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Technical Memorandum
Groundwater Pilot Study

Topock Compressor Station
Needles, California

Prepared for
Department of Toxic Substances Control

On behalf of
Pacific Gas & Electric Company

September 2003

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Table of Contents

Tables

Figures

Acronyms and Abbreviations

bgs	below ground surface
CACA	Corrective Action Consent Agreement
Cal-EPA	California Environmental Protection Agency
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CHSC	California Health and Safety Code
CMI	corrective measures implementation
CMS	Corrective Measures Study
COC	constituent of concern
CRBRWQCB	California Regional Water Quality Control Board – Colorado River Basin Region
CWG	Consultative Working Group
DTSC	Department of Toxic Substances Control
E&E	Ecology and Environment
MCL	maximum contaminant level
mg/kg	milligrams per kilogram
mg/L	milligrams per liter
O&M	operation and maintenance
PG&E	Pacific Gas and Electric Company
PRG	Preliminary Remediation Goals
RCRA	Resource Conservation and Recovery Act
RFI	RCRA Facility Investigation
TDS	total dissolved solids
USEPA	U.S. Environmental Protection Agency

1.0 Introduction

This Pilot Study Technical Memorandum presents the implementation strategy for pilot scale groundwater extraction and treatment at the Pacific Gas & Electric Company (PG&E) Topock Compressor Station Site. This Memorandum describes the proposed rationale, conceptual approach and scope of field tasks for the pilot test. The scope of the pilot study proposal is based on discussions with the California Environmental Protection Agency (Cal-EPA) Department of Toxic Substances Control (DTSC), California Regional Water Quality Control Board – Colorado River Basin Region (CRBRWQCB) and recommendations from the Topock Consultative Working Group (CWG).

The Topock Compressor Station is located in San Bernardino County, approximately 15 miles to the southeast of Needles, California (Figure 1). In February 1996, Pacific Gas and Electric Company (PG&E) and DTSC entered into a Corrective Action Consent Agreement (CACA) pursuant to Section 25187 of the California Health and Safety Code (CHSC). Under the terms of the CACA, PG&E was directed to conduct a RCRA Facility Investigation (RFI) and to implement corrective measures to address constituents of concern (COCs) released in the Bat Cave Wash Area near the PG&E Topock Compressor Station.

PG&E is currently proceeding with the corrective measure process. PG&E submitted the Corrective Measures Study (CMS) Workplan in December 2002, pursuant to the Resource Conservation and Recovery Act (RCRA) corrective action process and in accordance with the DTSC CACA. The CMS Workplan was approved by the DTSC in June 20003.

In August 2003, at the direction of DTSC, and in accordance with recommendations of the CRBRWQCB, PG&E agreed to conduct a Pilot Study of groundwater extraction and treatment. The purpose of the Pilot Study is to begin establishing hydraulic control of the chromium plume. The proposed system includes groundwater extraction from one extraction well, conveyance of extracted water to a skid-mounted treatment unit, treatment using chemical reduction/precipitation followed by filtration and discharge of the treated water.

1.1 Overall Approach to Site Remediation

The Pilot Study is part of the overall approach to the corrective measure process. It is a step in establishing a long-term strategy for site remediation. A background study is proposed to establish the range of naturally occurring Cr(VI) and Cr(T) concentrations near the site and in the surrounding region. Background concentrations will ultimately be considered when establishing clean up goals for the site. The results of the pilot study will be combined with the results of the background study in developing plans to remediate the site to the clean up levels and maintain hydraulic control of the plume.

2.0 Background

2.1 Site Description and History

The Topock facility began operations in 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 facility occupies approximately 100 acres owned by PG&E, 15 miles to the southeast of the City of Needles, along Interstate 40 in San Bernardino County, California (E&E, 2000). However, the study area covers land that is owned and managed by a number of federal and state agencies, as shown in Figure 2.

The site is characterized by arid conditions (precipitation averages less than 5 inches/year) and high temperatures. Vegetation is limited to the current river floodplain and includes salt cedar, tamarisk, and mesquite. The local geology consists of recent and older river deposits progressing westward to older alluvial deposits associated with the local mountains. Sands and gravels dominate these deposits, which comprise the principal groundwater aquifer at the site. More details on hydrogeology are provided below in Section 2.2. The main surface water drainage into the Colorado River is from Bat Cave Wash, an ephemeral streambed that is dry most of the year. This north-tending wash received the original discharges of cooling water containing chromium, as described below. Topography is abrupt, rising from around 450 ft above mean sea level (MSL) at the Colorado River to over 1200 feet above MSL within a mile to the south and southwest. Slopes encountered west of the river reflect a series of ancient river terraces.

The existing facility includes the compressor building, two water cooling towers, and an electric generator building for supplying power to the facility. Adjacent to the main buildings are various auxiliary buildings including offices, a warehouse, a vehicle garage, maintenance, equipment and chemical storage, an oil-water separator, and a water softener building. There are also tanks at the facility that are used to store water treatment chemicals, new and used compressor oil, and wastewater. Former structures that have been removed from service, or clean-closed in accordance with regulatory requirements, include a chromium treatment system, a chromate sludge reduction tank, and a chromate sludge drying bed (E&E, 2000).

The facility began operations in December 1951. From 1951 to 1985, a hexavalent chromium [Cr(VI)]-based corrosion inhibitor was added to the cooling water prior to its use in the cooling towers. In 1985, PG&E replaced the Cr(VI)-based corrosion inhibitor with a phosphate-based corrosion inhibitor. A chronology of the discharge history of cooling tower blowdown water and other nonhazardous wastewater from the facility is listed in Table 1 below (E&E, 2000).

Table 1: Discharge History

1951-mid 1960s	Cooling tower blowdown water was discharged to a percolation bed in Bat Cave Wash.
Mid 1960s-early 1970s	Cooling tower blowdown water was treated using a two-step chemical reduction process. Treated wastewater was discharged to percolation bed in Bat Cave Wash.
Early 1970s	Treated wastewater was discharged into injection well PG&E-8.
Early 1970s-1985	Treated wastewater was discharged to lined evaporation ponds. These ponds have since been closed and removed.
1985-1989	Phosphate-based corrosion inhibitor replaced the chromium-based corrosion inhibitor, and the wastewater was released to four new Class II double-lined evaporation ponds.
1989-present	Wastewater (not containing chromium) continues to be released to the four Class II double-lined evaporation ponds.

Other regulated and nonhazardous wastes that are not discharged to the evaporation ponds, such as waste compressor oil, are transported off site for recycling or disposal.

2.2 Site Hydrogeology

As discussed above, the main water-bearing zone of the subsurface is within sands and gravels associated with river and alluvial deposition. Adjacent to the Colorado River, shallow deposits consist mainly of poorly sorted sands from natural river deposits and from recent dredge spoils. Below these sands and further to the west, the sands grade into older alluvial deposits of sand, gravel, and minor silt. All but a few of the site monitoring wells are screened within these deposits, referred to collectively as unconsolidated alluvium.

Underlying the alluvium at the Topock Site is the Red Fanglomerate, a Miocene deposit of cemented sandy gravel (Metzger and Loeltz, 1973). The fanglomerate has been identified in several site wells, though the alluvium-fanglomerate contact is variable. The Bouse Formation has been mapped nearby, and where present it lies between the fanglomerate and the alluvium. It has not been positively identified in the boring logs of site wells, though distinction from the alluvium may not be apparent. The Bouse Formation was deposited in brackish or salt water, and where present, may be a source of salts in site groundwater (see discussion below). The basement bedrock of the area is composed of metadiorite. In both the fanglomerate and bedrock, groundwater occurs in secondary fractures. Local wells in these zones (PGE-7, PGE-8, MW-23, and MW-24BR) yield very little to moderate volumes of water.

Groundwater is encountered as little as 4 feet below ground surface in shallow wells in the current floodplain to over 200 feet at MW-16 in the western portion of the site. Horizontal groundwater gradients are gradual, on the order of 10^{-4} to 10^{-3}, with the higher gradients occurring in winter and spring. The gradients suggest a north-northeast flow direction, and the distribution of chromium in groundwater samples supports these flow directions. Water levels in well clusters at MW-20, -24, -30, -32, -33, and -34 all display upward gradients on the order of 10^{-2}, about 10 times the magnitude of the horizontal gradients. On the basis of screen elevations from these well clusters, the alluvium may be divided into upper, middle, and lower subzones. The majority of site wells are in the upper alluvium subzone.

Interaction of groundwater with the Colorado River is complex. The river levels fluctuate daily as much as 4 feet due to releases from Davis Dam for power generation. Historical water level data show that the river is lower than groundwater levels at least one third of the time and possibly more than half the time. Pressure transducers have been installed in newer wells close to the river to more closely monitor the surface water-groundwater interaction.

2.3 Nature and Extent of Chromium in Groundwater

Routine site-wide monitoring of the Topock site began in 1997. Currently, there is a network of approximately 35 wells from which groundwater samples are collected and analyzed for the COCs. Monitoring wells have been installed near and along Bat Cave Wash and to the east of the wash to characterize the Cr(VI) distribution in groundwater. The most recent installations included five wells located parallel to, and within the flood plain, of the Colorado River. The purpose of these wells is to better define the leading edge of the chromium plume in the groundwater, evaluate the vertical extent of the plume, and serve as sentry wells.

The majority of the monitoring wells are screened in the uppermost portion of the unconsolidated alluvium. In addition, seven surface water stations are located along the Colorado River and its tributaries. The locations of the wells and river stations are shown on Figures 2 and 3. In accordance with the CACA, COCs on the site are: total chromium, hexavalent chromium, nickel, copper, zinc, pH, and electrical conductivity (DTSC, 1996). Groundwater and surface water are routinely monitored for these COCs. In addition, groundwater and surface water are sampled periodically for general chemistry parameters including iron, lead, manganese, and total dissolved solids (TDS).

Given the historic chromium source location near MW-10, the current distribution of Cr(VI) in groundwater above the MCL of 0.05 mg/L reflects the north-northeast groundwater flow direction suggested by groundwater elevation contours. Figure 3 illustrates this distribution with data from the June 2003 sampling round. The distribution of wells with orange symbols on Figure 3 which indicate concentrations greater than 0.05 mg/L Cr(VI).

The reporting limit for analysis of Cr(VI) in groundwater used in the RFI and prior monitoring was 0.010 mg/L per the approved workplan (PG&E, 1997a). Beginning September 2003, as directed by the DTSC, a reporting limit of 0.001 mg/L will be used for Cr(VI) analyses for all surface water samples and groundwater samples collected from wells that have historically reported non-detect Cr(VI) concentrations (i.e., below the reporting limit of 0.010 mg/L). The more sensitive analytical method prescribed by California Department of Health Services (DHS) for water purveyors will be used to achieve the lower reporting limits (EPA Method 218.6 for drinking water and its equivalent SW 7199 method for wastewater and contaminated groundwater).

2.4 Groundwater Geochemical Conditions

Groundwater in the Needles-Topock vicinity is not used for drinking water supply due to high TDS concentrations. TDS ranges from 400-800 mg/L in river water to over 40,000 mg/L in groundwater. Most of the monitoring wells are in the TDS range of 1,000 to 3,000 mg/L. However, groundwater sampled in bedrock/fanglomerate wells and deep alluvium wells display higher values (8,000 to 12,000 mg/L).

Sources of salts are (1) connate water in bedrock, (2) remnants of the Bouse Formation, where it still exists, (3) evaporite salts associated with recent fluvial sands and dredge spoils, and (4) potentially PG&E historic cooling water discharge, reported to be about 6,600 mg/L (PG&E, 1997b). As a result, the distribution of TDS is variable.

Results of groundwater sampling also indicate pH ranges from 6.6 to 8.1. Sampling data indicate major ions, including chloride and sulfate, were found at concentrations of 800 to 6,000 mg/L and 300 to 1,300 mg/L, respectively. The preliminary indications of reduction-oxidation (redox) conditions reflect oxidizing conditions in which Cr(VI) is stable. Upon completion of the pilot test and further data collection, the hydrochemical nature of the groundwater and geochemical conditions of the site will be defined further.

The groundwater reduction/oxidation potential (redox) data collected during monitoring indicate generally oxidizing conditions with concentrations of dissolved oxygen ranging from 3.0 to 7.2 mg/L, and redox potential[1] up to 170 mV (indicative of oxidizing conditions). More reducing conditions were observed in shallow groundwater wells adjacent to the Colorado River. It is important to note that the oxidation or reduction of chromium in water is typically dominated by the solid aquifer material and soil structure, and not by the water itself. The hydrochemical nature of the groundwater and geochemical conditions of the site will be verified upon completion of the RFI and further data collection during the Pilot Study and the CMS.

[1] The redox potential of a system is a numerical measure of the degree to which that system provides conditions conducive to the oxidation or reduction of material within the system. In reduction-oxidation reactions one chemical species loses, while another gains electrons. A positive redox potential indicates an oxidizing environment.

3.0 Pilot Study

The Pilot Study will evaluate the aquifer response to pumping and the performance of the treatment system. The objective of the Pilot Study is to begin to achieve hydraulic control of the plume and to obtain information on the hydraulic and hygdrogeologic properties of the aquifer. An evaluation of the selected treatment technology will help determine the feasibility and design for a full-scale remediation system.

This section discusses the rationale for developing interim treatment goals for the pilot system, the groundwater flow model that will be used to evaluate the aquifer response and help design the long-term extraction system and the implementation of the pilot test. The implementation plan for the pilot study is a work in progress and the discussion presented in this section is based on our present understanding and information.

3.1 Interim Treatment Goals

The interim treatment goals for the pilot system will be determined based on a consideration of: (1) the California Primary Drinking Water Standards' maximum contaminant levels (MCLs) and (2) background levels of chromium in groundwater within the study area.

The California MCL for Cr(T) is 0.05 mg/L. To determine background levels of hexavalent chromium [Cr(VI)] and total chromium [Cr(T)] at and around the site, historic groundwater data, from monitoring wells that are located in areas not associated with past site chromium use/disposal, are being evaluated. These wells include monitoring wells around the new lined evaporation ponds i.e., MW-1 and MW-3 through MW-8 (see Figure 2), and wells MW-16, -17 and -18. Statistical analyses of this data will be conducted in accordance with DTSC's guidance. PG&E is working closely with the DTSC to ensure that the appropriate protocol is adopted in determining the background chromium levels.

3.2 Groundwater Flow Modeling

A numerical groundwater model is being developed to help satisfy the following objectives:

- Develop a tool to combine groundwater heads, aquifer properties, water balance, and river elevations to understand groundwater flow at the site;
- Evaluate the effect of the extraction well on groundwater flow; and
- Identify site locations for the long-term remedial system

As stated in the first objective, the model is an essential *tool* for understanding flow and comparing proposed scenarios. It is a working best-estimate that improves with newly collected data. The model will provide a better understanding of both the vertical and horizontal groundwater behavior at the site. With the information gained from the pilot study, the model will be updated and used to design a long-term plume containment strategy.

The model is currently being compiled from existing data and the updated site conceptual model. A finite element modeling code, MicroFEM (Hemker, 2003), will be used to provide very fine resolution in the floodplain area while also extending the model domain over a large area. The model domain will encompass the drainage basin around Bat Cave Wash, which begins in the hills behind the site, and will extend to Topock Slough and a limited area to the east of the Colorado River. Grid spacing will be around 10 feet in the floodplain area and gradually increase to 500 feet in the outer areas of the model. The model will be assigned five layers, approximately corresponding to the upper, middle, and deep alluvium followed by fanglomerate and bedrock. Initial model calibration will be under steady-state conditions, and calibration targets will be time-weighted average groundwater elevations from site monitoring wells. As transducer data from floodplain wells become available, refinement of the calibration will be performed by calibrating the model to these transient data.

Locations for the proposed extraction well will be reviewed with a preliminary version of the model. A goal in locating the pilot well will be to maximize the interception of chromium-containing groundwater while maintaining proximity to existing monitoring wells. The latter goal will result in better characterization of the alluvial aquifer. Data collected during testing of this well will help to improve model accuracy for use in long-term extraction design.

3.3 Pilot Test System

The pilot system includes the following elements:

- Extraction well (s)
- Treatment system
- Discharge / reuse of treated water

Implementation of the pilot system will involve siting, design, installation, start-up and operation of the system. The pilot system will be operated until the long-term corrective measure is selected. It is anticipated at this stage that the pilot system will be integrated into the long-term corrective measure.

A brief description of each element of the pilot system follows. The rationale for siting, selection of treatment technology(ies) and options for disposal / reuse are discussed below.

3.3.1 Extraction Wells and Monitoring System

The groundwater extraction system for the pilot test will consist of a single extraction (pumping) well. If practical, the extraction well will be located adjacent to the MW-24 cluster of wells which provides a network of monitoring wells within the area of influence. The information collected from these monitoring wells will be used to obtain hydraulic information. Groundwater modeling will be conducted to project the likely extent of the area of influence. The numerical groundwater model is currently being developed to evaluate the effect of the extraction well on groundwater flow and subsequently to help determine the location of additional extraction wells (see Section 3.3).

To best measure the aquifer properties within the area of influence, it is necessary to have monitoring wells positioned at various distances and directions from the pumping well. The monitoring wells need to be close enough to the extraction well to evaluate water table draw-down in the pilot test area. Preliminary calculations suggest that monitoring wells within approximately 100 feet of the extraction well will provide the best data. Both aquifer test analysis and zone of influence evaluation can be conducted on these monitoring wells. Wells located within 200 feet also may provide usable data. Beyond 200 feet, draw-down observed in monitoring wells is not expected to be significant enough to evaluate aquifer properties. Near the extraction well where vertical gradients are likely to develop, monitoring wells with discrete screened intervals at different depths will be used to provide information on the vertical hydraulic conductivity of the aquifer.

Based on the distribution of existing monitoring wells, the ideal location for the pilot test extraction well is in the vicinity of the MW-24 well cluster. The MW-24 cluster is located on a graded bench -west of the PG&E property boundary (Figure 4). The MW-24 cluster includes three monitoring wells: MW-24A screened in the upper alluvium, MW-24B screened in the lower alluvium / upper fanglomerate, and MW-24BR screened in the bedrock. By monitoring water levels in the MW-24 cluster, data could be obtained on vertical hydraulic conductivity between the upper and lower alluvium and potentially the bedrock.

Located within 1,000 feet of the MW-24 bench are monitoring wells MW-9, MW-10, MW-11, MW-12, MW-25 and MW-26. All of these wells are screened in the upper alluvium. These wells may provide an outer ring of groundwater level monitoring to help define the extent of the area of influence of a pumping well located on the MW-24 bench.

Also located on the MW-24 bench are wells PGE-6, and PGE-7. These wells were originally drilled in 1964 to provide water for the construction of the nearby interstate highway. Well PGE-6 was subsequently equipped with at pump and pipeline to connect to the station for use as a backup water supply. Historically however, PGE-6 was rarely used. Well PGE-6 is screened through the upper alluvium, from 110 to 180 feet below land surface with a 14 inch steel casing. A short-term aquifer test was conducted on PGE-6 in 1997 (E&E, 2002). Although it was reported that the well had low efficiency, it was able to produce approximately 50gpm without excessive drawdown. This indicates that the well is still open to the formation and could be used as a monitoring well or possibly an extraction well. Well PGE-7 was sleeved and deepened to 330 feet in 1969 and used as a monitoring well for a wastewater injection test. This well is no longer open to the upper aquifer but could provide a monitoring point for response in the bedrock / fanglomerate.

Three options for groundwater extraction have been identified. In arriving at these options, the existing network of monitoring wells, property ownership, site topography, and the potential discharge options were considered. These location options are described below and are summarized in Table 2. Figure 4 provides a map of the possible locations for a groundwater extraction well (includes topographic features).

Use Existing Well PGE-6 as an Extraction Well

Well PGE-6 is ideally located with respect to surrounding monitoring wells and proximity to PG&E property. This well is screened across most of the alluvial aquifer from 110 to 180 feet. The driller's log does not indicate the type of screen, but lists the perforations as 3/32 inch by 1 inch, which suggest either a slotted or louvered screen. The estimated depth of the red fanglomerate, based on the logs from the nearby MW-24 wells is approximately 205 feet. The depth to water in PGE-6 has been consistently measured at approximately 105-107 feet below land surface during recent years.

A video log was run on PGE-6 in 1998. PG&E has recently obtained and is in the process of reviewing the video tape to evaluate the condition of the well. Initial indications are that lower 20 feet of the well screen has silted in and is no longer open. The options for rehabilitation of well PG&E 6 are currently being evaluated to remove the silt from the bottom of the well and remove encrustation from the well screen. If the condition of the existing well casing is determined to be too poor to support the rehabilitation, consideration will be given to installing a new, smaller diameter casing and screen inside the existing well casing.

PGE-6 was drilled to provide water for the construction of the nearby interstate highway. The well was never used as a primary water supply for the compressor station, but it was equipped with a pump and a pipeline into the station for a standby water supply. The pipeline and power conduits are still in place, although the pump has been removed from the well. It is likely that the existing discharge piping and power conduits could be used for the Pilot Study which may provide a reduction in permitting time for this option. At present, it appears that PGE-6 could be brought online as a pilot test extraction well with minimal disturbance to offsite property. However a 45-day period associated with permitting from the Havasu Wildlife Refuge (HWR) is on the critical path in the schedule for implementation of this option.

Although well PGE-6 is not screened across the lower alluvium, aquifer test data will be leveraged using the MLU software, which is designed to utilize data from layered aquifers and partially penetrating wells (Hemker, 1985). A further description of the planned aquifer testing is provided in a subsequent section of this technical memorandum.

Based on groundwater sampling results, it appears that the lower alluvium contains water with high concentrations of TDS. The lower alluvial well (MW-24B) and the deep bedrock well (PGE-7) produce water with TDS in the range of 8,000 to 9,000 mg/L. However, wells MW-24A and PGE-6, completed in the upper alluvium, produce water with TDS in the range of 2,000 to 3,000 mg/L. Water with lower concentrations of TDS is favorable for the option of reusing treated water discharge at the PG&E compressor station. Water presently being used by the station has a TDS of approximately 1,600 mg/L. Reuse of treated water at the station may be one of the most appropriate discharge option to facilitate meeting the expedited implementation schedule. Hence this is a critical factor as well in the evaluation of groundwater extraction options.

To confirm that PGE-6 is still serviceable, a short - term aquifer test would be conducted at the earliest possible opportunity. This test would involve installation of a pump in PGE-6, and conducting an initial step draw-down test to determine optimum pumping rates, followed by a constant rate pumping test for a period of 8 to 10 hours. Water levels would be monitored in surrounding wells (MW-24 cluster and PGE-7). The primary purpose of this test would be to confirm the ability of PGE-6 to produce water for the pilot test and make an initial assessment of the degree of hydraulic connection between PGE-6 and the nearby monitoring wells. Water produced during this test would be stored in a portable, 20,000 gallon storage tank until the pilot treatment system becomes operational, at which time the water would treated and discharged along with other water generated during the Pilot Study.

In order to evaluate where the water is entering the well screen, logging will be conducted in the well during pumping. This logging would be conducted using either spinner or dye trace logging methods. Spinner logging involves pulling a small, propeller equipped for vertical monitoring through the well while pumping. Vertical velocity is determined from the rotational speed of the propeller. Dye trace logging is a method recently developed by the USGS. It involves release of small pulses of dye at different levels within the well and timing the arrival of the dye pulse in the pump discharge. If it is determined that water is only entering through a small section of the screen, it may indicate that the screen is plugged and that PGE-6 is not the best choice for use as a pilot test extraction well.

Installation of a New Extraction Well on the MW 24 Bench.

This option would include construction of a new groundwater extraction well on the MW-24 bench. There is limited area on this bench for access by drilling equipment. The exact location of the new well would be determined based on accessibility of the drilling site and proximity to existing piping and power lines for PGE-6.

The new extraction well would be constructed with 8-inch diameter casing and screen installed in a 14-inch diameter borehole. The borehole would be drilled to penetrate the entire thickness of the alluvial aquifer down to the depth of the red fanglomerate layer. This layer is estimated to be about 220 feet below land surface in the vicinity of the MW-24 bench. The well would be drilled using either mud rotary or dual-tube percussion drilling methods. The well will be cased with Schedule 80 PVC and screened with wire-wrapped stainless steel well screen. The screened interval would extend across the entire thickness of the alluvial aquifer, estimated to be at depths between about 110 and 220 feet below land surface.

Initial aquifer testing would be conducted in conjunction with the development of this well. The initial aquifer testing would consist of a short term, step draw-down test conducted over a period of a few hours. The primary purpose of this test is to estimate well capacity and sustainable flow rate. Water level monitoring will be conducted at surrounding wells to provide qualitative data on the degree of hydraulic connection between the wells. It is not anticipated that the water level data from this test would be used to estimate aquifer properties.

Implementation of this option would require an access permit from the Bureau of Reclamation as well as a well permit from the San Bernardino County. This option is on the schedule's critical path to meet the December 2003 start-up date.

Installation of a New Extraction Well on PG&E Property

Installation of an extraction well on PG&E property does not trigger the requirement for permitting. Siting the well on PG&E property therefore provides a scheduling advantage.

Due to topographic constraints, terrain, the most reasonable location for a new extraction well on PG&E property appears to be a flat area approximately 300 feet southeast of the MW-24 bench. Land surface in this area is approximately 60 feet higher than the land surface on the MW-24 bench, meaning that a well installed in this area would need to be deeper to penetrate the alluvial aquifer. A field survey would be required to determine if there is adequate space on this flat area to support a production well drilling effort. If this area turns out to be too small, an alternate location would be identified further to the south, likely within the fence line of the compressor station. The proposed new well would use the same design and construction techniques as the well described in the previous option. There is presently no power or pipeline routed to this area, however it would be relatively easy to bring those utilities in from the station.

The lack of nearby monitoring wells presents the biggest disadvantage to this option. The nearest wells are located on the MW-24 bench, approximately 300 feet away (Figure 4). Observed draw-down in the outer cone of depression (MW-24 cluster) is expected to be minimal. Permitting and installation of two or three monitoring wells within a radius of 100 feet from the new extraction well would therefore be required. The proposed additional wells are necessary to provide adequate groundwater monitoring during the pilot test. Two of these proposed wells would likely be sited on BLM land to the west of the new extraction well and one on PG&E land to the east. It is recommended that at least one of these wells be constructed as a cluster well, with discrete screened intervals in the upper and lower portions of the alluvial aquifer.

The water quality at this location must be reviewed for chromium concentrations. Potentially low chromium concentrations at this location could render the testing of the treatment technology inadequate.

3.3.2 Treatment System

The planned location of the pilot treatment system is within PG&E's property boundary to minimize property access and permitting issues, for ease of operation and proximity to discharge/reuse options.

Treatment technologies screened as potential options included: anion exchange, chemical reduction/precipitation followed by microfiltration, and reverse osmosis. These technologies were identified as promising options based on (i) the existing groundwater chemistry information in the area where the extraction well(s) is to be located (proximal to monitoring wells MW-24 cluster, PG&E-6 and -7), (ii) the proven effectiveness for treatment of chromium, (iii) the availability of these treatment systems as skid-mounted units, (iv) California case studies of the treatment of chromium in water.

Table 3 presents a comparison of the technologies that were screened. Based on feasibility of implementation and cost, the primary treatment technology selected for the pilot system is chemical reduction/precipitation followed by microfiltration. Pending the final decision on the discharge/reuse option(s), a secondary treatment unit may be required. The technology being considered for secondary treatment is reverse osmosis.

Preliminary criteria being assumed for design of the primary treatment system are:

- Flow rate ranging from 15-20 gallons per minute (gpm)
- Influent Cr(VI) concentration 1 - 5 mg/L
- Treated water discharge – single stream or multiple streams depending on final discharge/reuse options
- Target treated water Cr(VI) and Cr(T) concentrations – not to exceed 0.05 mg/L Cr(T), to be confirmed following establishment of interim treatment goals

A brief description of selected technologies is presented below.

Chemical Reduction/Precipitation/Filtration

Chemical reduction is commonly used to reduce soluble compounds to render them more suitable for removal by precipitation, and/or coagulation. Treatment chemicals are added to the influent to promote a chemical reduction reaction. Commonly used reducing agents for treatment of Cr(VI) are ferrous chloride, ferrous sulfate, sodium bisulfite, and sodium hydrosulfite. In the process selected for the pilot system, the reductant will be ferrous chloride/sulfate. Cr(VI) in the influent stream would gain electrons and be reduced to Cr(III), and iron (Fe) would lose electrons and be converted from Fe(II) to Fe (III). Normally, redox chemicals must be added in quantities greater than the stoichiometric ratio because the chemicals will be consumed by non-contaminant species, such as oxygen.

Unit processes in chemical reduction/precipitation systems for chromium removal typically include a reactant feed system, reaction (reduction) vessel, aeration tank for oxidation of excess iron, filtration system, and solids handling equipment for dewatering and disposal of precipitated residuals.

The ferrous iron reduction process is typically carried out with two reactors in series, the first for Cr(VI) reduction and the second, an aerated reactor to oxidize residual ferrous iron to the insoluble ferric state. Cr(VI) reduction can be achieved with ferrous iron compounds such as ferrous chloride/sulfate near neutral pH. Flocculants to aid settling of the Cr(III) and Fe(III) are added. The precipitated solids containing Cr(III) and Fe(III) hydroxides are removed by media or micro filtration (MF). Ferric chloride must be added and hydrolyzed to a precipitate prior to filtration. This will require rapid mixing facilities to mix the ferric chloride with sufficient energy to form a floc. The MF units will be backwashed on a periodic basis to remove accumulated ferric hydroxide solids.

Filter backwash is collected in a tank where solids are settled, and clear liquid decanted for reuse/disposal. Residual solids are often dewatered on- or off-site and disposed of according to federal and state regulations.

Operation and maintenance requirements include a part-time operator, supply of process chemicals including reagent, filter polymer, and dewatering polymer, and sludge transportation and disposal.

This technology has been proven effective for chromium removal in both bench and full-scale applications. Chemical reduction systems for Cr(VI) are off-the-shelf systems requiring appropriate sizing for varying flow rates and optimization for site specific conditions.

Reverse Osmosis

Reverse Osmosis (RO) is a membrane separation technology. This technology is being considered as a possible polishing step for the treated water prior to being reused as makeup water in the cooling towers at the Topock Compressor Station. The feasibility of reusing all or a part of the treated water at the Compressor Station is presently under consideration, pending information regarding the compatibility of treated water quality with plant operations (with respect to both total dissolved solids (TDS) and chromium concentration).

In RO systems, constituent removal is accomplished by pumping the water stream at high pressure across a semi-permeable membrane. RO membranes reject ions based on size and electrical charge and are commercially available in a variety of materials and chemical selectivities. RO had been used extensively for drinking water and industrial purposes and also to treat pumped groundwater or wastewater residual from a treatment process. The technology has been implemented at a number of sites and could be implemented at this site.

RO can be used to separate Cr (VI) (along with all the other dissolved solids) from the groundwater. This technology splits a feed stream into an effluent stream (the permeate stream) that would contain very low levels of Cr (VI), and a concentrated stream, which contains the Cr (VI) and other dissolved solids at elevated concentrations. The waste or reject stream, which commonly comprises about 25 percent of the feed flow rate, would then require further treatment or may be sent directly for disposal, possibly as a hazardous waste, depending upon the concentration of Cr(VI). The rejection percentage must be monitored to ensure Cr(VI) and TDS removal below the target level.

RO requires a careful review of influent water characteristics and pretreatment needs. Regular monitoring of membrane performance is also required to prevent membranes from fouling, scaling, or otherwise degrading. Suspended solids or solids formed by precipitation of reduced iron or manganese species in solution can foul the membrane.

Removal of suspended solids is necessary to prevent colloidal and bio-fouling, and removal of dissolved solids is necessary to prevent scaling and chemical attack. Acidic or caustic solutions are regularly flushed through the system at high volume/low pressure with a cleaning agent to remove fouling and scaling. Pressure, temperature, pH, and chemical requirements must meet membrane tolerances, and process operation requires significant operator supervision.

Treatment and management of the reject stream adds complexity and cost to the RO process. Depending on the allowable volume of treated water that could potentially be re-used at the station, the RO unit would be sized appropriately as a polishing step.

3.3.3 Discharge / Reuse of Treated Water

Discharge management is critical to the design and execution of the pilot system. The following alternatives were screened and evaluated to identify a reasonable disposal option that can be implemented within the short time schedule determined for the pilot system:

- Re-injection
- Re-use at the Topock compressor station
- Discharge to PG&E's existing lined evaporation ponds
- Discharge to the Colorado River.

Table 3 presents the screening matrix that was used to shortlist two of the four alternatives considered. As presented in the table, re-injection and reuse at the Topock Compressor Station appear to be the most feasible options at this stage for management of discharge from the treatment system.

The other two alternatives that were evaluated and eliminated during the screening process for the pilot system, include discharge to (i) the Colorado River and (ii) to the existing lined evaporation ponds at the Topock Compressor Station.

Discharge to the Colorado River is not considered a feasible option for management of treated water from the pilot system due to the time required to obtain an NPDES permit for the discharge (nominally 180 days), as well as to the possibility that effluent from the Pilot Study may not meet NPDES discharge requirements.

Discussions with PG&E's staff at the Topock compressor station indicated that the capacity of the lined evaporation ponds is 4 million to 5 million gallons. The waste discharge requirements (WDR) issued by the CRBRWQCB for the ponds allows a maximum flow rate to the ponds of 50,000 gallons per day. Although the compressor station rarely reaches this maximum daily flow rate, sustained flows at or near the rate would soon exceed the capacity of the ponds. The discharge flow rate from the compressor station varies greatly, ranging from about 8,000 gallons per day to greater than 40,000 gallons per day depending on the compression and gas flow rate. At high flow rates there is not enough extra pond capacity to allow significant outside flows to go to the ponds. Current predictions for the gas flow rate through the station are very high. If a discharge flow rate of 20-40 gpm is assumed from the pilot treatment system, and if this is to be discharged into the ponds, the daily rate outside of the discharge from the station would range from approximately 60,000 to 120,000 gallons per day. This would far exceed the capacity of the ponds and is therefore not being considered a feasible option for discharge management.

The options that appear feasible for implementation in a 3-4 month time frame therefore are: (i) re-injection using an infiltration gallery or injection well, (ii) reuse at the Topock compressor station as makeup water for the cooling towers.

These two options are currently being studied in greater detail for feasibility of implementation. Due to topographical constraints, siting of the re-injection system is complicated. In addition, there are hydraulic and water quality implications with re-injection which will be examined in greater detail while designing the system, using the groundwater flow model. The possibility of using existing injection wells is being explored.

Discussions are currently underway with the staff at the Topock Compressor Station to obtain more information on the water quality and compatibility issues and the infrastructural requirements / modifications required for re-use of the discharge water as makeup water in the cooling towers. Preliminary discussions indicate that part, if not all, of the treated water can be re-used at the compressor station. It is possible that the stream that is re-used in the cooling towers will need to be polished using RO to reduce the TDS levels in the water from the chemical reduction/ precipitation/ microfiltration system.

3.4 Pilot Test Implementation

Implementation of the pilot test will include: (i) aquifer testing to develop estimates of aquifer characteristics such as hydraulic conductivity and the hydraulic gradient in the test area and (ii) monitoring the effectiveness and performance of the treatment system.

3.4.1 Aquifer Testing

Once the pilot treatment system and extraction well are installed and operating reliably, aquifer testing will be initiated. The purpose of this testing is to obtain estimates of aquifer hydraulic properties that can be used to calibrate the groundwater flow model. The calibrated flow model will be used to design a full-scale groundwater extraction system. Key parameters to be estimated include vertical and horizontal hydraulic conductivity and specific yield.

The aquifer test will be designed as a constant rate pumping test with a pumping period of up to 10 days. The duration of the pumping period may be adjusted based on observed drawdowns during the test. Water levels will be monitored during both the pumping and recovery periods using pressure transducers installed in the pumping well and in surrounding monitoring wells where draw-down is expected to occur.

Aquifer test data will be analyzed using a software program (MLU) that is designed to accommodate partially penetrating wells and multiple layered aquifers (Hemker, 1985).

The MLU program utilizes a combination of analytical and numerical methods. It provides estimates of both horizontal hydraulic conductivity and the vertical leakance between aquifer layers. MLU allows simultaneous analysis of the water level data from the pumping well and multiple monitoring wells.

After estimates of the aquifer parameters are developed these values will be incorporated in the finite element groundwater model. Refinements to the parameter estimates will be developed as needed to replicate the aquifer test using the groundwater flow model.

Additional Data Collection Efforts

Several additional data collection efforts suggested by the USGS are being considered in conjunction with the pilot test. These data collection efforts will be considered as the pilot test progresses. A brief description of these additional activities is presented below:

1. Collection and Analysis of Soil Cores – soil cores would be obtained from any new wells drilled. These cores could be used for several purposes. Sub samples of the core could be submitted to a laboratory to obtain data on the vertical distribution of chromium and TDS. Sections of the core could also be used in bench-scale tests of in-situ remedial technologies for enhancement of the long-term remediation system. Finally, permeability testing could be carried out to evaluate the hypothesis that the high TDS water is associated with much lower permeability aquifer materials.
2. Borehole Geophysics – electromagnetic and gamma logs could be run on existing PVC cased wells and in any newly drilled boreholes. These logs could help define the lithology and better map the distinction between the relatively low TDS upper alluvium and the high TDS lower alluvium/fanglomerate.
3. Vertical Flow Measurements in Pilot Test Well – spinner logging or dye tracing could be conducted in the pumping well to determine where groundwater enters the well. Depth specific sampling could also be conducted to determine where the highest concentrations of chromium and TDS are entering the well. These studies could provide useful information for the design of a full-scale remediation system.

These data collection efforts will be considered and the details developed as the pilot test progresses.

3.4.2 Treatment System Monitoring

Monitoring the effectiveness and performance of the treatment system includes two main components: (i) treatment system operations monitoring and (ii) water quality monitoring. Treatment system operations monitoring involves the monitoring of the equipment operation and determining if the equipment is functioning within specification. Water quality monitoring is used to evaluate the effectiveness of the performance of the treatment process against established water quality treatment/disposal criteria. These two main types of monitoring are described in the following sections.

Treatment System Operations Monitoring

The treatment system will be designed to operate with minimal oversight by treatment operators. Electronic control loops will be included in the system design to:

- link extraction well operations with treatment system operations;
- regulate process flow rate within the plant;
- flow pacing of chemical feeds; and
- backwash filters.

Alarms will be provided to alert plant operators to process problems. Extraction well pumps and plant operations will shut down in the event of a process failure and/or mechanical damage. Alarms will be indicated on a local control panel at the treatment unit. Alarm conditions will also be relayed to the PG&E Compressor Station and the on-duty plant operator by means of an automatic phone or electronic dialer. A manual reset will be required to restart the plant. Water pH and oxidation-reduction potential (ORP) measurements will be conducted and filter effluent turbidity will be used to monitor treatment process performance. As long as reducing conditions (as measured by ORP) are maintained after chemical addition, there is confidence that the Cr(VI) in the groundwater will be reduced to target concentrations. Influent and treated water pH will also be monitored to ensure pH is within normal operating ranges. Low range turbidimeters will be used to evaluate filter performance.

The treatment plant operators assigned to operate this system will be qualified to calculate chemical doses, troubleshoot system chemistry and process operation, as well as be familiar with the mechanical and control equipment. The operator will be required to check chemical levels, check and adjust flow rates, clean and maintain instruments, and general maintenance and housekeeping.

Water Quality Monitoring

A Pilot Test Operation and Performance Monitoring Plan (PT Plan) will be developed to operate and evaluate performance of the pilot test system. The PT Plan will include detailed design criteria and assumptions to be used for the development of the pilot test design, and monitoring programs. Throughout the pilot test period, monitoring of system performance will be accomplished by monitoring both extracted water and treated water chemistry.

Monitoring of the pilot system will include characterization of extracted groundwater and treated water during start-up and initial operation (3-4 weeks following start-up) and during the performance monitoring period. Details of the monitoring frequency during these periods will be provided in the PT Plan. Sample characterization will include Cr(VI), Cr(T)], chemical reductant concentrations (ferrous chloride or ferrous sulfate) and geochemical parameters (TDS, alkalinity, chloride, phosphate, ammonia and nitrate, sulfate, dissolved iron and manganese). Parameters monitored at the unit, at time of sample collection, will include pH, dissolved oxygen and ORP.

4.0 Schedule

This section presents a preliminary schedule for the various tasks proposed as part of the Pilot Study and a conceptual schedule for the long-term remediation at the site. The activities for the long-term remediation at the site are in accordance with the requirements of the RCRA Corrective Action Process.

4.1 Pilot Study Schedule

A schedule for the various tasks for implementation of the pilot study is outlined below and presented in Figure 5.

- Implementation Planning — August – September 2003
- Fabrication, and Installation — September – December 2003
- System Start-up and Aquifer Testing — December 2003
- On-going Operation and Maintenance — December 2003 – continued

This schedule is subject to change based on additional information and decisions on the discharge system, regulatory review and approvals, and input from the CWG.

4.2 Long-term CMS Schedule

A conceptual schedule for the long-term corrective measure at the Topock site is summarized in Table 4 below. This schedule is for discussion purposes only and is at a preliminary stage. This schedule is also subject to change.

Table 4 Schedule for the Long-Term Corrective Measure Study

Task Name	Dates
Approval of Corrective Measure Study (CMS) Workplan by DTSC	June 2003
Preliminary Selection of Technologies	May 2003 - June 2003
Modeling	April 2003 – February 2004
Submit Technical Memorandum for Pilot Study	September 5, 2003
CWG Meeting to Discuss Technical Memorandum	September 18, 2003
Submit Workplan for Studies for Final Remedy	February 2004
DTSC Approval of Workplan	March 2004
Startup of Pilot System	December 2003

Task Name	Dates
Conduct Studies for Final Remedy	March 2004 – June 2004
Data Evaluation	June 2004 – July 2004
CMS Draft Report	June 2004 – August 2004
DTSC Approval of CMS Draft Report	August 2004 – September 2004
CMS Final Report	September 2004 – October 2004
Public Review	October 2004 – December 2004
Prepare CMS Implementation (CMI) Plan	October 2004 – January 2004
DTSC Approval of CMI	January 2005
Begin CMI Implementation	February 2005

5.0 Project Management

CH2M HILL will manage the Pilot Study. The proposed project management approach is intended to: (1) ensure a direct, continuous line of communication between DTSC, the PG&E project team and all stakeholders in the Consultative Technical Workgroup (CWG) (2) facilitate effective and efficient coordination and management of the various tasks; (3) implement this Pilot Study on time in compliance with the requirements of the DTSC.

The progress and performance of the project will be monitored through progress conference calls with the Consultative Workgroup, project team meetings, as necessary, and regular meetings with DTSC representatives and other stakeholders to discuss and resolve project issues and concerns.

6.0 References

Department of Toxic Substance Control (DTSC). 1996. Corrective Action Consent Agreement. February 2. 1996

Ecology and Environment, Inc. (E&E). 2000. *Draft RCRA Facility Investigation (RFI) Report, Bat Cave Wash Area, PG&E's Topock Compressor Station, Needles, California*. April 17. 2000.

Ecology and Environment, Inc. (E&E), 2002. Hydrogeological Testing Results, PG&E's Topock Compressor Station, Needles, California, April 1, 2002.

Hemker, C.J. 1985. A general purpose microcomputer aquifer test evaluation technique, Ground Water . v23, no.2, p. 247-253.

Metzger, D.G., Loeltz, O.J., and Irelan, B., 1973, Geohydrology of the Parker-Blythe- Cibola area, Arizona and California: U.S. Geological Survey Professional Paper 486-G, 130p.

PG&E, 1997a. RCRA Facility Investigation RFI Workplan, PG&E Topock Compressor Station. May 1997.

PG&E, 1997b. Current Conditions Report, PG&E Topock Compressor Station. May 1997.