160	---	---	---
PW-14A	01/07/2006	ND (0.2)	ND (1.0)	1120	7.81	-170	---	---	---
PW-14B	01/07/2006	ND (0.2)	ND (1.0)	1010	7.56	-161	---	---	---
PW-14C	01/07/2006	ND (0.2)	ND (1.0)	1540	6.99	-152	---	---	---
PW-14C FD	01/07/2006	ND (0.2)	ND (1.0)	1550	7.00	FD	---	---	---
PW-14D	01/07/2006	ND (0.2)	ND (1.0)	5050	7.45	-151	---	---	---
PW-15A	01/07/2006	ND (0.2)	ND (1.0)	1380	7.11	-112	---	---	---
PW-15B	01/07/2006	ND (0.2)	ND (1.0)	1080	7.60	-164	---	---	---
PW-15C	01/07/2006	ND (0.2)	ND (1.0)	1620	7.29	-168	---	---	---
PW-15D	01/07/2006	ND (0.2)	ND (1.0)	4860	7.16	-161	---	---	---
PW-16A	01/07/2006	ND (0.2)	ND (1.0)	1100	7.44	-180	---	---	---
PW-16B	01/07/2006	ND (0.2)	ND (1.0)	991	7.58	-172	---	---	---
PW-16C	01/07/2006	ND (0.2)	ND (1.0)	1550	7.10	-175	---	---	---
PW-16D	01/07/2006	ND (0.2)	ND (1.0)	2510	7.22	-151	---	---	---

TABLE 8-1

Pore Water Sampling Results - Chromium, Other Metals, Specific Conductance, ORP, and pH, February 2003 and January 2006

RCRA Facility Investigation/Remedial Investigation (Volume 2)
PG&E Topock Compressor Station, Needles, California

Notes:

FD	field duplicate
ND	not detected at the listed reporting limit
µS/cm	microsiemens per centimeter
µg/L	micrograms per liter
ORP	oxidation reduction potential
---	not analyzed
J	concentration or reporting limit estimated by laboratory or data validation

*Total metal concentrations from samples were not filtered

† Not analyzed in a laboratory. Results are from field instrumentation

Refer to Appendix H for complete analytical data for pore water sampling.

Sample W-3 previously reported was a rinse blank with detected metal concentrations of 1.1 J µg/L for Cr(T) and 13 µg/L for zinc.

TABLE 8-2

Pore Water Extended Suite Analytical Results, January 2006

RCRA Facility Investigation/Remedial Investigation (Volume 2)

PG&E Topock Compressor Station, Needles, California

Location ID	**Sample Date**	**Dissolved Organic Carbon (mg/L)**	**Nitrate (mg/L)**	**Dissolved Ammonia-Nitrogen (mg/L)**	**Total Phosphorus (mg/L)**	**Sulfide (mg/L)**	**Sulfate (mg/L)**	**Dissolved Iron (mg/L)**	**Dissolved Manganese (mg/L)**	**Field Dissolved Oxygen (mg/L)**	**Calcium (mg/L)**	**Magnesium (mg/L)**	**Potassium (mg/L)**	**Sodium (mg/L)**	**Chloride (mg/L)**	**Fluoride (mg/L)**	**Alkalinity, Bicarbonate as CaCO3 (mg/L)**
PW-3B	1/5/2006	2.60	ND (0.5)	1.40	ND (0.1)	ND (2.0)	230	0.727	1.18	4.22	90.6	25.8	5.23	62.6	80.5	ND (0.5)	142
PW-3B FD	1/5/2006	2.35	ND (0.5)	1.30	0.109	ND (2.0)	228	0.775	1.21	FD	89.0	25.7	5.37	65.8	84.5	ND (0.5)	130
PW-5B	1/6/2006	2.29	ND (0.5)	2.60	0.181	ND (2.0)	216	0.549	ND (0.5)	2.37	92.8	31.7	7.05	62.7	79.7	ND (0.5)	180
PW-7B	1/6/2006	5.15	ND (0.5)	3.58	0.192	ND (2.0)	ND (0.5)	3.10	1.03	3.10	101	39.4	8.22	61.4	68.7	ND (0.5)	479
PW-8B	1/7/2006	5.88	ND (0.5)	16.5	1.21	ND (2.0)	ND (0.5)	16.8	1.38	2.48	141	48.0	14.6	167	262	0.511	564
PW-9B	1/4/2006	3.29	ND (0.5)	3.35	0.12	ND (2.0)	2.24	4.04	1.11	3.13	101	35.9	7.44	72.5	81.3	ND (0.5)	508
PW-11B	1/5/2006	4.41	ND (0.5)	3.79	0.256	ND (2.0)	7.14	1.56	ND (0.5)	5.50	122	37.0	6.53	77.3	96.6	0.544	486
PW-12B	1/6/2006	5.43	ND (0.5)	4.88	ND (0.1)	ND (2.0)	31.0	3.25	2.44	3.71	94.4	34.9	11.3	65.3	82.2	0.613	422
PW-13B	1/6/2006	3.45	ND (0.5)	4.27	ND (0.1)	ND (2.0)	1.51	2.18	0.626	3.82	81.2	26.5	6.70	75.9	292	ND (0.5)	583
PW-14B	1/7/2006	3.67	ND (0.5)	6.22	0.168	ND (2.0)	19.6	2.18	0.56	3.25	99.5	29.8	7.96	68.8	87.9	ND (0.5)	391
PW-15B	1/7/2006	3.87	ND (0.5)	5.45	0.296	ND (2.0)	1.64	1.74	ND (0.5)	3.62	111	35.0	8.46	69.3	78.0	ND (0.5)	496

Notes:

PW	pore water
mg/L	milligrams per liter
FD	field duplicate, field measurements are not taken on field duplicate samples
ND	not detected at the listed reporting limit

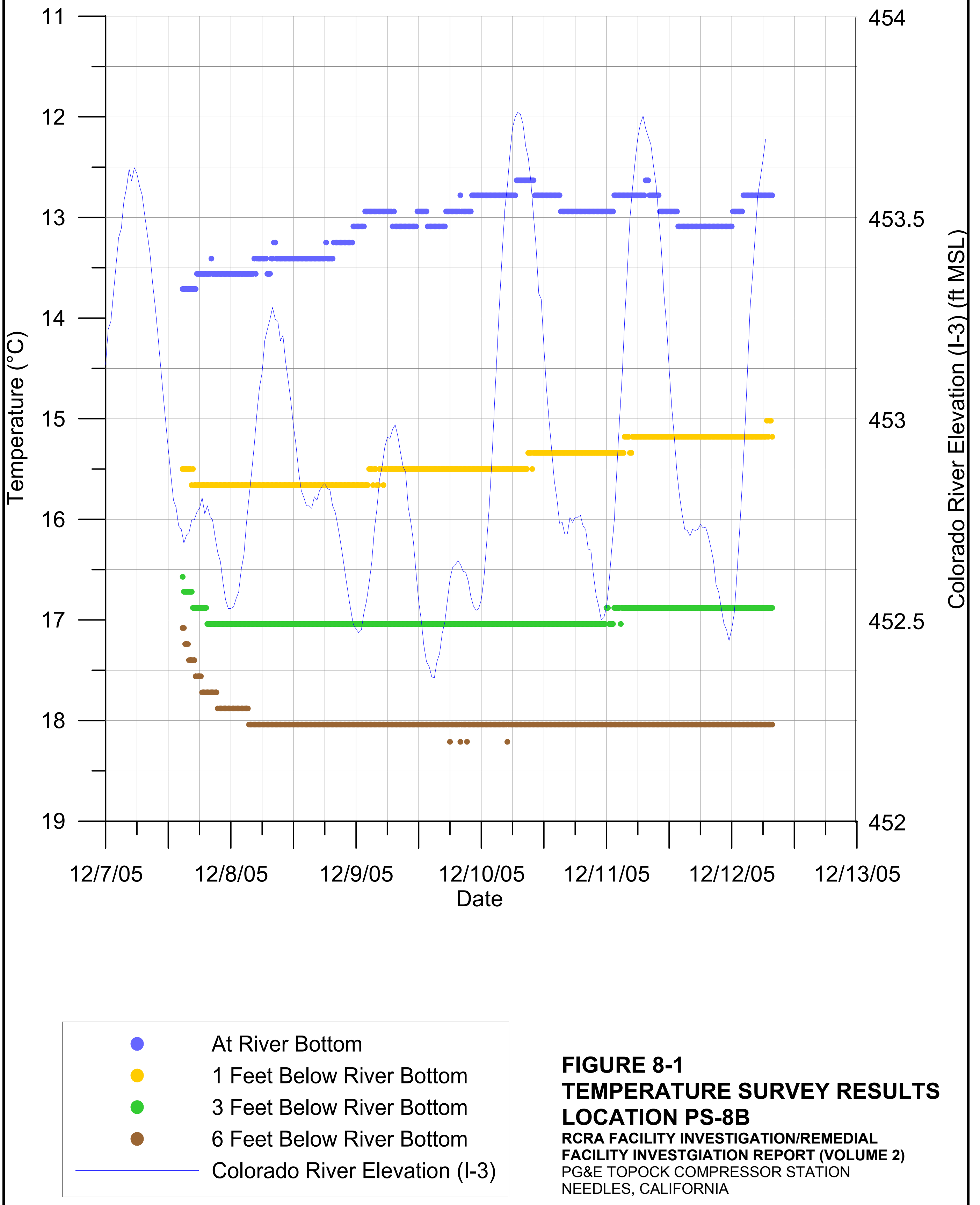

FIGURE 8-1
TEMPERATURE SURVEY RESULTS
LOCATION PS-8B
RCRA FACILITY INVESTIGATION/REMEDIAL
FACILITY INVESTGIATION REPORT (VOLUME 2)
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

CH2MHILL

9.0 River Sediment Characterization

This section presents the results and findings of the river sediment investigations and characterization completed for this RFI/RI.

9.1 Comparative Criteria for River Sediment

There are no chemical-specific ARARs for sediment (Appendix G). Table 9-1 summarizes comparison values for constituents in river sediment, which are used in this section to provide some comparative context to the concentrations of constituents in river sediment. The comparison values for this media are consensus based sediment quality guidelines (SQGs) for freshwater ecosystems (MacDonald et al., 2000). Below these threshold effects concentrations, harmful effects to aquatic organisms are unlikely to be observed.

9.2 River Sediment Characterization Data

Sampling and analyses for river sediment characterization has occurred on two occasions during the RFI/RI: during Phase 4 and Phase 6 (under the pore water study).

9.2.1 RFI Phase 4 (2003)

During Phase 4 of the RFI, 17 river sediment samples were collected upstream, downstream, and at the mouth of Bat Cave Wash on the banks of the Colorado River. These samples were collected from sediments that are saturated for most, if not all, of the time and could potentially support aquatic communities (e.g., aquatic invertebrates). Sediment samples were collected from saturated sediment from the Colorado River and sands dredged from the river. These Colorado River sediment samples were collected by wading into the river and using a sediment coring device or hand auger. The dredged sand samples were collected while drilling wells or by using a shovel. The analytical results of the 2003 sediment samples are summarized in Table 9-2, and the locations are depicted in Figure 4-8.

9.2.1.1 Upstream Sediment Samples

The eight upstream sediment samples consist of SED-1 through SED-5 and DrSED-1 through DrSED-3. The DrSED-series samples represent samples of dredged sediments that historically have been placed by others along portions of the river bank (Figure 4-8). Upstream samples SED-1 through SED-5 were collected from 2 feet below the river bed and were analyzed for Cr(T), Cr(VI), copper, nickel, zinc, and pH. The samples from the dredged sediments were collected from 1 foot bgs and were analyzed for the same parameters plus additional metals, including lead.

In the upstream sediment samples, detected concentrations of Cr(T) ranged from 1.75 to 5.48 milligrams per kilogram (mg/kg) (Table 9-2). None of the detected concentrations of Cr(T) was above the sediment quality guideline of 43.4 mg/kg for Cr(III). Since Cr(III) is one of the forms of Cr(T), if concentrations of Cr(T) do not exceed the guidelines, then Cr(III) concentrations would not exceed the guidelines. Cr(VI) was not detected in any of the eight upstream sediment samples. None of the analyzed metal samples from the upstream sediment samples was detected above SQG (Table 9-1).

9.2.1.2 Sediment Samples from Mouth of Bat Cave Wash

This report considers river sediment samples to be samples collected from the main channel and at the mouth of Bat Cave Wash on the river side Red Rock Bridge. Sediment samples collected from the landward side of Red Rock Bridge and further upgradient in Bat Cave Wash will be discussed in the RFI/RI Volume 3 Report. The six sediment samples collected at the mouth of Bat Cave Wash consist of SED-6 through SED-11, which were collected from 2 feet below the river bed. SED-6, SED-7, and SED-11 were analyzed for Cr(VI), Cr(T), copper, nickel, zinc, and pH. SED-8, SED-9, and SED-10 were analyzed for the same parameters plus additional metals, including lead.

In the sediment samples from the mouth of Bat Cave Wash, detected concentrations of Cr(T) ranged from 5.1 to 22.1 mg/kg. None of the detected concentrations of Cr(T) was above the sediment quality guidelines. Cr(VI) was not detected in any of the sediment samples from the mouth of Bat Cave Wash. None of the analyzed metal samples from the six sediment samples was detected above SQG (Table 9-1). There is subsequent planned sampling after the RFI/RI Volume 2 cutoff date of the stratification of the sediments at the mouth of Bat Cave Wash to determine if there are contaminants at depths deeper than initially sampled. These results will be presented in the RFI/RI Volume 3 Report.

9.2.1.3 Downstream Sediment Samples

The three downstream sediment samples consist of SED-27 through SED-29, which were collected from 2 feet below the river bed and were analyzed for Cr(VI), Cr(T), copper, nickel, zinc, lead, and pH plus additional metals.

In the downstream sediment samples, detected concentrations of Cr(T) ranged from 4.48 to 6.87 mg/kg. None of the detected concentrations of Cr(T) was above the sediment quality guideline of 43.4 mg/kg for Cr(III). Cr(VI) was not detected in any of the downstream sediment samples. None of the analyzed metal samples from the three downstream sediment samples was detected above SQG (Table 9-1).

9.2.2 Pore Water Study (2005 to 2006)

The objective of river bottom sediment sampling during the pore water study was to assess the geochemical conditions in shallow sediments below the Colorado River (CH2M HILL, 2006p). The intent was primarily to determine whether aerobic or anaerobic conditions are present in the shallow river sediments.

Sediment cores were collected from locations at 10 of the 16 pore water sampling transects (see Section 8.2). Table 9-3 presents the sediment analytical results from the pore water study. Figure 4-8 presents the locations of the river sediment sampling locations. The samples were analyzed for a variety of geochemical indicators that distinguish aerobic zones from anaerobic zones. A multiple lines-of-evidence approach, using results of sediment sampling in conjunction with the results from the pore water sampling, was used to evaluate the encountered sediment conditions. Sediment cores were collected using the

GeoProbe® Macro-Core® drive-point system. Two-foot-long sediment cores were collected from approximately 6 inches to 30 inches below the river bottom.

The sediment samples were analyzed for geochemical parameters and particle-size distribution to assess the geochemical and physical conditions of the Colorado River sediments in the pore water study area. There were no detections of total organic carbon or acid volatile sulfide at concentrations above the reporting limit in any of the sediment samples (Table 9-3). Detections above these limits would indicate a very strongly-reducing environment (more typical of marsh areas)—stronger than that required for Cr(VI) reduction. Grain-size analyses indicate samples were consistently dominated by sand-sized material, with occasionally significant amounts of gravel. This grain-size distribution indicates the effects of upstream dams, which retain most of the fine materials, and the swift current of the Colorado River, which carries the fines that are present away from this area.

Sediments sampled in the shallow zone (two feet bgs) in the section of the river included in the pore water study were below reporting limits for geochemical indicators of strongly reducing conditions. Five of six sediment samples analyzed for TOC from 2003 did show the presence of organic carbon at elevated concentrations. Due to the limited amount of sediment data, definitive conclusions pertaining to shallow sediment redox conditions cannot be made. The presence of total organic carbon in river sediment is suggestive of a mildly reducing environment.

TABLE 9-1
Ecological Comparison Values for River Sediment
RCRA Facility Investigation/Remedial Investigation (Volume 2)
PG&E Topock Compressor Station, Needles, California

Analyte [(a)]	**Sediment Quality Guidelines** [(b)] **mg/kg**
Antimony	NA
Arsenic	9.79
Barium	NA
Beryllium	NA
Cadmium	0.99
Hexavalent chromium	NA
Trivalent chromium	43.4
Total chromium	NA
Cobalt	NA
Copper	31.6
Iron	NA
Lead	35.8
Manganese	NA
Mercury	0.18
Molybdenum	NA
Nickel	22.7
Selenium	NA
Silver	NA
Thallium	NA
Vanadium	NA
Zinc	121
Fluoride	NA
Phosphate	NA
pH	NA
Total Organic Carbon	NA

NA - Not Available   mg/kg – milligrams per kilograms

Notes:
(a) Analytes sampled in river sediment from the Topock site.
(b) Consensus-Based Sediment Quality Guidelines for Freshwater Ecosystem (MacDonald et al., 2000).

TABLE 9-2
River Sediment Sample Results, February 2003
RCRA Facility Investigation/Remedial Investigation (Volume 2)
PG&E Topock Compressor Station, Needles, California

			General Chemistry (mg/kg unless otherwise noted)				**Metals (mg/kg)**																		
Location	**Date**	**Depth (ft bgs)**	**pH (pH units)**	**Fluoride**	**Phosphate**	**Total Organic Carbon**	**Antimony**	**Arsenic**	**Barium**	**Beryllium**	**Cadmium**	**Cr(VI)**	**Cr(T)**	**Cobalt**	**Copper**	**Iron**	**Lead**	**Manganese**	**Mercury**	**Molybdenum**	**Nickel**	**Selenium**	**Silver**	**Thallium**	**Vanadium**	**Zinc**
Sediment Quality Guidelines:			NA	NA	NA	NA	NA	9.79	NA	NA	0.99	NA	NA	NA	31.6	NA	35.8	NA	0.18	NA	22.7	NA	NA	NA	NA	121
SED-1	02/18/2003	2	8.8	---	---	---	---	---	---	---	---	ND (5.5)	3.33	---	2.5	---	---	---	---	---	3.21	---	---	---	---	11.8
SED-2	02/18/2003	2	8.8	---	---	---	---	---	---	---	---	ND (5)	4.61	---	3.39	---	---	---	---	---	3.79	---	---	---	---	13.4
SED-3	02/18/2003	2	8.7	---	---	---	---	---	---	---	---	ND (5)	3.64	---	3.12	---	---	---	---	---	5.5	---	---	---	---	11.3
SED-4	02/18/2003	2	8.7	---	---	---	---	---	---	---	---	ND (5.8)	5.48	---	4.46	---	---	---	---	---	3.99	---	---	---	---	15.6
SED-5	02/17/2003	2	8.5	---	---	---	---	---	---	---	---	ND (5)	2.41	---	1.95	---	---	---	---	---	3.4	---	---	---	---	7.32
SED-6	02/17/2003	2	7.4	---	---	---	---	---	---	---	---	ND (4.9)	5.1	---	2.13	---	---	---	---	---	6.42	---	---	---	---	9.83
SED-7	02/17/2003	2	7.5	---	---	---	---	---	---	---	---	ND (6)	22.1	---	11.7	---	---	---	---	---	12.1	---	---	---	---	37.3
SED-8	02/17/2003	2	8	1.48	ND (2.48)	9650 J	ND (2.38)	1.54	64.3	0.215 J	ND (0.595)	ND (4.8)	8.27	2.53	5.71	6660	6.22	127	ND (0.0394)	ND (1.19)	7.15	0.702 J	0.28 J	ND (1.19)	12.1	20.3
SED-9	02/17/2003	2	8.5	0.582 J	ND (2.44)	1380 J	ND (4.2)	ND (1.05)	135	0.614	0.0822 J	ND (4.9)	19.1	7.44	25.6	19600	6.33	224	ND (0.0311)	0.451 J	12.7	0.675 J	ND (1.05)	0.573 J	39	39.1
SED-10	02/17/2003	2	8.1	1.63	ND (2.79)	10100 J	ND (2.79)	2.72	100	0.219 J	0.0789 J	ND (5.7)	6.79	2.07	5.17	5610	5.15	122	ND (0.0445)	ND (1.4)	4.59	0.891 J	0.343 J	ND (1.4)	10.9	18
SED-11	02/17/2003	2	7.9	---	---	---	---	---	---	---	---	ND (5.6)	15.7	---	7.88	---	---	---	---	---	6.87	---	---	---	---	26
SED-27	02/19/2003	2	8.6	2.68	ND (3.03)	17700 J	ND (2.86)	3.68	151	0.338 J	0.198 J	ND (6)	6.87	2.7	6.84	7270	9.5	202 J	0.0573	0.821 J	5.56	ND (1.43)	0.373 J	ND (1.43)	14.8	28.5
SED-28	02/19/2003	2	8.4	0.918 J	ND (2.8)	4770 J	ND (2.19)	1.58	69.3	0.156 J	0.0772 J	ND (5.4)	4.62	1.47	2.8	3510	3.7	92.1 J	ND (0.0348)	ND (1.09)	3.04	0.668 J	0.341 J	ND (1.09)	7.64	10.3
SED-29	02/19/2003	2	8.7	0.54 J	ND (2.66)	ND (2640)J	ND (2.11)	1.54	170	0.17 J	0.0666 J	ND (5.3)	4.48	1.65	2.93	4630	4.15	113 J	ND (0.0339)	ND (1.06)	3.12	ND (1.06)	ND (1.06)	ND (1.06)	11	12
DrSed-1	02/18/2003	1	9.3	---	---	---	ND (1.56)	1.57	92.6	0.105 J	ND (0.39)	ND (4.2)	2.27	1.14	1.26	---	4.12	---	ND (0.0333)	ND (0.78)	1.94	ND (0.78)	0.176 J	ND (0.78)	6.33	9.27
DrSed-2	02/18/2003	1	8.8	---	---	---	ND (1.58)	1.27	65.9	0.0963 J	ND (0.394)	ND (4.2)	1.78	1.07	1.07	---	3.44	---	ND (0.0327)	ND (0.788)	1.88	ND (0.788)	0.219 J	ND (0.788)	4.46	7.14
DrSed-3	02/19/2003	1	9	---	---	---	ND (1.81)	1.67	45.8	0.101 J	ND (0.453)	ND (4.2)	1.75	1.02	1.38	---	3.69	---	ND (0.0351)	ND (0.906)	1.7	ND (0.906)	0.203 J	ND (0.906)	4.65	6.74

Notes:

ft bgs	feet below ground surface
mg/kg	milligrams per kilogram
---	not analyzed
ND	not detected at the reporting limit listed
J	estimated value
NA	not applicable

Sediment Quality Guidelines - see Table 9-1.
Results greater than or equal to the Sediment Quality Guidelines in bold.
Cr(VI) - Hexavalent Chromium
Cr(T) - Total Chromium

TABLE 9-3

River Sediment Sampling Results, December 2005

RCRA Facility Investigation/Remedial Investigation (Volume 2)

PG&E Topock Compressor Station, Needles, California

Location ID	Sample Date	Sample Depth Below River Bottom (feet)	Total Organic Carbon (mg/kg)	Acid Volatile Sulfides (mg/kg)	Gravel (%)	Sand (%)	Silt (%)	Clay (%)
PS-3B	12/08/2005	0.5 - 2.5	ND (250)	ND (24)	40.7	59.0	0.6	0.1
PS-5B	12/08/2005	0.5 - 2.5	ND (250)	ND (24)	5.1	94.3	1.0	0.2
PS-7B	12/08/2005	0.5 - 2.0	ND (250)	ND (24)	10.8	88.8	0.9	0.2
PS-8B	12/08/2005	0.5 - 2.5	ND (250)	ND (24)	7.3	92.2	0.0	0.0
PS-9B	12/09/2005	0.5 - 2.5	ND (250)	ND (24)	12.6	87.0	1.6	0.2
PS-11B	12/09/2005	0.5 - 2.5	ND (250)	ND (24)	0.8	98.8	0.0	1.2
PS-12B	12/09/2005	0.5 - 2.5	ND (250)	ND (24)	4.0	95.7	0.8	1.2
PS-13B	12/09/2005	0.5 - 2.5	ND (250)	ND (24)	0.6	99.0	0.8	1.2
PS-14B	12/09/2005	0.5 - 2.5	ND (250)	ND (24)	0.5	99.1	0.8	1.2
PS-15B	12/09/2005	0.5 - 2.5	ND (250)	ND (24)	0.3	99.1	0.8	1.2

Notes:

mg/kg = milligrams per kilogram
ND = not detected at the listed method detection limit

Total organic carbon method: Walkley-Black 1947
Acid volatile sulfides method: E821/R-91-100
Particle size distribution method: D421-85

10.0 Conclusions and Recommendations

This RFI/RI report presents the results of hydrogeologic characterization and groundwater and surface water investigations and data collection conducted at the PG&E Topock site from 1997 through October 2007. Appendix H1 discusses the PG&E Topock analytical program, designed to ensure that field investigation data are of the appropriate quality to support decision-making in the RFI/RI. The characterization data presented address the nature, occurrence, and extent of the groundwater COPCs associated with the historical discharges to Bat Cave Wash (SWMU 1/AOC 1) and the inactive injection well PGE-8 (SWMU 2). This section provides the overall conclusions and recommendations of this RFI/RI report based upon the data and evaluations presented in the preceding sections.

10.1 Conclusions

The overall conclusions of the hydrogeologic characterization and groundwater and surface water investigations at the PG&E Topock site are summarized below.

10.1.1 Completeness of the RFI/RI

This report, combined with the forthcoming risk assessment satisfies all of the requirements to complete the RFI/RI for the media and SWMUs/AOCs addressed, namely, the former percolation bed in Bat Cave Wash (SWMU 1/AOC 1) and the inactive injection well PGE-8 (SWMU 2). With the exception of the identification of human and/or ecological receptors and the evaluation of the potential impacts to them, to be addressed in the forthcoming risk assessment, all of the elements and requirements discussed in Section 1.3 are included in this RFI/RI Report. In addition, all of the comments from DTSC and DOI on the February 2005 RFI/RI Report and the July 2008 RFI/RI Volume 2 Report, as summarized in Appendix A, have been addressed. Therefore, with completion of this document and the forthcoming risk assessment, the RFI/RI is considered complete, with the exception of the characterization of the eastern extent of the groundwater plume, as discussed in Section 6.3.3.

Additional characterization of potential additional sources of impacts to groundwater at the Topock Compressor Station and adjoining East Ravine area are ongoing. The results of the additional investigations will be reported in the RFI/RI Volume 2 Addendum, RFI/RI Volume 3 or data summary reports, as appropriate, given the nature of the data and the effect on RFI/RI conclusions. Table 4-6 summarizes the status and anticipated reporting of the groundwater RFI/RI characterization data collected subsequent to the cut-off date for the Volume 2 RFI/RI Report.

10.1.2 Affected Media

The media addressed in this report are groundwater, surface water, pore water, and sediment. The following summarize the key findings of this report pertaining to the affected media.

10.1.2.1 Groundwater Characterization

As described in Section 2.0, site information and past disposal practices were the basis for identifying the groundwater COPCs for SWMU 1/AOC 1 (former percolation bed and area around former percolation bed) and SWMU 2 (inactive injection well PGE-8). The groundwater COPCs identified in the RFI/RI Report, Volume 1 for both units were Cr(T), Cr(VI), copper, lead, nickel, zinc, specific conductance (electrical conductivity), pH, and TPH. Other COPCs were also evaluated for each unit.

The findings and conclusions of the groundwater characterization of SWMU 1/AOC 1 and SWMU 2 are summarized below.

- In the Alluvial Aquifer at and downgradient of SWMU 1, Cr(T) and Cr(VI) occur at concentrations that exceed the calculated background UTL values for the Topock site, and Cr(T) exceeds the California and federal MCLs. For this RFI/RI, the Cr(VI) concentration value of 32 µg/L (the Cr[VI] UTL rounded to whole unit) is used for delineating the groundwater Cr(VI) plume at the site. The extent of Cr(VI) and Cr(T) are well-defined in the shallow and mid-depth zones of the Alluvial Aquifer, and no additional characterization is required. In the deep zone of the Alluvial Aquifer, the extent of these COPCs is well-defined to the west and north but is not fully defined in the east. Additional characterization data to complete the delineation of the Cr(VI) plume in the east will be presented in an addendum to this report.
- In the bedrock characterization, Cr(VI) was not detected in groundwater samples from the inactive injection well PGE-8 and from bedrock wells in the vicinity of PGE-8. The concentrations of Cr(T) in groundwater at PGE-8 and bedrock wells do not exceed the groundwater ARARs. The chromium results observed at bedrock well MW-23 warrant additional characterization to better define this area along the southeastern site boundary. The distribution of Cr(VI) in the vicinity of bedrock well MW-23 will be further characterized in the East Ravine groundwater investigation, to be submitted in a supplementing investigation report.
- Specific conductance of groundwater varies with sample depth and distance from the Colorado River. While specific conductance occurs at values above the groundwater ARARs, the elevated specific conductance is interpreted to be a natural property of the deep alluvial and bedrock groundwater and is also found in some shallow fluvial zones. Elevated specific conductance and TDS values within the plume appear to be biased high due to wells within the plume being screened closer to the bedrock surface. It is therefore recommended that specific conductance not be considered a COPC in groundwater related to SWMU 1/AOC 1.
- Like specific conductance, natural variation of pH in groundwater is not well-represented by the background study data because of the bias towards high-quality water zones. The vast majority of samples from plume and non-plume wells, have pH values within the Secondary MCL range of 6.5 to 8.5. The few slightly elevated pH values do not appear to be associated with the groundwater plume or any site activity; therefore, pH should not be considered as a COPC in groundwater related to SWMU 1/AOC 1.

- The concentrations of copper, lead, nickel, and zinc in some wells exceed the calculated the site background UTL concentrations and/or the groundwater ARARs. It is expected that at least 5% would exceed the UTL. The occurrence and distribution of these COPC exceedances do not coincide with the historical discharges to Bat Cave Wash or the inactive injection well PGE-8, or with other identifiable sources. The exceedances do not follow the flowline from Bat Cave Wash and their distribution is not related to that of the chromium plume. The conclusion is that these exceedances reflect local variability of naturally occurring groundwater in the basin. On the basis of these observations, none of the four metals are recommended for further consideration as COPCs in groundwater related to SWMU 1/AOC 1.

- TPH was not detected in groundwater samples at the site, and is therefore not recommended for consideration as a COPC in groundwater related to SWMU 1/AOC 1. The RFI/RI sampling for VOCs, SVOCs, and PCBs indicate no impacts to groundwater by organic compounds.

- Arsenic is present in groundwater with average concentrations above the site background UTL concentrations and is found in several locations at concentrations exceeding ARARs. With the possible exception of the well MW-10 area (as postulated by DTSC), arsenic exceedances are discontinuous and do not coincide with the historical discharges to Bat Cave Wash or the inactive injection well PGE-8, or with other site-related sources. The sampling data generally suggest either a non-PG&E source, natural elevated concentrations or localized, anomalous detections. Based on the discontinuous distribution or localized occurrence, and the lack of identifiable sources or association with facility operations, arsenic is not considered a COPC in groundwater related to SWMU 1/AOC 1.

- Molybdenum was found above UTL in numerous wells around the site, both within the plume area and outside the plume. There is no chemicals-specific ARAR associated with molybdenum. The use of molybdenum by the facility, coupled with its detection in facility wastewater analyses do not allow molybdenum to be ruled out as a COPC in groundwater associated with SWMU 1/AOC 1. Additional Title 22 metals data have been collected and will be reported to further evaluate this conclusion.

- Selenium concentrations do not form a pattern that suggests a plume. Only one sample (from well TW-1) has exceeded the chemical-specific ARAR for selenium, but this is the only sample from this well. It is understood that DTSC has concluded that selenium should be considered a COPC due to the anomalously high concentration located near SWMU 1/AOC 1. Although the distribution of selenium concentrations over space and time do not clearly suggest a facility source of contamination, there is no definitive evidence to refute DTSC's conclusion. Additional Title 22 metals data have been collected and will be reported in the RFI/RI Volume 2 Addendum Report to verify this conclusion.

- Vanadium and antimony concentrations have exceeded ARARs or background UTLs in a few samples. However, due to the inconsistent detections and the scattered distribution of wells with elevated samples, vanadium and antimony are not considered COPCs associated with SWMU 1/AOC 1.

- Only one well average exceeds the ARAR for beryllium, but solely due to one non-detect sample with a high reporting limit. On the basis of the infrequent UTL exceedances, and the locations far from the plume area, beryllium is not considered a COPC in groundwater related to SWMU 1/AOC 1. The locations of the wells where aluminum was detected and the inconsistent nature of the detections indicates that aluminum was not associated with SWMU 1 or SWMU 2. Therefore, aluminum is not considered a COPC in groundwater related to SWMU 1/AOC 1. The distribution of elevated manganese concentrations is consistent with distribution of reducing conditions in groundwater and does not appear to be associated with SWMU 1 or SWMU 2. Therefore, manganese is not considered a COPC in groundwater related to SWMU 1/AOC 1.
- Fluoride concentrations are elevated above ARAR in both site and Background Study wells. Site wells with average concentrations exceeding the UTL for fluoride are limited to three wells. Fluoride is a geochemically conservative element that would be expected to move as freely through the aquifer as Cr(VI). Due to the inconsistent, non-plume-like nature of the concentration distribution, fluoride is not considered a COPC.
- The geochemistry of mixing water types associated with fluvial and alluvial units, the stable isotope results, the occurrence of high specific conductance groundwater in wells sampled as part of the background study, and the lack of clear correlation between elevated Cr(VI) concentrations and high specific conductance values support the natural occurrence of the high specific conductance groundwater at the site. The historical discharge of high specific conductance wastewater at SWMU 1 should have contributed elevated dissolved solids during the early stages of facility operations, but it is not clear that the elevated specific conductance found in some monitoring wells today was caused by this discharge. The distribution of specific conductance in plume wells is biased high due to the screened intervals of these wells being more commonly closer to the bedrock surface than non-plume wells. An analysis of relationships between specific conductance and Cr(VI) over time in site alluvial wells will be conducted and later appended as part of the RFI/RI Volume 2 Addendum to further evaluate this conclusion.

10.1.2.2 Surface Water Characterization

Though no COPCs have been identified for surface water, for the purposes of characterization, the RFI/RI examined COPCs similar to those identified for SWMU 1/AOC 1. Surface water samples included shoreline and in-channel subsets. Over 700 surface water samples were collected from 43 locations in the Colorado River to determine the occurrence and extent of COPCs in surface water. Cr(T) and Cr(VI) did not occur at concentrations above the ARARs for those constituents found in either in-channel or shoreline surface water samples. The one exception is the Cr(VI) shoreline samples collected in June 2002 that data quality review indicates were false positives, which are discussed in Section 7.2.1.1. None of the other site COPCs had average concentrations that exceeded the respective ARARs. There was no discernable difference between results in samples collected upstream or downstream of Bat Cave Wash in the Colorado River.

The extent of COPCs is well-defined in surface water, and no additional characterization work is required. Based on data collected during the monitoring period of this RFI/RI, no site-related contamination of surface water was observed.

A limited ongoing surface water monitoring program through implementation of the groundwater remedial action at the site is suggested.

10.1.2.3 Pore Water Characterization

Though no COPCs have been identified for pore water, for the purposes of characterization, the RFI/RI examined COPCs similar to those identified for SWMU 1/AOC 1. Cr(T), Cr(VI), copper, nickel, and zinc did not occur at concentrations above surface water ARARs for those constituents found in pore water samples. The combination of (a) lack of detections of chromium in any of the pore water and associated surface water samples, (b) the consistency of reducing condition indicators in pore water samples along with slant well groundwater samples below the river bottom, and (c) anaerobic core sample laboratory testing results, provide compelling evidence for the presence of a naturally-occurring geochemical zone that would reduce or eliminate Cr(VI) in groundwater migrating toward the river, assuming no IM-3 extraction were occurring. Based on the results of the anaerobic core study and consistent with published literature, reducing materials found in core samples collected near and beneath the river rapidly reduce Cr(VI) to Cr(III), which is removed from solution by mineral precipitation and adsorption reactions. The reduction capacity and aquifer matrix concentration of the reducing material is variable, so quantification of the amount of Cr(VI) that may be reduced is currently an estimate, based on laboratory testing of a limited number of core samples from localized boreholes.

The extent of COPCs is defined in pore water, and no additional characterization work is required. Based on the data in this report, there is no contamination in pore water from the past operations at the Topock Compressor Station.

10.1.2.4 River Sediment Characterization

Cr(T) was not detected at or above concentrations of the sediment quality guidelines in river sediment samples collected near the site. Cr(VI) was not detected, and none of the analyzed metals were detected in downstream samples above sediment water quality guidelines. Further, sediments sampled in the section of the river included in the pore water study provided additional evidence for whether geochemical conditions in the shallow sediments below the Colorado River favor the reduction of Cr(VI). However, due to the limited amount of sediment data, definitive conclusions pertaining to shallow sediment redox conditions cannot be made. The presence of total organic carbon in river sediment is suggestive of a mildly reducing environment.

The extent of COPCs is defined in saturated river sediments due to groundwater/surface water interaction, and no additional characterization work is currently required. Based on the data in this report, there is no contamination in river sediment from groundwater/surface water interaction at the site. Soil and unsaturated sediment samples are being collected around the mouth of Bat Cave Wash as a part of the soil sampling program for SWMU 1/AOC 1. These results will be reported in the RFI/RI Volume 3 Report or separate investigation reports to verify this conclusion.

10.1.2.5 Affected Media Conclusion

The media addressed in this report are groundwater, surface water, pore water, and sediment. This report does not address soil media for SWMU 1/AOC 1 - that will be addressed in RFI/RI Volume 3. Based on the data and conclusions presented in this report, the only medium that appears to be affected currently by SWMU 1/AOC 1 is groundwater. The RFI/RI data show no effects from SWMU 1/AOC 1 operations on surface water, pore water, or river sediment in the vicinity of the site. The collected data are sufficient to make this conclusion. Consistent with the RFI/RI requirements, the typical RCRA/CERCLA process, and the specific agency requirements for this site, a risk assessment is being completed, as appropriate, to finalize the media to be carried forward to the CMS/FS.

10.1.3 Identification of COPCs in Affected Media

While RFI/RI Volume 1 identified the COPCs in groundwater based on site history, the RFI/RI Volume 2 further refines the list of COPCs in groundwater based on characterization data. The characterization data presented in this report include not only those COPCs identified in RFI/RI Volume 1 based upon site history but also numerous additional constituents to ensure completeness and to account for any uncertainties associated with the site history. Based on the characterization data presented and the discussion in this report, the COPCs in groundwater are Cr(T) and Cr(VI), molybdenum, and selenium. Other COPCs (copper, nickel, lead, zinc, pH, electrical conductivity, arsenic, vanadium, antimony, and fluoride) were found occasionally above the calculated statistical UTL concentrations for regional background conditions and/or the groundwater ARARs. However, with the possible exception of arsenic in the well MW-10 area (as postulated by DTSC), the occurrence and distribution of these exceedances do not coincide with the historical discharges to Bat Cave Wash or the inactive injection well PGE-8. TPH (identified as a COPC associated with the historic discharge of wastewater from the facility) was not found in groundwater samples above analytical reporting limit. Consistent with RFI/RI requirements, the typical RCRA/CERCLA process and the specific agency requirements for this site, a risk assessment is being completed to finalize the list of COCs to be carried forward in the RCRA/CERCLA process.

10.1.4 Characterization of COPCs

For those COPCs in groundwater that appear to be related to the SWMU 1/AOC 1, Cr(T), Cr(VI), molybdenum, and selenium, the data in this report show that the extent of Cr(T) and Cr(VI) is defined sufficiently well for the purpose of establishing remedial action objectives and evaluating remedial alternatives. There are groundwater delineation wells with chromium concentrations below reporting limits in all downgradient directions from the established plume, including two slant well clusters screened beneath the river. Additional data are recommended to verify the conclusions made for molybdenum and selenium. In the spring of 2008, a groundwater investigation was performed to (a) install and sample additional delineation monitoring wells on the Arizona side of the river and (b) to sample selected site monitoring wells for Title 22 metals. This supplemental investigation is anticipated to complete the groundwater characterization for SWMU 1/AOC 1.

10.2 Recommendations

Recommendations are provided below for the disposition of the SWMUs/AOCs addressed in this report under RCRA Corrective Action and CERCLA based on the site history (presented in RFI/RI Volume 1) and the characterization data presented in this report.

10.2.1 SWMU 1/AOC 1

Based on site history and characterization data, it is recommended that SWMU 1/AOC 1 (the former percolation bed and area around former percolation bed) be carried forward into the CMS/FS. The historical discharge of wastewater to the percolation beds in Bat Cave Wash has resulted in a chromium plume of approximately 90 acres, concentrations of which are greater than the chemical-specific ARARs. Molybdenum and selenium are also carried forward as COPCs associated with SWMU 1/AOC 1. Following the completion of the risk assessment for SWMU 1/AOC 1, the CMS/FS will define the remedial action objectives for SWMU 1/AOC 1, identify potential corrective/remedial measure technologies, and evaluate corrective/remedial measure alternatives based on RCRA and CERCLA selection criteria, in accordance with the *Revised Corrective Measures/Feasibility Study Work Plan, Topock Compressor Station* (CH2M HILL, 2008c).

10.2.2 SWMU 2

Based on site history and characterization data, it is recommended that SWMU 2 (the inactive injection well PGE-8) be closed with the RFI/RI and not be carried forward into the CMS/FS. This recommendation is based on the following reasons:

- Site history indicates that untreated cooling tower blowdown water from the compressor station was never discharged to PGE-8.
- The quantity of data that have been collected to evaluate bedrock conditions in the vicinity of PGE-8 indicate that the characterization data are adequate to make this conclusion.
- Hydraulic test data at PGE-8 indicate that a clear hydraulic connection exists between bedrock groundwater and the Alluvial Aquifer. These findings strongly suggest that discharge of treated wastewater to the injection well would have followed the preferential flow path of discharge to the Alluvial Aquifer.
- Based on the recent data collected, it is assumed reducing conditions within PGE-8 during times of historical waste discharge would have resulted in any Cr(VI) remaining in the water discharged to PGE-8 after treatment at the compressor station to have been reduced to insoluble Cr(III) and, therefore, removed from groundwater.
- The consistent lack of Cr(VI) above reporting limits in groundwater samples from bedrock wells in the vicinity of the SWMU 2 area indicate that no negative effects to bedrock groundwater have resulted from the PGE-8 past operations.

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