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June 17, 2005

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Subject: Groundwater Compliance Monitoring Plan (CMP)
Interim Measures No. 3
PG&E Topock Compressor Station, Needles, California

Dear Mr. Shopay:

Enclosed is the *Groundwater Compliance Monitoring Plan (CMP) for the Interim Measures No. 3 Injection Area*, prepared in compliance with DTSC's monitoring requirements for the injection well field and in response to DTSC comments of May 24, 2005 on the Draft CMP.

This plan is also being submitted to the Colorado River Basin Regional Water Quality Control Board, in response to the Board's comments of May 16, 2005 and in compliance with Monitoring and Reporting Program (MRP) No. R7-2004-0103 associated with the Board Order (CRBRWQCB 2004b).

If you have any questions on this report, please call me at (805) 546-5243.

Sincerely,

*Teri Hanson
For Yvonne Meeks*

Enclosure

CC: Liann Chavez/CRBRWQCB
Jose Cortez/ CRBRWQCB
Kate Burger/DTSC

Groundwater Compliance Monitoring Plan for Interim Measures No. 3 Injection Area

**Waste Discharge Requirements
Order No. R7-2004-0103
PG&E Topock Compressor Station
Needles, California**

Prepared for
**California Regional Water Quality Control Board
Colorado River Basin Region**
and
California Department of Toxic Substances Control

on behalf of
Pacific Gas and Electric Company

June 17, 2005

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**Groundwater Compliance Monitoring Plan for
Interim Measures No. 3 Injection Area
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June 17, 2005

**This monitoring plan was prepared under supervision of a
California-certified Engineering Geologist**



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Acronyms and Abbreviations

CRBRWQCB	Regional Water Quality Control Board Colorado River Basin Region
CMP	Compliance Monitoring Program
COC	constituent of concern
Cr(T)	total chromium
Cr(VI)	hexavalent chromium
DTSC	Department of Toxic Substances Control
IM	interim measures
MRP	Monitoring and Reporting Program
µg/L	micrograms per liter
mg/L	milligrams per liter
PG&E	Pacific Gas and Electric Company
TDS	total dissolved solids
USEPA	United States Environmental Protection Agency
WDR	Waste Discharge Requirements

1.0 Introduction

On July 29, 2004, Pacific Gas and Electric Company (PG&E) submitted an application and Report of Waste Discharge for subsurface injection of treated water to the California Regional Water Quality Control Board Colorado River Basin Region (CRBRWQCB). Subsurface injection is proposed as a water management option for Interim Measures Number 3 (IM No. 3) at the Topock Compressor Station in Needles, California. IM No. 3, which is being conducted under the lead oversight of the California Environmental Protection Agency, Department of Toxic Substances Control (DTSC), requires expansion of groundwater extraction and treatment facilities to maintain hydraulic control of the chromium plume boundaries near the Colorado River, in compliance with DTSC directives under previous interim measures (CH2M HILL 2004a). The project consists of groundwater extraction, construction of a new groundwater treatment facility, installation of piping to convey the water from the extraction wells to the treatment facility, and disposal of treated water by injection wells. The proposed location for the injection well field is on PG&E property, identified as Parcel 650-151-06, near the groundwater extraction and treatment facilities.

On October 13, 2004, CRBRWQCB adopted Waste Discharge Requirements (WDR) Order No. R7-2004-0103 specifying effluent limitations, prohibitions, specifications, and provisions for subsurface injection (CRBRWQCB 2004a). This groundwater compliance monitoring plan has been prepared in accordance with the requirement in the Monitoring and Reporting Program (MRP) No. R7-2004-0103 associated with the Board Order that specifies that such a plan be submitted at least 30 days prior to start of discharge (CRBRWQCB 2004b). It also addresses DTSC's monitoring requirements for the injection well field.

The objectives of this groundwater compliance monitoring plan are to:

- Describe the objectives of the groundwater compliance monitoring program (CMP) for IM No. 3.
- Describe the components of the CMP.
- Present the proposed monitoring frequency, analytical program, and additional monitoring well installation program.
- Present the proposed data evaluation procedures and the process for making any future modifications to the monitoring program.
- Describe the schedule and contents of reports.

1.1 Project Background

The Topock Compressor Station is located in eastern San Bernardino County, approximately 15 miles to the southeast of Needles, California (Figure 1-1). As directed by the DTSC under Interim Measures No. 2, PG&E is currently pumping groundwater from one deep extraction well (TW-2D) located on a bench along the station access road and above the Colorado River

floodplain. The bench, referred to as the monitoring well MW-20 bench, is owned by the United States Bureau of Reclamation and is managed by the United States Bureau of Land Management. PG&E began pumping from this location in March 2004 and is currently pumping at a rate of approximately 70 gallons per minute.

On June 30, 2004, DTSC issued to PG&E conditional approval to implement the IM No. 3 project to expand the existing groundwater extraction and management facilities to address hydraulic control of the chromium plume at the Topock site (DTSC 2004a). PG&E purchased San Bernardino County Parcel No. 650-151-06, the proposed site of the project, from the Metropolitan Water District of Southern California in September 2004. The parcel encompasses 100 acres and is located approximately 1,650 feet north of the PG&E compressor station property.

Three general areas were identified on Parcel 650-151-06 as potential sites for injection. Two primary areas, identified as the East and West Mesas, were selected based on the topography of the site, representing areas of relatively flat ground that could be made accessible to drilling equipment with only minor grading. A secondary area, identified as the Center Mesa, which is relatively flat but not easily accessible, was identified as a contingency area that would be used only if hydrogeologic conditions turned out to be unfavorable for injection wells on one or both of the primary areas. Initial investigations (installation of observation wells) were conducted on the East and West Mesas. Based on favorable hydrogeologic conditions and proximity to the new treatment system, it was decided to further investigate the East Mesa as an injection well site. An investigation of Center Mesa was not performed after it was determined that sufficient injection capacity could be obtained by wells on the East Mesa alone. Figure 1-2 shows the locations of Parcel No. 650-151-06 and the IM No. 3 project area and features.

1.2 Project Documents and Approvals

The installations of injection, observation, and compliance monitoring wells for the IM No. 3 project were implemented under the following work plans, documents, and agency approvals:

- Technical Memorandum “Revised-Final Field Activities Summary for Observation Well Installation and Groundwater Characterization under IM No. 3,” dated September 1, 2004 (CH2M HILL 2004b). The DTSC conditionally approved the plan in a letter dated September 3, 2004 (DTSC 2004b).
- *Final Work Plan for Injection Well Installation on Parcel 650-151-06*, dated November 15, 2004 (CH2M HILL 2004c). The DTSC conditionally approved the work plan in a letter dated November 2, 2004 (DTSC 2004c).
- Technical Memorandum “Selection of Locations for Compliance Monitoring Wells,” dated November 9, 2004 (CH2M HILL 2004d). The DTSC conditionally approved the compliance wells selection plan in a letter dated December 23, 2004 (DTSC 2004d).
- *Draft Design Plan for Groundwater Compliance Monitoring, PG&E Topock Compressor Station, Needles, California*, dated November 23, 2004 (CH2M HILL 2004e). The DTSC conditionally approved the design plan in a letter dated December 23, 2004

(DTSC 2004d). The CRBRWQCB conditionally approved the design plan in a letter dated December 1, 2004 (CRBRWQCB 2004c). The *Final Design Plan for Groundwater Compliance Monitoring, PG&E Topock Compressor Station, Needles, California* (CH2M HILL 2005a) was submitted on January 5, 2005.

The results and assessment of the well drilling, groundwater sampling, and testing program conducted during September 2004 through May 2005 to characterize the hydrogeology and groundwater quality conditions in the IM No. 3 injection area are summarized in the June 22, 2005 report entitled *Groundwater and Hydrogeologic Report for Interim Measures No. 3 Injection Area* (CH2M HILL 2005b). That report documents the baseline hydrogeologic and water quality conditions of the injection area, and serves as a companion document to this compliance monitoring plan.

2.0 Background

Background hydrogeologic and water quality information relevant to the IM No. 3 groundwater compliance monitoring program is presented below.

2.1 Site Hydrogeology

The Topock site is located at the extreme southern end of the Mohave Valley along the western floodplain of the Colorado River. Bedrock outcrops to the south and west of the site create barriers to groundwater flow. While the overall trend of groundwater flow throughout most of the Mohave Valley is southerly, groundwater flow directions at the Topock site are predominantly north to northeasterly. Groundwater is forced to flow in this direction as it approaches the low-permeability bedrock of the Chemehuevi Mountains that prevents further regional groundwater flow to the south.

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. The water table in the Alluvial Aquifer is very flat throughout the site and typically equilibrates to an elevation within 2 to 3 feet of the river level. 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 in the IM No. 3 injection area has a total saturated thickness of over 250 feet and is composed primarily of moderately-consolidated, sandy gravel and silty/clayey gravel alluvial fan deposits of Tertiary age. These deposits comprise a thick sequence of undeformed oldest alluvium that unconformably overlies older Miocene and pre-Tertiary metamorphic bedrock formations. In the East Mesa injection area, bedrock is encountered at approximately 340 to 350 feet below ground surface and is characterized by both metamorphic (metadiorite, gneiss) and sedimentary rock types.

For convenience during the IM No. 3 hydrogeologic characterization, the Alluvial Aquifer was subdivided into upper, middle, and lower zones. These zones do not represent distinct hydrostratigraphic units. There are no laterally extensive aquitards present to hydraulically segregate the aquifer. There are gradational changes in water quality with depth in the aquifer and vertical head gradients. Defining three zones in the aquifer provides a convenient way to evaluate water quality and horizontal gradients within a group of wells that are similar in depth. In the IM No. 3 investigation area, groundwater occurs under unconfined to semi-confined conditions. The depth to groundwater ranges from 110 feet below ground surface in higher mesa areas to 25 feet below ground surface in lower Bat Cave Wash (eastern portion of Parcel 650-151-06).

A more detailed discussion of the site hydrogeologic setting is available in the draft *RCRA Facility Investigation/Remedial Investigation Report* (CH2M HILL 2005c).

2.2 Summary of Conclusions from Baseline Sampling

Groundwater samples from the IM No. 3 injection, observation, and compliance monitoring wells, as well as other monitoring wells in the area, were collected and analyzed during various field investigations conducted from June 2004 through May 2005 (CH2M HILL 2005b). Groundwater was analyzed for hexavalent chromium [Cr(VI)], total chromium [Cr(T)], general chemistry, metals, and field water quality parameters.

The general chemistry of the groundwater is dominated by sodium and chloride, with a few exceptions. Total dissolved solids (TDS) of IM No. 3 injection area groundwater ranges from 650 milligrams per liter (mg/L) to over 12,000 mg/L, increasing with depth. The median average TDS concentration in the East Mesa injection area is 4,200 mg/L (CH2M HILL 2005b). Oxidation-reduction (redox) indicators show a trend of more reducing conditions with depth, similar to other alluvial wells at the site. The strongest reducing conditions are found in the deep wells at the East Mesa.

In the IM-3 investigation area, data indicate that elevated concentrations of chromium (i.e., greater than 50 micrograms per liter [$\mu\text{g/L}$]) are limited in vertical and lateral extent. The elevated concentrations are limited to the lower depths of the Alluvial Aquifer beneath portions of Bat Cave Wash to the south of well MW-41D (Figure 1-2). This is expected as the original release occurred in the southern Bat Cave Wash area.

The shallow wells in the IM No. 3 injection area contains a median Cr(VI) concentration of about 22 $\mu\text{g/L}$ and a range of <0.2 to 34.3 $\mu\text{g/L}$. This range is considered to be consistent with the potential range of natural background levels on the basis of Cr(VI) disposal locations, present and historical groundwater flow direction, and published data in the region. The median concentration of Cr(VI) in the middle-depth and deep wells of the IM No. 3 injection area is 4.8 $\mu\text{g/L}$, reflecting the more reducing conditions in these wells. A chromium background study is currently underway to estimate the concentration range of naturally occurring Cr(VI) at the Topock site and surrounding area.

Proposed injection in the East Mesa well field will be designed so that injected water will be of similar quality to average groundwater. The approximate TDS of injectate will be 4,200 mg/L, the average of East Mesa groundwater. This is more than 1,500 mg/L lower than that of the raw groundwater currently being pumped from TW-2D, so there will be a net reduction in site groundwater salinity. Geochemical modeling of the injection of water treated to match the average salinity of the East Mesa aquifer showed no predicted scaling or clogging effects from mixing between native East Mesa groundwater and treated groundwater.

3.0 Compliance Monitoring Program Objectives

This section presents the objectives of the groundwater compliance monitoring under WDR No. R7-2004-0103 and describes the network of monitoring wells to be used in the program.

3.1 Monitoring Objectives

The primary objective of the CMP is to monitor the aquifer in the injection well area to ensure that the injection of treated groundwater is not causing an adverse effect on the aquifer water quality. The objectives will be achieved by collecting and analyzing groundwater samples, as well as measuring groundwater levels in the vicinity of the injection wells. Groundwater analyses will be performed to ensure that the distribution and concentrations of constituents of concern (COCs) remain consistent with the baseline sampling results, which were established during multiple rounds of sampling conducted from June 2004 to May 2005 (CH2M HILL 2005b, 2005e). The collection of water levels will determine whether or not the aquifer is able to accept the additional water from the injection wells without adverse effects (such as surface soil instability or surface discharge of groundwater via springs).

The specific objectives of the CMP are to:

- Monitor water levels to assess groundwater flow directions and the development of groundwater mounding near the injection wells.
- Monitor the rate at which injected groundwater migrates from the injection wells.
- Monitor water quality throughout the shallow, middle, and lower depths of the aquifer to evaluate the degree of vertical migration and mixing of groundwater during groundwater injection.
- Detect any measurable aquifer plugging due to turbidity in the injected water, precipitation of minerals in the aquifer matrix, or cation exchange effects.
- Assess whether injection of treated groundwater results in any mobilization of trace metals from aquifer sediments to groundwater as a result of changes in pH, oxidation-reduction potential, and major ion composition.

In order to meet these objectives, the CMP includes the:

- Collection of spatially-appropriate chemical and hydraulic data representative of the site conditions.
- Collection of groundwater data at an appropriate frequency (monthly, quarterly, and semi-annually) to assess any changes in the distribution and concentration of the COCs.
- Use of appropriate State-certified laboratory methods for the COC analyses and data quality control measures to support decision-making.

- Use of laboratory reporting limits at levels below screening criteria (i.e., drinking water maximum contaminant levels).

These data quality objectives are sufficient to support data needs for the current and future CMP activities at the Topock site.

3.2 Description of CMP Monitoring Well Network

The IM No. 3 groundwater injection system consists of the two injection wells IW-2 and IW-3 in the East Mesa area and a network of monitoring wells that surround the injection wells (Figure 1-2). The CMP monitoring well network consists of both observation wells and compliance monitoring wells. Well construction details for the injection, observation, and compliance monitoring wells are provided in Table 3-1. The CMP monitoring well network is described in detail below.

3.2.1 Observation Wells Clusters

The observation well clusters OW-1, OW-2, and OW-5 in the East Mesa constitute the inner network of monitoring wells surrounding the injection wells. They are located within approximately 50 to 100 feet from the injection wells; therefore, any change in groundwater hydraulics or quality is likely to be detected in the observation wells long before it is observed in the more distant compliance monitoring wells. The estimated travel time for the injected groundwater to reach the observation wells is approximately 2 to 4 months, based on the groundwater model used to design the injection system.

Each observation well cluster consists of three monitoring wells screened at shallow, medium, and deep intervals in the Alluvial Aquifer. The well clusters will allow the measurement of changes in water chemistry and water levels across the entire aquifer thickness and will permit an analysis of the degree of vertical mixing of groundwater that is occurring during injection. Monitoring of the observation wells will also allow any impacts to groundwater quality from injection to be identified and evaluated early during the operation of the groundwater injection system. Corrective action can be taken accordingly for any potential negative effects that may arise such as aquifer plugging, excessive mounding, or mobilization of trace metals from the aquifer matrix.

3.2.2 Compliance Monitoring Wells

The compliance monitoring well clusters CW-1 through CW-4 represent the outer network of monitoring wells surrounding the two injection wells. They are located approximately 300 to 550 feet away from the injection wells, or approximately a 2- to 4-year travel time from the injection wells. Each compliance monitoring well cluster consists of two monitoring wells with 50-foot screened intervals. The combined screened intervals in each compliance well cluster approximately correlate to those in the injection wells, which were screened from about 60 feet below the water table to near the bottom of the Alluvial Aquifer.

Water level and chemical data will be collected at the compliance monitoring wells to monitor the arrival of the injected water front, evaluate any mounding effects or changes in

groundwater quality, and provide information to adjust parameters in the groundwater model, if necessary.

3.2.3 Other Monitoring Wells

Several other monitoring wells are located in the general vicinity of the injection area. These wells (OW-3 cluster, MW-18, MW-14, MW-41S, MW-41M, MW-41D, MW-13, MW-37S, and MW-37D) are located at distances representing approximately 8 to 12 years or more in travel time from the injection wells. These locations would not be useful for compliance monitoring in the near term; therefore, they are not addressed in this plan. However, if the results of monitoring at the observation and compliance monitoring wells indicate that these wells would be useful in future monitoring, the plan will be revised accordingly.

4.0 Proposed Monitoring Program

This section describes the proposed monitoring, sampling, and analysis program for the groundwater compliance monitoring under WDR No. R7-2004-0103. All groundwater monitoring activities will be performed in accordance with the procedures, analytical methods, reporting limits, and quality control plan for the Topock program as described in the *Sampling, Analysis, and Field Procedures Manual* (CH2M HILL 2005d).

4.1 Overview of CMP Monitoring Activities

The CMP activities consist of:

- **Manual water level monitoring** at the observation and compliance monitoring wells to assess hydraulic gradients and to calibrate transducers.
- **Use of dedicated transducers** in observation wells and compliance monitoring wells for continuous measurement of water levels and specific conductance to evaluate any immediate changes in hydraulic gradient and groundwater quality.
- **Sampling of observation wells** during the initial 2 to 4 months of operation to assess impacts of treated groundwater injection on groundwater quality.
- **Sampling of compliance monitoring wells** to assess background water quality and the arrival of the injected water front in approximately 2 to 4 years.
- **Installation of shallow compliance monitoring wells** at the 4 compliance monitoring well clusters.
- **An optional tracer test** to evaluate groundwater flow velocities and flow paths.

4.1.1 Manual Groundwater Level Monitoring

Manual water level measurements are performed quarterly for the Topock Groundwater Monitoring Program at all monitoring wells at the Topock site, including the observation and compliance monitoring wells. In addition, water levels will be manually measured at each monitoring well prior to purging and sampling. These water level data will be used to calibrate the transducers installed in the observation wells.

4.1.2 Water Level/Specific Conductance Transducers

Two types of dedicated transducers will be installed in the wells surrounding the injection area. Wells OW-2D and OW-5D have Insitu™ Troll 9000 transducers (or equivalent) that continuously measure hydraulic head and the specific conductance and temperature of groundwater. The remaining wells (OW and CW) have Insitu™ miniTrolls (or equivalent) that continuously measure hydraulic head and temperature. The use of transducers will assist in determining when the injected water arrives at the wells, as indicated by increases

in hydraulic head and changes in the specific conductance and possibly temperature of the groundwater.

After an extended period (several months) of injection, it is anticipated that the natural groundwater at the radius of the observation wells will be displaced with injected water and the water quality in the observation wells will begin to mirror the water quality of the injected water. After this happens, there may be no reason to continue monitoring water quality at the observation wells. However, monitoring water levels in these wells would continue as a way of tracking the performance of the injection wells. Transducers are needed in the compliance monitoring wells to discern between injection effects and the influence of the Colorado River.

Specific conductance values can be used to estimate the TDS of groundwater in the observation wells. TDS data are important as they will be used to assess the lateral migration of injected groundwater and potential vertical mixing of deeper, higher TDS groundwater with the shallower, lower TDS groundwater.

The transducers will be operated, downloaded, and maintained in accordance with the standard operating procedures described in the *Sampling, Analysis, and Field Procedures Manual* (CH2M HILL 2005d).

4.1.3 Sampling of Observation and Compliance Monitoring Wells

The collection and analysis of groundwater samples from the observation and compliance monitoring wells constitute the main portion of the monitoring program. These data will be used to characterize background water quality conditions, assess any changes in water quality as the front of injected groundwater arrives, and confirm that groundwater impacted by injected water meets applicable water quality standards. The frequency of sampling and the laboratory and field parameters to be analyzed are described in Sections 4.2 and 4.3, respectively.

4.1.4 Shallow Compliance Monitoring Wells

Four monitoring wells will be installed under the Compliance Monitoring Plan to provide additional shallow depth information for the aquifer in the vicinity of the injection wells. A work plan for the installation of one shallow monitoring well at each of four existing compliance well clusters will be submitted for approval prior to installation. The schedule for installation will be provided in the work plan and will be based on simulation results of the updated injection area groundwater flow model. Regardless of the results of model simulation, the wells will be installed within 545 days of injection startup.

Pending DTSC approval of installation, the additional wells will be added into the manual water level, transducer and analytical sampling programs after they have been installed, developed and completed.

4.1.5 Optional Tracer Test

A tracer test may be performed to provide additional data regarding groundwater flow paths, velocities, mixing, and dispersion. Fluorescein dye is currently under consideration as the tracer due to its non-toxic properties, low cost, ease of use, and ability to be detected at low levels. Adsorber “socks” can be suspended in the monitoring wells, and they can be

recovered and analyzed on a routine schedule to determine the arrival time of the tracer. PG&E is considering a tracer test to provide data on groundwater flow velocities needed for evaluating other types of remedial actions, such as *in-situ* chemical reduction and *in-situ* bioremediation. It is possible that smaller scale tracer tests could be performed in conjunction with the pilot testing of these technologies. If a tracer test in conjunction with the operation of the injection wells is determined to be desirable, the proposed procedures will be described in a separate work plan.

4.2 Sampling Frequency

The proposed sampling frequency for the observation and compliance monitoring wells is based on the site hydrogeologic model and the baseline sampling results established during multiple rounds of sampling from June 2004 to May 2005 (CH2M HILL 2005b, 2005e). During the first 2 years of operation, the observation wells will be sampled monthly for the first 6 months of operation. If significant changes or trends in water quality are not observed during that time, the sampling frequency for the observation wells will then decrease to quarterly for the remainder of the 2-year sampling period. Data evaluation procedures that will be used to assess concentration trends are described in Section 5. The compliance monitoring wells will be sampled semi-annually (every 6 months) for the first 2 years of operation. The proposed sampling schedule for the observation and compliance monitoring wells is outlined in Table 4-1. The sampling frequency will be re-evaluated after the conclusion of the initial 2-year sampling period, and a proposal for any modifications to the program will be submitted to the CRBRWQCB and DTSC for consideration.

Observation wells are proposed to be sampled more frequently than the compliance monitoring wells due to their proximity to the injection wells. Because the injected water front is anticipated to reach the observations within 2 to 4 months, the data collected from the observation wells will provide valuable information regarding any negative impacts to groundwater quality or aquifer plugging. If significant impacts are observed, the early identification of these issues will allow sufficient time for corrective action before the injected groundwater reaches the compliance wells. After an extended period of injection, it is anticipated that the natural groundwater at the radius of the observation wells will be displaced with injected water and the water quality in the observation wells will begin to mirror the water quality of the injected water. After this happens, a discontinuation or a decrease in frequency of sampling of the observation wells may be warranted. This will be evaluated after the initial 2-year sampling period.

Semi-annual monitoring of the compliance monitoring wells is expected to provide sufficient data to meet the sampling objectives. Since the injected groundwater front is not anticipated to reach the compliance wells until approximately 2 to 4 years after the start of injection, it is estimated that at least four rounds of monitoring will have been performed at the compliance wells prior to the arrival of the injected water front and the onset of any potential changes in groundwater quality.

As a supplement to this monitoring plan, a contingency plan for the IM No. 3 groundwater injection system has been submitted to DTSC (CH2M HILL 2005f). The plan outlines the criteria and notification procedures when concentrations of specified parameters reported for the observation and compliance monitoring wells exceed target values established in the

submittal *Baseline Groundwater Quality for the IM No. 3 Injection Area* (CH2M HILL 2005e). The contingency plan includes provisions for verification sampling and initiating response actions for the IM injection system, including increasing the frequency of sampling.

4.3 Analytical and Testing Program

Groundwater samples collected from the compliance monitoring network will be analyzed for field and laboratory parameters, as described below.

4.3.1 Field Water Quality Parameters

A flow-through cell will be used to measure water quality parameters during well purging and sampling of all groundwater monitoring wells. The field parameters to be measured include specific conductance, temperature, pH, turbidity, oxidation-reduction potential, and dissolved oxygen. These parameters typically are used to determine when wells have been sufficiently purged prior to sampling, but the parameters will also be useful as indicator parameters to help determine when the injected water reaches the observation wells. The parameters are also needed to assess the geochemical conditions of groundwater and to evaluate potential subsurface reactions between injected water and the aquifer materials. Procedures for measurement of field water quality parameter are provided in the *Sampling, Analysis, and Field Procedures Manual* (CH2M HILL 2005d).

4.3.2 Laboratory Analytical Parameters

Two suites of laboratory analytical parameters are proposed for use in the CMP, as summarized below:

- Full Suite - Cr (VI), Cr(T), metals, TDS, general minerals
- Limited Suite - Cr (VI), Cr(T), TDS, general minerals

Table 4-2 provides a detailed list of these parameters.

Groundwater samples from the observation wells will be analyzed for the full suite of analytes for the first year of monitoring. The metals and general mineral analyses will assist in evaluating when the injected water front arrives at the observation wells and will provide the data needed to assess if there are any short term immediate negative impacts to groundwater quality (such as mobilization of trace metals from the aquifer matrix). Based on an evaluation of data collected from the observation wells during the first year using the methods described in Section 5, PG&E will request RWQCB and DTSC for approval to analyze observation well samples for the limited suite quarterly and for the full suite semi-annually after the first year. Groundwater samples from the compliance monitoring wells will be analyzed for the full suite of analytes at every semi-annual event during the initial 2-year monitoring period. The entire analytical program will be re-evaluated after the conclusion of the initial 2-year sampling period, and a proposal for any modifications to the program will be submitted to the CRBRWQCB and DTSC for consideration.

Analytical methods, sample volumes and containers, sample preservation requirements, and quality control sample requirements are provided in the *Sampling, Analysis, and Field Procedures Manual* (CH2M HILL 2005d). Data validation and management will be conducted

in accordance with the *Quality Assurance Project Plan* provided as Appendix D of the *Sampling, Analysis, and Field Procedures Manual*.

5.0 Data Evaluation Methods

This section describes the methods that will be used to summarize and evaluate the data collected as part of the Compliance Monitoring Program.

5.1 Hydraulic Evaluation

Groundwater levels at the Topock site fluctuate in response to changes in river level. Wells near the injection well field exhibit small fluctuations which are lagged in time from the rivers cycles. Because of this complex and nearly continuous fluctuation in groundwater levels, it is not possible to accurately measure average gradients at this site from a single round of water level measurements. In order to resolve accurate average gradients, the set of water level data collected at each well using transducers will be averaged over a period of time to determine the average gradient. A monthly averaging period has been established for compliance monitoring, to be consistent with the concurrent Performance Monitoring Program for Interim Measures in the floodplain area (CH2M HILL 2005g).

Hydraulic evaluation of the data will consist of normalization of water level data to freshwater head, calculations of horizontal and vertical gradients, and comparison of gradients to baseline and predicted conditions, as described below.

5.1.1 Groundwater Elevation Calculations and Adjustments

The temperatures and salinity of surface and groundwater are highly variable across the Topock site. In general, colder, lower salinity groundwater is found in shallow wells closest to the river and warmer, higher salinity groundwater is found in deep wells farther from the river. Historically, groundwater temperatures have ranged from 62°F to over 100°F; the salinity of groundwater ranges from <0.1 percent to 4 percent. In order to obtain water level elevation data that are comparable across the site, adjustments for temperature and salinity must be made to the raw data to obtain water levels normalized to freshwater head.

Well-specific average salinity and the best-available temperature data will be used to adjust the groundwater elevation data. The salinity data for each well will be routinely evaluated to identify any trends in salinity and insure that correct average salinity values are being used for each well. Daily average temperatures from pressure transducers are considered the best-available temperature data. If transducer temperature data are not available, then temperature data from groundwater sampling will be used.

The methodology to adjust groundwater elevations for differences in density due to salinity and temperature are further described in Appendix A. Both the unadjusted and density-corrected groundwater elevations will be stored in the project database.

5.1.2 Horizontal Gradient Calculation and Presentation

Groundwater elevations (adjusted to equivalent fresh water heads with salinity and temperature) from transducer data will be evaluated quarterly. The monthly average and

quarterly average groundwater elevations will be calculated at each monitoring location, and these data will be posted on plan view maps. The three plan view maps will contain the monitoring wells separated into shallow, middle-depth, and deep wells of the Alluvial Aquifer. The quarterly average groundwater elevation data posted onto each map will then be contoured to assist with an evaluation of any changes in hydraulic gradient and flow directions in relation to groundwater injection.

The onset of injection is expected to change gradients and flow fields in the region surrounding the injection sites, so a comparison will be made to the conceptual model for how the groundwater mound was estimated to grow. The gradient and flow data will be compared on a quarterly basis to both baseline conditions and simulated conditions predicted by the groundwater flow model as described in the *Groundwater and Hydrogeologic Investigation Report for Interim Measures No. 3 Injection Area* (CH2M HILL 2005b). Since the original model was used projected injection rates, model inputs will be updated to reflect actual conditions. Simulations will be re-run on a semi-annual basis to incorporate operational injection rates. The development of any groundwater mounding near the injection wells will be monitored to ensure that surface discharge does not occur.

5.1.3 Vertical Gradient Calculation and Presentation

The quarterly-average groundwater elevation data also will be used to calculate vertical gradients for each well cluster or pair. The vertical gradient information will be provided in tabular form, and will be assessed for any changes that result from groundwater injection.

5.2 Water Quality Evaluation

Analytical data collected as part of the CMP will be compared to target values proposed in the *Baseline Groundwater Quality for the IM No. 3 Injection Area* (CH2M HILL 2005e). A portion of the target values were set equivalent to the concentration levels at which groundwater quality exceeded RWQCBWDR groundwater discharge limit. To protect the Alluvial Aquifer, action levels for these parameters will be set so that a response is initiated before concentrations reach target values. A value of 75% of the target level seen at any compliance point within the injection well monitoring network would mandate implementation of the Contingency Plan notification procedures and response actions.

For the remaining parameters, baseline concentration measured in the injection area groundwater prior to injection exceeded the standard of 75% of the RWQCB WDR discharge limit (all remain parameters exceeded the WDR with the exception of boron, which was 95% of the WDR). Target values were selected as the highest occurrence concentration for that parameter measured within the Alluvial Aquifer wells in the injection area. Action levels for parameters whose naturally occurring concentrations exceed the RWQCB discharge limits in injection area groundwater will be determined in a different manner. For these parameters, the action level is set as an exceedance of one standard deviation above the current baseline upper limit value. Since additional information is collected each sampling round, the standard deviation will be updated on a continuing basis.

Table 5-1 lists the target values and action levels for each of the monitored parameters.

If reported concentrations of the specified monitored parameters exceed their respective action levels during any event, notification procedures and response actions will be implemented as outlined in the contingency plan for IM No. 3 groundwater injection (CH2M HILL 2005f). The initial response action is re-sampling to verify the exceedance, which is followed by an increased frequency of sampling if the verification is positive.

There are a number of parameters that are being monitored for operational or geochemical purposes, but are not considered to have action levels. Concentrations of metals, general minerals, and field water quality parameters will be evaluated to assess changes in groundwater geochemistry with time, and to monitor for potential negative effects that may arise such as aquifer plugging or mobilization of trace metals from the aquifer matrix. Once a sufficient set of data has been collected (at least 3 events), graphs of selected analyte concentrations over time will be prepared for each well to evaluate concentration trends. The Mann-Kendall test, or some similar non-parametric statistical test for trend analysis, will be used to determine if there is a significant trend to the data.

6.0 Reporting

This section identifies the reporting schedule for the CMP. The reports will be submitted to both CRBRWQCB and DTSC.

6.1 Quarterly Monitoring Reports

As specified in MRP No. R7-2004-0103, the quarterly CMP reports will be submitted by January 15, April 15, July 15, and October 15 of each year.

- First quarter monitoring period (January through March): report due April 15
- Second quarter monitoring period (April through June): report due July 15
- Third quarter monitoring period (July through September): report due October 15
- Fourth quarter monitoring period (October through December): report due January 15

Injection is currently projected to start in late July 2005; accordingly, the first quarterly report will be submitted on October 15, 2005 for third quarter 2005 and will cover the period from start of injection to end of September 2005. If injection is delayed, the first quarterly report will be similarly delayed. Each report will summarize all sampling activities that occurred within the specified quarter. Hydraulic and analytical data collected during each quarter, as well as historic data, will be summarized in tabular format. Groundwater elevation contour maps will be prepared for the upper, middle, and lower zones of the Alluvial Aquifer. Horizontal and vertical gradients in the well field vicinity will be discussed. Each report will include an evaluation of hydraulic and water quality conditions relative to baseline conditions and target values.

6.2 Semi-annual Monitoring Reports

The second and fourth quarter reports, to be submitted July 15 and January 15 of each year, will serve as semi-annual monitoring reports. The reports will summarize all sampling activities that occurred within the specified semi-annual period. Hydraulic and analytical data collected during that period, as well as historic data, will be summarized in tabular format. Groundwater elevation contour maps will be prepared for the shallow, middle-depth, and deep wells in the Alluvial Aquifer. Horizontal and vertical gradients in the well field vicinity will be discussed. Each report will include an evaluation of hydraulic and water quality conditions relative to baseline conditions and target values. .

6.3 MRP Specifications

Other reporting specifications are outlined in MRP No. R7-2004-0103, and are summarized below.

- The data will be presented in tabular form so that the specified information is readily discernible. The data will be summarized in such a manner as to clearly illustrate whether the facility is operating in compliance with WDRs.
- Records of monitoring information will include:
 - The date, exact place, and time of sampling or measurement(s).
 - The individual(s) who performed the sampling or measurement(s).
 - The date(s) analyses were performed.
 - The individual(s) who performed the analyses.
 - The analytical techniques or method used.
 - The results of such analyses.
- The results of any analysis taken more frequently than required at the locations specified in the MRP will be reported to the CRBRWQCB.
- Monitoring reports will be certified under penalty of perjury to be true and correct and will contain the required information at the designated frequency.
- Each report will contain the following statement:

“I declare under the penalty of law that I have personally examined and am familiar with the information submitted in this document, and that based on my inquiry of those individuals immediately responsible for obtaining the information, I believe that the information is true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of a fine and imprisonment for knowing violations.”
- A duly authorized representative of the discharger may sign the documents if:
 - The authorization is made in writing by the discharger.
 - The authorization specifies an individual or person having responsibility for the overall operation of the regulated disposal system.
 - The written authorization is submitted to the CRBRWQCB’s Executive Officer.
- Reporting of any failure in the facility will be performed as described in WDR Order No. R7-2004-0103. Results of any analysis performed as a result of a failure of the facility will be provided within 14 days after collection of the samples.
- A cover letter will be attached to each report. The information contained in the cover letter will clearly identify violations of the WDRs, discuss corrective actions taken or planned, and the proposed time schedule of corrective actions. Identified violations will include a description of the requirement that was violated and a description of the violation.

7.0 References

- California Department of Toxic Substances Control (DTSC). 2004a. Letter. "Approval of *Summary of Proposed Project for Interim Measures No. 3.*" June 30.
- _____. 2004b. Letter. "Conditional Approval of Observation Well Installation Work Plan, dated September 1, 2004." September 3.
- _____. 2004c. Memorandum. "DTSC Geological Services Unit comments on Draft Work Plan for Injection Well Installation on Parcel 650-151-06, dated September 27, 2004." November 2.
- _____. 2004d. Letter. "Conditional Approval of the Draft Design Plan for Groundwater Compliance Monitoring, dated November 23, 2004." December 23.
- California Regional Water Quality Control Board, Colorado River Basin (CRBRWQCB). 2004a. *Waste Discharge Requirements for Pacific Gas and Electric Company Groundwater Remediation Facility, Order No. R7-2004-0103.* October 13.
- _____. 2004b. *Monitoring and Reporting Program for Pacific Gas and Electric Company Groundwater Remediation Facility, Order No. R7-2004-0103.* October 13.
- _____. 2004c. Letter to PG&E. "Approval of Draft Design Plan for Groundwater Compliance Monitoring, Waste Discharge Requirements Order No. R7-2004-0103." December 1.
- CH2M HILL. 2004a. *Summary of Proposed Project for Interim Measures Number 3.* July 8.
- _____. 2004b. Technical Memorandum. "Revised-Final Field Activities Summary for Observation Well Installation and Groundwater Characterization under IM No. 3, Pacific Gas and Electric Company, Topock Project." September 1.
- _____. 2004c. *Final Work Plan for Injection Well Installation on Parcel 650-151-06, PG&E Topock Compressor Station, Needles, California.* November 15.
- _____. 2004d. *Selection of Locations for Compliance Monitoring Wells (Revised), Interim Measures No. 3, Pacific Gas & Electric Co., Topock Project.* November 9.
- _____. 2004e. *Draft Design Plan for Groundwater Compliance Monitoring, PG&E Topock Compressor Station, Needles, California.* November 23.
- _____. 2005a. *Final Design Plan for Groundwater Compliance Monitoring, PG&E Topock Compressor Station, Needles, California.* January 5.
- _____. 2005b. *Groundwater and Hydrogeologic Investigation Report for Interim Measures No. 3 Injection Area, PG&E Topock Compressor Station, Needles, California.* June 22.
- _____. 2005c. *Draft RCRA Facility Investigation/Remedial Investigation Report, PG&E Topock Compressor Station, Needles, California Volume 1-3.* February.

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- _____. 2005d. *Sampling, Analysis, and Field Procedures Manual, Revision 1, PG&E Topock Compressor Station, Needles, California*. March 31.
- _____. 2005e. Technical Memorandum. "Baseline Groundwater Quality for the IM No. 3 Injection Area." June 10.
- _____. 2005f. Interim Measures No. 3 Injection Well Operation and Maintenance Plan Addendum.
- _____. 2005g. *Draft Performance Monitoring Plan for Interim Measures in the Floodplain Area, PG&E Topock Compressor Station, Needles, California*. April 15.

Tables

TABLE 3-1

Well Elevations and Construction Summary

Interim Measures No. 3. Groundwater Compliance Monitoring Program, PG&E Topock Compressor Station

Well ID LocID_Post	Well Note	Date Installed	Well Elevation		Boring Total Depth (ft bgs)	Well Depth (ft bgs)	Approx Depth to Water (ft TOC)	TOP of Screen		BASE of Screen		Well Casing & Sump Length	Screen Length (feet)
			Measure Pt. Elevation (ft MSL)	Ground Elevation (ft MSL)				Depth (ft bgs)	Elevation (ft MSL)	Depth (ft bgs)	Elevation (feet MSL)		
Observation, Compliance & Injection Wells													
CW-1M	IM3 compliance MW	Jan-05	566.07	563	195	190	112	140	423	190	373	2" PVC	50
CW-1D	IM3 compliance MW	Jan-05	566.46	564	360	320	112	250	314	300	264	2" PVC - 20' sump	50
CW-2M	IM3 compliance MW	Jan-05 / Feb-05	549.45	547	203	202	95	152	395	202	345	2" PVC	50
CW-2D	IM3 compliance MW	Jan-05	549.43	547	385	355	96	285	262	335	212	2" PVC - 20' sump	50
CW-3M	IM3 compliance MW	Feb-05	534.10	532	223	222	80	172	359	222	309	2" PVC	50
CW-3D	IM3 compliance MW	Jan-05	534.14	532	360	340	80	270	262	320	212	2" PVC - 20' sump	50
CW-4M	IM3 compliance MW	Jan-05	518.55	516	170	170	64	120	396	170	346	2" PVC	50
CW-4D	IM3 compliance MW	Jan-05	518.55	516	337	303	65	233	283	283	233	2" PVC - 20' sump	50
OW-1S	IM3 observation well	Nov-04	550.15	548	115	114	95	84	464	114	434	2" PVC	30
OW-1M	IM3 observation well	Sep-04	550.36	548	186	189	92	165	383	185	363	2" PVC	20
OW-1D	IM3 observation well	Sep-04	550.37	548	291	277	92	257	291	277	271	2" PVC	20
OW-2S	IM3 observation well	Dec-04	548.75	546	104	101	94	71	475	101	445	2" PVC	30
OW-2M	IM3 observation well	Dec-04	548.52	546	210	210	94	190	356	210	336	2" PVC	20
OW-2D	IM3 observation well	Nov-04 / Dec-04	549.01	547	347	340	95	310	237	330	217	2" PVC - 10' sump	20
OW-5S	IM3 observation well	Nov-04	551.75	549	112	110	97	70	479	110	439	2" PVC	40
OW-5M	IM3 observation well	Nov-04	551.75	549	252	250	97	210	339	250	299	2" PVC	40
OW-5D	IM3 observation well	Nov-04	552.35	550	350	350	98	300	250	320	230	2" PVC - 30' sump	20
IW-2	IM3 injection well	Jan-05	550.11	547	412	340	96	170	377	330	217	6" SS - 10' sump	160
IW-3	IM3 injection well	Jan-05	554.44	551	411	330	100	160	391	320	231	6" SS - 10' sump	160

NOTES:

1. Well elevations for IM-3 wells in feet above mean sea level (MSL) from PG&E well survey conducted 2/15/05.
2. Ground surface elevations and all well/screen depth and elevations rounded-off to whole-foot values.
3. Depth to water values are average depths in feet below top of well casing (TOC) rounded off to whole-foot values.

TABLE 4-1
Proposed Sampling Schedule and Analyses
Interim Measures No. 3. Groundwater Compliance Monitoring Program
PG&E Topock Compressor Station

Wells	FIRST YEAR								SECOND YEAR			
	Month 1	Month 2	Month 3	Month 4	Month 5	Month 6	Month 9	Month 12	Month 15	Month 18	Month 21	Month 24
Observation Wells												
OW-1S	F	F	F	F	F	F	F	F	L ¹	F	L ¹	F
OW-1M	F	F	F	F	F	F	F	F	L ¹	F	L ¹	F
OW-1D	F	F	F	F	F	F	F	F	L ¹	F	L ¹	F
OW-2S	F	F	F	F	F	F	F	F	L ¹	F	L ¹	F
OW-2M	F	F	F	F	F	F	F	F	L ¹	F	L ¹	F
OW-2D	F	F	F	F	F	F	F	F	L ¹	F	L ¹	F
OW-5S	F	F	F	F	F	F	F	F	L ¹	F	L ¹	F
OW-5M	F	F	F	F	F	F	F	F	L ¹	F	L ¹	F
OW-5D	F	F	F	F	F	F	F	F	L ¹	F	L ¹	F
Compliance Wells												
CW-1M						F		F		F		F
CW-1D						F		F		F		F
CW-2M						F		F		F		F
CW-2D						F		F		F		F
CW-3M						F		F		F		F
CW-3D						F		F		F		F
CW-4M						F		F		F		F
CW-4D						F		F		F		F

Notes:

F - Full Suite: Cr(VI), Cr(T), TDS, metals, general minerals

L - Limited Suite: Cr(VI), Cr(T), TDS, general minerals

¹ Depending on data collected during the first year, PG&E will request agency approval to analyze observation well samples for the limited suite during alternate quarters in the second year.

TABLE 4-2

Proposed Analytical Program

*Interim Measures No. 3. Groundwater Compliance Monitoring Program**PG&E Topock Compressor Station*

Constituents	Units	Proposed Groundwater Sampling for Compliance Monitoring Plan		Treatment System Effluent Parameters Required Under MRP No. R7-2004-0103
		Full Suite	Limited Suite	
General Minerals				
TDS	mg/L	X	X	X
Turbidity	NTU	X	X	X
Specific Conductance	µmhos/cm	X	X	X
pH	pH units	X	X	X
Fluoride	mg/L	X	X	X
Ammonia (as N)	mg/L	X		X
Nitrate/nitrite (as N)	mg/L	X	X	X
Sulfate	mg/L	X	X	X
Chloride	mg/L	X	X	
Total Iron	mg/L	X		X
Boron	mg/L	X	X	X
Calcium	mg/L	X		
Magnesium	mg/L	X		
Potassium	mg/L	X		
Sodium	mg/L	X		
Alkalinity (as CaCO ₃)	mg/L	X		
Metals				
Aluminum	µg/L	X		X
Antimony	µg/L	X		X
Arsenic	µg/L	X		X
Barium	µg/L	X		X
Beryllium	µg/L	X		
Cadmium	µg/L	X		
Cobalt	µg/L	X		
Chromium, Total	µg/L	X	X	X
Chromium VI	µg/L	X	X	X
Copper	µg/L	X		X
Lead	µg/L	X		X
Manganese	µg/L	X		X
Mercury	µg/L	X		
Molybdenum	µg/L	X		X
Nickel	µg/L	X		X
Selenium	µg/L	X		
Silver	µg/L	X		
Thallium	µg/L	X		
Vanadium	µg/L	X		
Zinc	µg/L	X		X

TABLE 5-1

Target Levels and Action Levels for WDR Constituents for Observation Wells in East Mesa Injection Area
 Groundwater Compliance Monitoring Plan
 Interim Measures No 3. Injection Area, PG&E Topock Compressor Station

Constituent	Range	Standard Deviation	Upper Limit of Range Exceeds WDR Discharge Limit	WDR Discharge Limit		Target Value	Action Level
				Average	units		
Aluminum	ND (52)	NA		50	µg/L	50	37.50
Ammonia (as N)	ND (0.5)	NA		1.5	mg/L	1.5	1.13
Barium	0.0319 - 0.113	NA		0.3	mg/L	0.3	0.23
Boron	0.374 - 1.80	0.44	X	1.9	mg/L	1.9	2.3
Copper	1.55 - 10.6	NA		20	µg/L	20	15
Fluoride	ND (0.5) - 2.16	0.76	X	0.3	mg/L	2.16	2.92
Hexavalent Chromium	ND (1.0) - 32.6	8.65	X	8	µg/L	32.6	41
Iron (total)	ND (0.021) - 0.407	0.117	X	0.3	mg/L	0.407	0.52
Lead	ND (1) - ND (2.1)	NA		2	µg/L	2	1.50
Manganese	1.07 - 628	154	X	50	µg/L	628	782
Molybdenum	11.5 - 89.3	22.8	X	10	µg/L	89.3	112
Nickel	ND (1) - 21	4.8	X	12	µg/L	21	25.8
Nitrate as N	0.107 - 3.18	NA		10	mg/L	10	7.50
pH	7.53 - 8.62	0.2	X	7.5	units	8.62	8.82
Sulfate	107 - 571	142	X	250	mg/L	571	713
TDS	908 - 10,800	2,380	X	500	mg/L	10,800	13,180
Total Chromium	ND (1.0) - 29.5	8.7	X	25	µg/L	29.5	38
Zinc	ND (10) - 80.2	11	X	80	µg/L	80.2	91.2

Notes:

1. Concentrations: micrograms per liter (µg/L), milligrams per liter (mg/L), and pH units
2. ND = not detected at listed reporting limit
3. NA = not applicable
4. Shading indicates upper limit of parameter range exceeds WDR discharge limits
5. Refer to Section 5.2 for explanation of Target Values and Action Levels

Figures

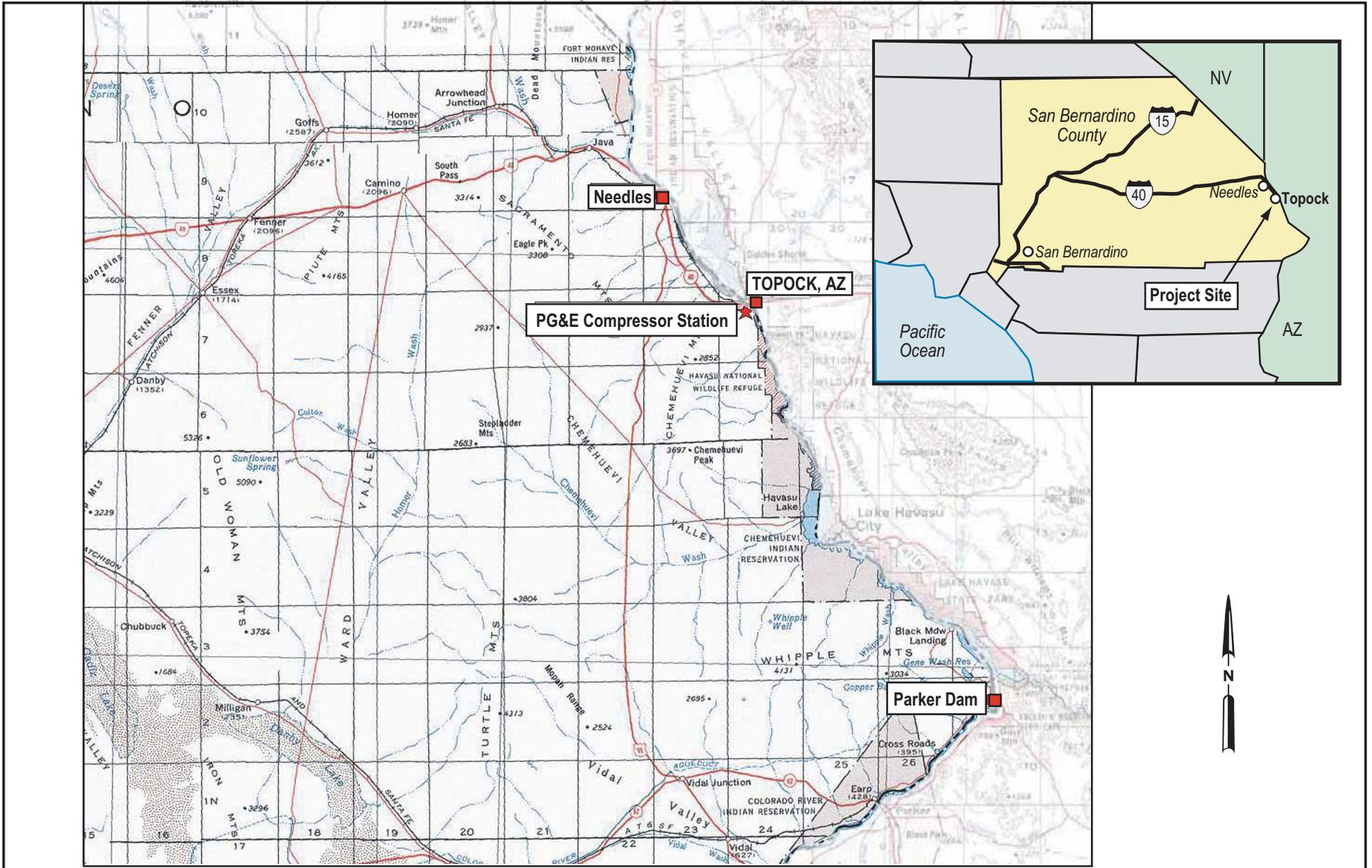


FIGURE 1-1
SITE LOCATION
 IM-3 COMPLIANCE MONITORING PROGRAM
 PG&E TOPOCK COMPRESSOR STATION
 NEEDLES, CALIFORNIA

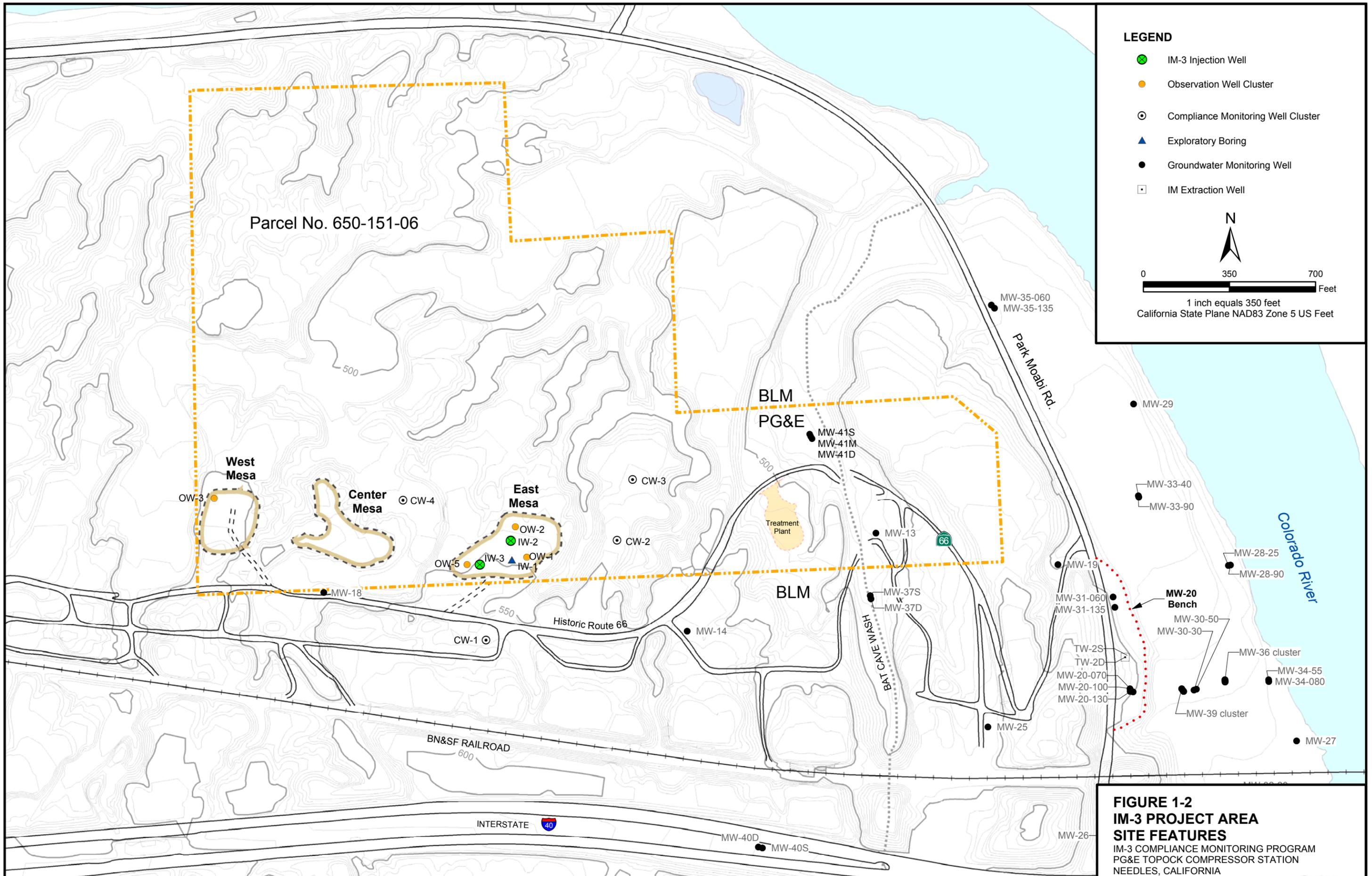


FIGURE 1-2
IM-3 PROJECT AREA
SITE FEATURES
 IM-3 COMPLIANCE MONITORING PROGRAM
 PG&E TOPOCK COMPRESSOR STATION
 NEEDLES, CALIFORNIA

Appendix A
Procedures for Calculation of Freshwater
Equivalent Heads, PG&E Topock Program

Procedures for Calculation of Freshwater Equivalent Heads

PG&E Topock Program

This technical procedure details instructions for adjusting groundwater elevations to freshwater equivalent heads. As necessary, this document also identifies procedures for “legacy” data (data collected before current protocols were implemented).

FIELD MEASUREMENT OF SALINITY

The following parameters may be measured in the field or laboratory to determine the density of the water column:

Parameter	Units	Typical Range	Description
Specific Conductance (SC)	μS/cm @ 25°C	FW: 0-1,500 μS/cm BW: 1,500-15,000 μS/cm SW: 15,000-150,000 μS/cm BR: >150,000 μS/cm	The conductivity normalized to a temperature of 25°C. Note that a typical seawater SC is approximately 47,000 μS/cm. The term Electrical Conductivity (EC) is often used interchangeably, though this parameter is not corrected to 25°C.
Salinity	%	FW: 0-0.1% BW: 0.1-1% SW: 1-10% BR: >10%	A measure of the dissolved salts in water on a mass per mass basis. Note that a typical seawater salinity is approximately 3.5.
Total Dissolved Solids (TDS)	mg/L	FW: 0-1,000 mg/L BW: 1,000-10,000 mg/L SW: 10,000-100,000 mg/L BR: >100,000 mg/L	A measure of the mass of dissolved solids in water on a mass per volume basis. Note that a typical seawater TDS is approximately 35,000 mg/L.

Notes:

FW – Fresh Water; BW – Brackish Water; SW – Salt Water; BR – Brine

Field instruments typically report EC at 25°C, which is by definition specific conductance.

CALCULATION OF DENSITY

The density of water in a well is required to adjust hydraulic heads to freshwater equivalent heads. However, the density of water is rarely measured in the field. Rather, either the salinity or conductance of the water is measured in the field or the conductance or total dissolved solids is measured in the laboratory and a density is calculated from these values.

Salinity and TDS measure very similar properties and conversion between the two parameters can be done using the following formula:

$$\text{Salinity}(\%) = \frac{\text{TDS}(\text{mg} / \text{L})}{10,051.1}$$

Salinity and TDS are typically laboratory-based measurements. If salinity or TDS are provided as field measurements, they are likely based upon a linear, non-site-specific conversion from a specific conductance measurement.

Specific conductance (electrical conductivity at 25°C), however, is often the most commonly available measurement in both field and laboratory data. Specific conductance is a measure of a water’s ability to conduct electricity, but can be used to estimate the density of the water. With site-specific information regarding the relationship between the specific conductance and the salinity, TDS, or density, the specific conductance measurements can be used to accurately make the freshwater head corrections. The following formula is used to convert specific conductance to TDS:

$$TDS (mg / L) = SC (\mu S / cm) \cdot K$$

where K is a dimensionless constant typically ranging between 0.55 to 0.8.

The dimensionless constant K is often assumed to be 0.65 for typical groundwater. However, K is dependent upon the type of groundwater. For example, water that contains predominantly sodium and chloride will have a different constant than water that contains predominantly sodium and bicarbonate. Where a high level of accuracy is required in calculating the density from specific conductance is required, site-specific constants can be obtained for calculating salinity or TDS from specific conductance. An evaluation of the site-specific constants at the Topock site is provided in Appendix A.

DATABASE SETUP

Within the Topock database, manual and transducer water level data are stored in the tables *tblWaterLevel* and *tblIPT*, respectively. Salinity and temperature data used to adjust the water levels are also stored for each measurement in these tables. The design of both tables is shown below.

tblWaterlevel : Table			
	Field Name	Data Type	Description
	LocID	Text	Location ID (e.g., well, boring, station)
	SampleDate	Date/Time	Date of measurement
	SampleTime	Date/Time	Time of measurement
	EventCode	Text	Monitoring event code
	SrcCode	Text	Data source (e.g., CH2M HILL, PG&E, Legacy, etc.)
	MeasPtElev	Number	Elevation (ft AMSL) from which depth to water was measured (e.g., top of PVC)
	DTW	Number	Depth to water (ft)
	RawSalinity	Number	Raw salinity measurement (e.g., salinity, field measured specific conductance, lab TDS, etc.)
	RawSalinityDate	Date/Time	Date of salinity measurement, if applicable
	CalcCode	Text	Code identifying the type of raw salinity and conversion used to convert to salinity
	CalcComment	Text	Comment on salinity conversion
	Salinity	Number	Final salinity of water column (%)
	Temperature	Number	Temperature of water column (°F)
	TemperatureComment	Text	Comment on temperature conversion
	RawWElev	Number	Unadjusted groundwater elevation (ft AMSL)
	CorrectWElev	Number	Final salinity and temperature adjusted groundwater elevation (ft AMSL)
	Comments	Text	General comment
	dbdate	Date/Time	db upload date

Field Name	Data Type	Description
LocID	Text	Location ID (e.g., well, boring, station)
Date	Date/Time	Date of measurement
Time	Date/Time	Time of measurement
ElapsedTime	Number	Elapsed time since transducer test began (minutes)
Temp	Number	Temperature (°C)
PressHead	Number	Raw pressure head (ft)
Offset_ft	Number	Offset or elevation of transducer above datum (ft)
Salinity	Number	Salinity of water column (%)
SalCorr	Number	Salinity correction to be applied (ft)
TempCorr	Number	Temperature correction to be applied (ft)
HydHead	Number	Final salinity and temperature adjusted hydraulic head (ft AMSL)
Comment	Text	Comment regarding measurement
DST	Number	True (-1) if PDT; FALSE (0) if standard PST
Exclude	Number	True (-1) if data point to be excluded; FALSE (0) if valid data

In *tblWaterLevel*, the field *CalcCode* identifies what value is stored in the *RawSalinity* field and how the final salinity value is determined. Possible conversions codes and the corresponding conversions to salinity (in %) include:

- FEC2SAL** field-measured EC¹ (uS/cm) converted to salinity (%)
[SAL=EC*0.65/10051.1]
- LEC2SAL** laboratory-measured EC¹ (uS/cm) converted to salinity (%)
[SAL=EC*0.65/10051.1]
- FTDS2SAL** field-measured TDS (mg/L) converted to salinity (%) [SAL=TDS/10051.1]
- LTDS2SAL** laboratory-measured TDS (mg/L) converted to salinity (%)
[SAL=TDS/10051.1]
- LSAL** laboratory-measured salinity (%) [no conversion]
- FSAL** field-measured salinity (%) [no conversion]
- PSAL** salinity (%) measured during previous event [no conversion]

DETERMINATION OF DENSITY AS A FUNCTION OF SALINITY

Data collected and reported prior to 2002 were not adjusted to freshwater equivalent heads. In 2003, well and date-specific salinity data were used to adjust these legacy data to freshwater equivalent heads. The legacy data have numerous sources and field-measured salinity data were often not available. The following, in order of precedence, details the methodology to populate the salinity value for the legacy manual water level measurement.

1. Field salinity (%) available ±3 days of the water level measurement:
 - *RawSalinity* is the field salinity value in %
 - *RawSalinityDate* is the date of the field salinity measurement
 - *CalcCode* is FSAL for a direct field salinity measurement
 - *Salinity* is populated with *RawSalinity* x 1.00 (the *CalcConversion* for FSAL)

¹ The term “EC” as used here is actually SC, as Topock field meters already convert to conductance at 25°C.

2. Field (1st) or Lab (2nd) SC available at ± 3 days of the water level measurement:
 - *RawSalinity* is the field or lab SC value
 - *RawSalinityDate* is the date of the field or lab SC measurement
 - *CalcCode* is FEC2SAL LEC2SAL indicates the field or lab SC value, respectively, is to be converted to salinity
 - *Salinity* is populated with $RawSalinity * 0.75 / 10051.1$ (or multiply 0.000074619)
3. Field (1st) or laboratory (2nd) TDS available at ± 3 days of the water level measurement:
 - *RawSalinity* is the field or lab TDS value
 - *RawSalinityDate* is the date of the field or lab TDS measurement
 - *CalcCode* is FTDS2SAL or LTDS2SAL indicates the field or lab TDS value, respectively, is to be converted to salinity
 - *Salinity* is populated with $RawSalinity / 10051.1$ (or multiply 0.000099492)
4. Salinity value from previous sampling/monitoring event:
 - *RawSalinity* is the salinity (%) from previous monitoring event
 - *RawSalinityDate* is the date of the measurement for the previous event
 - *CalcCode* is PSAL indicating salinity is from a previous event
 - *Salinity* is populated with *RawSalinity* (i.e., no conversion)

On 06/02/03, there were 506 manual water level measurements (data through 12/02/02) in the Topock db. As outlined in Steps 1 through 3, salinity values were populated into *tblWaterLevels* using date matches (± 3 days) between water level and salinity (including EC or TDS) measurements. The results were as follows:

FSAL (measured field salinity):	74 records (15%)
FEC2SAL (field measured SC):	79 records (16%)
LEC2SAL (lab measured SC):	189 records (37%)
FTDS2SAL (field measured TDS):	0 records
LTDS2SAL (lab measured TDS):	0 records

Further evaluation was required for legacy manual water level data which did not have salinity measurements on the same date. Some older legacy data only had year and month, and in such cases salinity values from that month were used. Many others slightly exceeded the ± 3 days search window, but had data ± 10 days. Ultimately, reasonably close dates for legacy manual water level and salinity data were found, so that salinity adjusted groundwater elevations could be calculated.

Data collected between January 2003 and August 2004 were corrected for salinity using field measured salinity. If a field salinity measurement was not available, the same routine was used to populate the salinity field as shown above for the legacy data.

Beginning August 2004, a median salinity for the water column has been used to adjust groundwater elevations for salinity. The median salinity value is used because:

- the median salinity of the water column is more representative of the water column than the salinity obtained from sampling the aquifer

- an error during a single even can result in an erroneous groundwater elevation whereas the median salinity is not significantly affected

The median salinity value for each well is evaluated quarterly to ensure trends in salinity are not present. In addition, sampling protocols have been changed to ensure the entire well casing volume (blank and screened portions of a well) are purged during sampling events.

DETERMINATION OF DENSITY AS A FUNCTION OF TEMPERATURE

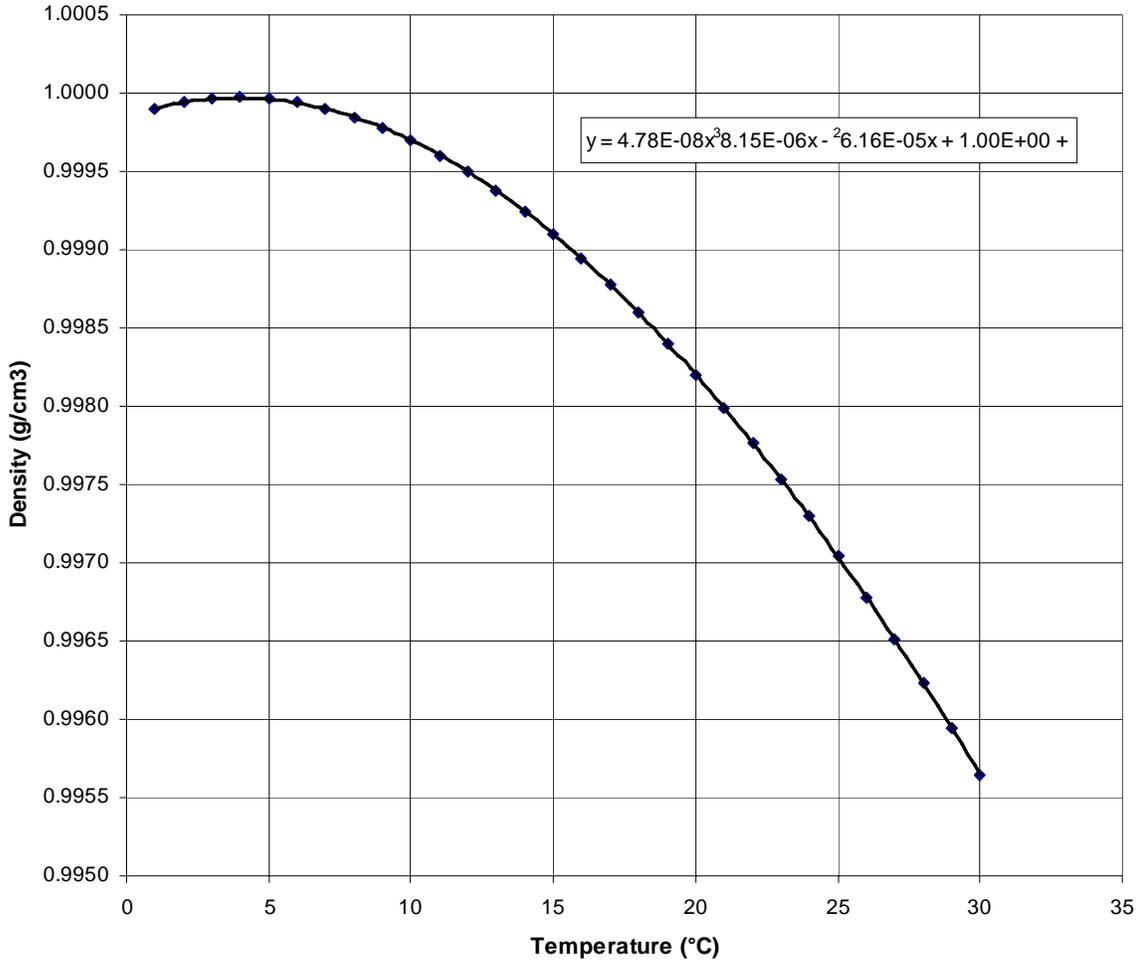
The density of water is dependant upon temperature. The following table and graph summarize the density of water at various temperatures.

**TABLE A2-1
 RELATIONSHIP BETWEEN TEMPERATURE
 AND DENSITY OF WATER**

Temp. (°C)	Density (g/cm3)	Temp. (°C)	Density (g/cm3)	Temp. (°C)	Density (g/cm3)
1	0.999900	11	0.999605	21	0.997992
2	0.999941	12	0.999498	22	0.997770
3	0.999965	13	0.999377	23	0.997538
4	0.999973	14	0.999244	24	0.997296
5	0.999965	15	0.999099	25	0.997044
6	0.999941	16	0.998943	26	0.996783
7	0.999902	17	0.998774	27	0.996512
8	0.999849	18	0.998595	28	0.996232
9	0.999781	19	0.998405	29	0.995944
10	0.999700	20	0.998203	30	0.995646

Source: Win-Situ 4 User Manual (In-Situ 2003)

FIGURE A2-1
 RELATIONSHIP BETWEEN TEMPERATURE AND FRESH WATER



Source: Win-Situ 4 User Manual (In-Situ 2003)

The following, quoted from the USGS WRIR 00-4014 (Quality Assurance and Analysis of Water Levels in Wells on Pahute Mesa and Vicinity, Nevada Test Site), summarizes the methodology to correct groundwater elevations for temperature-dependant density:

The following equation, described by Winograd (1970), can be used to calculate a water-level change resulting from a temperature change:

$$n'/n = s/s'$$

where n' is the length of water column above the point of inflow after a given temperature change; n is the measured water column length above the point of inflow (assumed to be the top of the open interval, in this example); s is the specific weight (or density) of water in the column at the mean water-column temperature and hydrostatic pressure; and s' is the specific weight (or density) of water at the new temperature and identical hydrostatic pressure.

For the purposes of the following example, the density of distilled water for a given temperature at 1 bar, obtained from Lide (1992, p. 6-10), will be used.

The density of water, s , in well PM-1 at a mean temperature of 113.5°F is 0.9900 gm/cc (grams per cubic centimeter). Assuming that the mean temperature in the well rose 5°F to 118.5°F, the new density of water, s' , would be 0.9888 gm/cc. The measured water-column length above the assumed point of inflow, n , is 5,450 ft. Solving the above equation for n' , the length of the water column after a 5°F rise in temperature would be 5,456.6 ft, resulting in an increase in water level of 6.6 ft. (<http://water.usgs.gov/pubs/wri/WRIR00-4014/text/waterlevel.htm#Temperature%20Effects>)

SALINITY AND TEMPERATURE ADJUSTMENTS FOR GROUNDWATER ELEVATIONS

Manual and transducer water level data have been corrected for salinity and temperature since January 2003. The salinity and temperature adjusted water elevations are stored in the *CorrectWElev* and *HydHead* fields in *tblWaterLevel* (manual water level data) and *tblPT* (transducer data), respectively. It is assumed that:

- The salinity of the water column with the wells is constant throughout the water column.
- The bottom of the well is the measurement point and the entire water column is adjusted for salinity and temperature.

The salinity adjustment (*SalCorr*) for each water elevation is calculated as follows:

$$SalCorr (ft) = Column \times SAL \times 0.0071$$

where *SAL* is the salinity of the water column in percent, and *Column* is the height of the water column to be adjusted in feet.

For manual water level data, the height of the water column is the distance from the water table to the bottom of the screen. For transducer data, the water column is the distance from the transducer to the bottom of the screen, since the water column above the transducer is inherently adjusted for density (i.e., the transducer measures pressure and not distance).

The temperature-dependant density of water within the well is determined using the following empirical equation (see chart on previous page):

$$Density (g/cm^3) = 4.78 \times 10^{-8} T^3 - 8.15 \times 10^{-6} T^2 + 6.16 T + 1.00$$

where *T* is temperature in degrees Celsius (°C).

The temperature adjustment (*TempCorr*) for each water elevation is calculated as follows:

$$TempCorr (ft) = Column \times [1 / Density] - Column$$

For manual water level data, the temperature and salinity adjusted groundwater elevation is calculated as follows:

$$CorrectElev (ft AMSL) = RawElev + SalCorr + TempCorr$$

where RawElev (ft AMSL) is the groundwater elevation with no adjustment for temperature or salinity.

For transducer data, the temperature and salinity adjusted groundwater elevation is calculated as follows:

$$\text{HydHead (ft AMSL)} = \text{PressHead} + \text{Offset} + \text{SalCorr} + \text{TempCorr}$$

where PressHead (ft) is the height of the water column above the transducer and offset (ft AMSL) is the elevation of the transducer above the datum.

Example Salinity Correction

From MW-22 on 09/30/99

Well Depth = 23' below top of casing (BTOC)

Top of PVC = 459.93' AMSL

Depth to water (DTW) = 4.78' BTOC

Field SC measurement = 25,600 μ S/cm

According to FEC2SAL:

$$\begin{aligned} \text{SAL} &= \text{SC} [\mu\text{S}/\text{cm}] * 0.75 / 10051.1 \\ &= 25,600 * 0.000074619 \\ &= 1.91\% \end{aligned}$$

The unadjusted groundwater elevation is:

$$\begin{aligned} \text{RawWElev} &= \text{Top of PVC} - \text{DTW} \\ &= 459.93' \text{ AMSL} - 4.78' \text{ BTOC} \\ &= 455.15' \text{ AMSL} \end{aligned}$$

The salinity adjusted groundwater elevation is:

$$\begin{aligned} \text{CorrWElev} &= \text{RawWElev} + (\text{Well Depth} - \text{DTW}) \times \text{Salinity} [\%] \times 0.0071 \\ &= 455.15' + (23' - 4.78') \times 1.91\% \times 0.0071 \\ &= 455.15' + 0.247' \\ &= 455.40' \text{ AMSL} \end{aligned}$$

Example Salinity & Temperature Corrections

Parameter/Calculation	MW-24BR	MW-33-90	MW-33-90	MW-10
Top of Casing (ft AMSL)	563.95	487.57	487.57	530.65
Well Depth (ft BTOC)	441.21	91	91	97.64
DTW (ft BTOC)	107.09	31.19	31.19	74.03
Water Column (calculated)	334.12	59.81	59.81	23.61
Raw or Uncorr. GW Elev. (from db)	456.86	456.38	456.38	456.62
Uncorr. GW Elev. (calculated)	456.86	456.38	456.38	456.62
Salinity (%)	0.82	0.5	0.5	0.2
Salinity Corr. GW Elev. (from db)	458.8053	456.5923	456.5923	456.6536
Head Difference (Salinity - Raw)	1.9453	0.2123	0.2123	0.0336
Approximate Temperature ($^{\circ}$ F / $^{\circ}$ C)	84.5 / 29.2	80.0 / 26.7	85.0 / 29.4	82.8 / 28.2
Temp. Corr. GW. Elev.	455.3989	456.1707	456.1277	456.5307
Head Difference (Temp - Raw)	-1.4611	-0.2093	-0.2523	-0.0893