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October 28, 2005

Norman Shopay
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California Department of Toxic Substances Control
Geology and Corrective Action Branch
700 Heinz Avenue
Berkeley, California 94710

Subject: Interim Measures Compliance Monitoring Program, Work Plan for Installation of Shallow Groundwater Compliance Monitoring Wells, PG&E Topock Compressor Station, Needles, California

Dear Mr. Shopay:

Enclosed is the *Work Plan for Installation of Shallow Groundwater Compliance Monitoring Wells* for the Interim Measure Compliance Monitoring Program at the PG&E Topock Compressor Station. This document presents both the results of the updated injection area groundwater flow model and a work plan to install four shallow monitoring wells at the existing compliance well locations. The work plan is submitted for review in conformance with Condition 17 in DTSC's July 15, 2005 letter "Conditional Approval for the Start Up and Operation of the Interim Measures No. 3 Treatment System and Injection Wells".

An additional requirement of Condition 17 in DTSC's July 15, 2005 letter is that the shallow compliance wells be installed within 90 days of work plan approval. The available data does not support the need for installation of new monitoring wells within this short time frame. Modeling simulations indicate that the effects of injection may not be seen at the radius of the compliance wells for several years. Monitoring data also indicate that it will be years before the injection front reaches the compliance monitoring points.

In submitting this document, PG&E is keenly aware of the sensitivity of cultural areas to the potential disturbance that would be caused by this work. The compliance well network is located within a sacred landscape. Drilling of additional wells and the associated management of waste cuttings, storage of materials, and vehicle traffic in and out of the well sites has the potential to affect an irreplaceable resource, and as such the necessity for these activities should be weighed carefully against the impacts of the work. Waiting until sufficient data are available to evaluate the need for new wells, and making informed decisions about their locations, would be a more prudent course of action, considering the potential for damage to cultural resources.

In recognition of these potential impacts, PG&E respectfully requests that DTSC reconsider the need to install shallow compliance wells within the current 90-day requirement. In the May 24, 2005 DTSC letter regarding "Interim Measures No. 3 Injection Well Field

Investigation and Monitoring," results of the groundwater model were used to determine appropriate timing, with a maximum installation time set at 545 days following the startup of injection. While it is not evident that shallow groundwater at the compliance points would be affected even within this time frame, the additional information obtained from the ongoing sampling program would be useful in evaluating the need for these wells.

Please contact me at (805) 546-5243 if you have any questions on the work plan or our request for a change to the installation schedule.

Sincerely,

Paul Betts for
Yvonne Meeks

cc. Kate Burger/ DTSC

Enclosure

Work Plan for Installation of Shallow Groundwater Compliance Monitoring Wells

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

October 28, 2005

CH2MHILL
155 Grand Avenue, Suite 1000
Oakland, CA 94612

Work Plan for Installation of Shallow Groundwater Compliance Monitoring Wells
Waste Discharge Requirements Order No. R7-2004-0103
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Needles, California

Prepared for
California Regional Water Quality Control Board, Colorado River Basin Region
and
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October 28, 2005

This work plan was prepared under supervision of a California Certified Engineering Geologist.

Paul Bertucci, C.E.G.
Project Hydrogeologist

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Acronyms and Abbreviations

ASTM	ASTM International, formerly American Society for Testing and Materials
bgs	below ground surface
BLM	United States Bureau of Land Management
CMP	Compliance Monitoring Plan
Cr(T)	total chromium
Cr(VI)	hexavalent chromium
CRBRWQCB	Regional Water Quality Control Board, Colorado River Basin
CW-#	Compliance Monitoring Well
CWG	Consultative Workgroup
DTSC	California Department of Toxic Substances Control
gpm	gallons per minute
IDW	investigation-derived waste
IM	Interim Measure
IW-#	injection wells
MRP	Monitoring and Reporting Program
PG&E	Pacific Gas and Electric Company
PVC	polyvinyl chloride
RCRA	Resource Conservation and Recovery Act
RFI	RCRA Facility Investigation
RO	reverse osmosis
TDS	total dissolved solids
TDS	Total Dissolved Solids
WDR	Waste Discharge Requirements

SECTION 1.0

Introduction

Pacific Gas and Electric Company (PG&E) is implementing an Interim Measure (IM) to address chromium concentrations in groundwater at the Topock Compressor Station near Needles, California under the oversight of the California Environmental Protection Agency, Department of Toxic Substances Control (DTSC). The IM consists of groundwater extraction for hydraulic control of the plume boundaries near the Colorado River floodplain, and management of extracted groundwater. The groundwater extraction, treatment, and injection systems are collectively referred to as Interim Measure No. 3 (IM No. 3). Currently, the IM No. 3 facilities include a groundwater extraction system, conveyance piping, a groundwater treatment plant, and an injection well field for the discharge of the treated groundwater. Figure 1-1 shows the location of the IM extraction, conveyance, treatment, and injection facilities.

On October 13, 2004, the California Regional Water Quality Control Board Colorado River Basin Region (CRBRWQCB) adopted Waste Discharge Requirements (WDR) Order No. R7-2004-0103, which authorizes PG&E to re-inject treated groundwater into injection wells located in the East Mesa area of the Topock site. The WDRs specify effluent limitations, prohibitions, specifications, and provisions for subsurface injection. Provision 6 of the Board Order required that a design plan for a representative groundwater compliance monitoring system in the vicinity of the subsurface injection wells be approved, and construction of the groundwater monitoring system be implemented prior to initiation of injection. The *Final Design Plan for Groundwater Compliance Monitoring* for IM-3 was approved by DTSC on December 23, 2004, with installation of the system being complete by March, 2005.

Four well clusters consisting of 2 wells each were installed during the December 2004 field program. This included CW-1M/D, CW-2M/D, CW-3M/D, and CW-4M/D. Screen intervals were chosen to correspond to coarser grained layers within the same general depth range as the injection wells, which are screened from about 60 feet below the water table to near the bottom of the alluvial aquifer (approximately 350 feet bgs). The measured water levels in the vicinity of the compliance wells range from approximately 60 to 110 feet below ground surface (bgs), while installed top of screen intervals for the medium depth wells range from 120 to 170 feet bgs.

On June 17, 2005, the Groundwater Compliance Monitoring Plan (CMP) for the IM-3 Injection Wellfield (CH2M HILL 2005c) was submitted to DTSC and CRBRWQCB, in accordance with the requirement in the Monitoring and Reporting Program (MRP) No. R7-2004-0103 associated with the Board Order. As per DTSC's requirement by letter of May 24, this plan outlined the conceptual framework for the installation of four monitoring wells, to provide additional shallow-depth information for the aquifer in the vicinity of the existing compliance monitoring well clusters (CW-wells). At that time, DTSC directed that the timing for installation was to be evaluated after considering groundwater flow simulation results from the updated injection area model, but no later than 545 days after start-up of IM-3 treatment. DTSC's conditional approval letter for the start-up of the IM-3 treatment system dated July 15, 2005, subsequently revised the installation schedule requirement for the shallow compliance wells to within 90 days of workplan approval.

This workplan meets the conditions of DTSC's May 24 and July 15 approval letter by providing the results of the updated groundwater flow model simulations for the vicinity of the injection system, the proposed design of four shallow groundwater compliance monitoring wells, and the scope of work and schedule to install and initially sample the wells.

1.1 Project Background

The Topock Compressor Station is located in San Bernardino County, approximately 15 miles to the southeast of Needles, California (inset map, Figure 1-1). In February 1996, PG&E and DTSC entered into a Corrective Action Consent Agreement pursuant to Section 25187 of the California Health and Safety Code. Under the terms of that agreement, PG&E was directed to conduct a Resource Conservation and Recovery Act (RCRA) Facility Investigation (RFI) and to implement corrective measures to address constituents of concern released in the Bat Cave Wash Area near the PG&E Topock Compressor Station. The primary constituents of concern at Topock are hexavalent chromium [Cr(VI)] and total chromium [Cr(T)]. The source was Cr(VI) salts historically used as a corrosion inhibitor in the station's cooling towers.

DTSC is the lead administering agency for the project. Assisting DTSC and PG&E with the planning and review of interim remedial measures are the members of the Topock Consultative Work Group (CWG), constituted under California's Site Designation Process, and consisting of representatives of DTSC, CRBRWQCB, Metropolitan Water District of Southern California, Arizona Department of Environmental Quality, various federal agencies who own or manage adjacent property, and other project stakeholders.

In March 2004, as directed by the DTSC PG&E began implementation of an Interim Measure consisting of groundwater extraction and management of extracted groundwater. Components of the current IM-3 system include continued groundwater extraction, piping, and conveyance of extracted groundwater to a treatment system; treatment of extracted groundwater using reduction-precipitation-filtration and reverse osmosis; and disposal of treated groundwater water by injection wells. Operation of the treatment system was conditionally approved on July 15, 2005, and injection began at the IM-3 Injection well field on July 31, 2005.

The injection well program includes two injection wells (IW-2 and IW-3). Four observation well clusters consisting of three wells each were installed to monitor changes in water levels and water quality in the immediate vicinity of the injection wells. Figure 1-2 shows the locations of the existing mid-depth and deep compliance monitoring wells (CW-1, CW-2, CW-3, and CW-4 clusters). Four compliance well clusters consisting of two wells each were located based on a ranking of four criteria, which included groundwater travel time, equipment access, cultural resource risk, and biological resource risk. Compliance wells were installed to monitor changes in water levels and water quality at the predetermined compliance points.

1.2 Project Objectives

The overall objective of this project is to provide adequate means to determine compliance with WDR Order No. R7-2004-0103, with respect to monitoring injection impacts on shallow groundwater surrounding the IM-3 injection wells. Previous model simulations estimated the time for impacted water to reach the compliance points to be from 3 to 9 years. Mid-depth and deep wells were installed at the compliance points with an assumption that shallow compliance wells could be installed at a later date - should monitoring of shallow depth, mid-depth and deep observation wells and compliance wells indicate that they were needed. In light of this, the specific objectives of this project are to:

- Use the available water quality and water level data to evaluate the current effects of injection on compliance point shallow groundwater.
- Prepare a workplan for the installation of shallow monitoring wells at the existing compliance monitoring well surface locations.
- Reduce impacts of future data collection activities on local cultural and biological resources. While ongoing data assessment may indicate the need for additional sampling frequency or the installation of additional monitoring points, reducing the impact of collecting data on sensitive resources will be taken into consideration to the extent possible during the scoping of additional work.

1.3 Overview of Recent Activities

Injection of IM-3 treatment plant effluent began on July 31, 2005. Approximately 80 gpm is currently being injected into injection well IW-2 on a continuous basis. The surrounding wells are monitored for water level and water quality changes as defined in the CMP, which specifies continuous water level monitoring using transducers and monthly analytical sampling until December 2005 (after December 2005, sampling frequency changes to quarterly).

Observation well clusters OW-1S/M/D, OW-2S/M/D and OW-5S/M/D were sampled for water quality in July, August and September 2005. Compliance monitoring well clusters CW-1M/D, CW-2M/D, CW-3M/D and CW-4M/D were sampled for groundwater quality in September 2005. All wells were continuously monitored for water levels, using dedicated transducers. The sampling methods, procedures, field documentation of the CMP sampling, water level measurements, and field water quality monitoring were performed in accordance with the *Sampling, Analysis, and Field Procedures Manual, Revision 1* (CH2M HILL 2005b).

Results of monthly sampling in July, August and September 2005 show that the water quality effects of injection have not been observed at the medium or deep wells at the compliance points. The water levels have increased slightly in the medium and deep compliance wells, although this increase occurred almost simultaneously with the start of injection and has not shown an increasing trend after two months of injection. Water levels in the shallow wells at the observation clusters close to the injection wells have not increase due to injection, so it is likely that water levels in the shallow groundwater at the compliance points have also been unaffected by the injection.

SECTION 2.0

Groundwater Modeling

2.1 Introduction

The purpose of this section is to provide information with respect to the timing of shallow compliance well installation. The existing compliance monitoring wells are designed to provide mid-depth and deep groundwater quality data, and to meet the Waste Discharge Requirements for a compliance monitoring program after injection begins. Specifically, the objective of future shallow compliance monitoring wells is to provide information on the effects of injecting effluent treated by the IM-3 treatment plant on the surrounding shallow groundwater quality in the East Mesa area.

A previous technical memorandum (CH2M HILL 2004b) selected the existing compliance well sites based on a ranking of four potential criteria (groundwater travel time, equipment access, cultural resource risk and biological resource risk). While this current modeling work will not re-visit the evaluation of compliance monitoring well site locations, the availability of post-injection water levels and water quality data presented an opportunity to refine the travel time estimates for IM-3 effluent-effected water to reach the previously selected well sites. To minimize any potential impacts to site resources, timing for the installation of shallow compliance monitoring wells should be based on these updated estimates.

The CRB RWQCB WDR R7-2004-0103 requires a minimum of one upgradient and two downgradient compliance monitoring wells associated with each injection well field. The DTSC has indicated that, where possible, compliance monitoring wells should be located within a distance representing about 2 years of groundwater travel time from the injection well fields. As previously mentioned, the computer groundwater flow model developed for design of the IM-3 extraction and treatment system was used to simulate the groundwater flow patterns from the injection well fields. The travel time and direction from the injection well fields were considered the most important criteria for selection of preferred compliance monitoring well locations, with the first-simulated advective front travel times as follows: CW-1 cluster, 3 years; CW-2 cluster, 3 years; CW-3 cluster, 6 years; CW-4 cluster, 9 years. These travel times were simulated using a combined injection rate of 21 gpm into IW-2 and IW-3.

2.2 Model Simulations of Groundwater Travel Time

Groundwater modeling was conducted to estimate the travel times through the aquifer between the East Mesa injection well field and the proposed shallow compliance monitoring well locations. Particle tracking was used to show groundwater flow paths in a steady-state groundwater flow field.

The model uses four vertical layers to simulate a total aquifer thickness of about 250 feet near the injection wells. Model parameter values for each model layer in the East and West

Mesa areas were estimated from aquifer tests conducted shortly after the injection and observation wells were installed. These values were assigned to this area of the aquifer, and verified with data obtained from transducers during the first several days of injection.

It was assumed for the newer simulations presented here that the treatment plant would be operating at its designed capacity of 135 gpm. However, the treatment system includes a reverse osmosis (RO) process that removes salts from the water. The byproduct of RO is a concentrated salt solution known as RO concentrate. This concentrate, which represents approximately 10 percent of the water passing through the RO unit, is not re-injected to the aquifer. Consequently, the injection rate used in the new model simulations was 120 gpm, about 10 percent less than the assumed pumping rate.

Injection simulations assumed 60 gpm flow into each of the IW-2 and IW-3 wells. The injection wells were simulated as fully penetrating wells, screened through all four model layers. The rate of injection into each layer is proportional to that layer's contribution to total transmissivity, which was estimated from the spinner test results obtained from wells IW-2 and IW-3 (CH2M HILL 2005d).

The effective porosity value used in these newer simulations was calibrated using the specific conductance breakthrough data recently collected at well OW-2D. The specific conductance in Well OW-2D began to change within 3 days of the start of injection. Within 2 weeks, the specific conductance in OW-2D was identical to that of the water being injected into IW-2, located about 50 feet away. To incorporate the transport velocity indicated by the observed breakthrough at OW-2D, the effective porosity in the model was set to a value of 5.2 percent. Typical values of effective porosity in sand and gravel would be 10 to 15 percent. Using a value of 5.2 percent provides equivalent transport velocities to a condition where most of the aquifer is lower-permeability silty and clayey sands, while higher-permeability cleaner sands and gravels make up about one third of the saturated thickness in the vicinity of the injection wells.

In alluvial fan depositional environments, sand and gravel zones that constitute higher-permeability zones are typically localized. The chaotic nature of alluvial deposition does not favor the development of laterally extensive layers or channels across large distances. It is therefore very unlikely that the higher-permeability material that exists between IW-2 and OW-2D extends laterally to the radius of the compliance wells. Hence, actual travel times to the compliance wells are likely to be much longer than the model projections, which are currently based on the 5.2 percent effective porosity calculated from injectate breakthrough at OW-2D. As more data become available, observation of breakthrough in multiple observation wells will be used to develop a much more accurate understanding of the range of effective porosity at the site. This will improve the accuracy of future model projections.

Using the current estimate of an effective porosity of 5.2 percent, particle tracking was used to simulate groundwater flow paths in a steady-state groundwater flow field. The results are provided in Figure 2-1. To simplify the figure, only representative particle flowpaths reaching each of the four proposed shallow compliance wells are shown. The deflections in the pathlines generally correspond to locations where particles move between model layers. This provides estimates of travel times for advective fronts to reach the compliance wells. Newly simulated advective front travel times are as follows: CW-1S, 4.2 years; CW-2S, 2.9 years; CW-3S, 2.4 years; CW-4S, 5.0 years. Heterogeneities in the aquifer between the injection wells and the proposed compliance wells could significantly alter actual travel times.

As the injection progresses and more data become available, model parameter values can be refined and the accuracy of projected travel times can be improved. At present, it appears unlikely that the travel times will be considerably less than recent projections. As discussed above, the effective porosity used in recent simulations is probably lower than the average value for this formation, and model-projected groundwater velocities are therefore likely to be higher than the actual average velocity.

SECTION 3.0

Effects of Injection on Groundwater

The compliance monitoring points were designed to provide additional site characterization and baseline groundwater quality data to satisfy the conditions of the Waste Discharge Requirements for a compliance monitoring program after injection began. Mid-depth and deep wells were installed to monitor the same strata as the screened interval of the injection wells. The top of the IW-2 and IW-3 well screens are 170 and 160 feet below ground surface, respectively. The top of the compliance well screens are 140 (CW-1M), 152 (CW-2M), 172.4 (CW-3M) and 119.5 (CW-4M) feet below ground surface. Injected water was anticipated to spread out largely in a horizontal direction from the injection points, moving in a vertical direction only as groundwater mounding developed around the injection wells (which have not yet been observed to a significant degree).

The compliance wells were scheduled to be monitored on a regular basis (semi-annually), to ensure that there are no unexpected adverse effects on water quality as a result of the injection. The observation wells are monitored more frequently, to track the hydraulic and water quality effects of injection in the vicinity of the injection wells.

3.1 Observation Well Response

3.1.1 Groundwater Quality

Water quality and water level information for the IM-3 monitoring wells can be found in *Compliance Monitoring Program Groundwater Monitoring Report for the Third Quarter 2005* (CH2M HILL 2005f). Observation wells were sampled in the months of July, August and September 2005. Preliminary review of these data shows that well OW-2D had been affected by injection waters by the August 2005 sampling event, and well OW-2M had been affected by the September 2005 sampling event. No other wells showed significant changes from pre-injection chemistry. Well OW-2S, a shallow depth groundwater well approximately co-located with OW-2M and OW-2D at a radius of approximately 50 feet from the IW-2, did not show any effects of injection after approximately 2 months. It is anticipated that shallow wells would be less affected than mid-depth or deep wells, because they are screened above the screened interval of the injection wells, and the vertical permeability of most sedimentary aquifers is much less than the horizontal permeability.

3.1.2 Water Level

Water level response for the mid-depth and deep observation and compliance wells was almost simultaneous with the start of injection. In contrast, shallow observation wells have not shown any discernible response to injection, when the system was operated at high and low flow rates. Shallow depths appear to be responding under unconfined conditions, while the deeper depths are responding under semi-confined conditions. The implication is that physical mounding, or increases in the water level, at shallow depths will be slow and will not propagate rapidly from the injection well through the shallow groundwater.

Prior to injection, vertical gradients at observation well clusters were variable, with gradient direction varying from upward to downward between surface locations. Post injection, all observation wells show upward gradients. Compliance well clusters all show this upward gradient both pre and post injection, with post injection gradients increasing in magnitude. This may be a transient effect, because the water levels in shallow wells are slower to respond to injection. The upward gradients suggest that water will tend to move upwards in the aquifer over time and shallow wells may eventually be affected by the injection. Impacts to shallow wells are expected occur long after they are seen in the deep and mid-depth wells, if at all.

3.2 Summary of Injection Effects on Shallow Groundwater

A preliminary review of the available water quality and water level data shows the following effects of injection on compliance point shallow groundwater:

- Water quality has not been affected at the closest shallow observation well, OW-2S. Since OW-2M and OW-2D have shown a progressive effect, it is likely that OW-2S will be the first shallow well to be affected. Using distance from the injection point as a guide, OW-1S would be the next shallow well, followed by OW-5S. Shallow wells will most likely not be affected until after their deep counterparts, with OW-1M and OW-1D showing effects prior to OW-1S, and OW-5M and OW-5D before OW-5S.
- Flow from the injection well appears to be as predicted, relative to the permeability of the formation with depth. Velocity logs for IW-2 were interpreted to show a relatively high permeable zone at depth corresponding to the screened interval of the deep observation wells, with permeability over the remaining screened interval being moderate. Injection wells were not screened in the shallow depth, so no water is being directly injected into that interval. Water will move quickest through the deeper interval, and less rapidly through the mid-depth interval. Little or no water will move directly from the injection well into the shallow depth interval.

Once injected into the formation, water follows horizontal and vertical gradients. Injection has created upward vertical gradients throughout the monitoring network, even in areas that previously showed downward gradients. The rate at which water moves vertically is expected to be much smaller than the rate at which it moves horizontally, because vertical permeability is typically much less than horizontal permeability in sedimentary aquifers. Upward gradients will tend to slowly move water from deeper to shallow depths, so the water quality in the shallow wells could eventually show the effects of injected water chemistry. This effect would likely not be the same as the mid-depth or deep wells (i.e., displacement by injected water), because the water is not being directly injected at shallow depths. Current data does not show that shallow wells have been impacted, but in the event that an effect does occur, the likely response would reflect a mixing of injected with mid- and shallow depth water chemistry.

SECTION 4.0

Well Design and Installation

4.1 Well Locations

The primary objective of the compliance monitoring wells is to monitor for any adverse effects on aquifer water quality due to the operation of the injection wells. DTSC has directed that four shallow monitoring wells (CW-1S, CW-2S, CW-3S, and CW-4S), one at each of the four existing compliance well clusters CW-1, CW-2, CW-3, and CW-4 respectively, are to be installed to provide additional shallow-depth information for the aquifer in the vicinity of the injection wells. Figure 1-2 shows the proposed locations of these shallow compliance monitoring wells.

4.2 Site Preparation and Access

The access routes and the work area at the proposed shallow compliance well sites were previously surveyed for biological and cultural resources prior to drilling the existing compliance monitoring wells. Results of these surveys and specific mitigation measures for access and for working in area locations of compliance monitoring well clusters CW-1, CW-2, CW-3, and CW-4 are outlined in *Topock Project: Review of Access Routes for Groundwater and Surface Water Data Collection Locations, and Proposed Mitigation Measures* (CH2M HILL 2005e) and *Action Memorandum on Time Critical Removal Action No. 3: Mitigation Measures* (Bureau of Land Management 2004). These mitigation measures, which must be applied on a year-round basis, are to be followed to prevent impacts on biological and cultural resources, as well as to prevent enlargement of previously used areas during construction of the shallow compliance monitoring wells. In general, personnel and vehicles are required to stay within the areas that were previously used and within the inclusive fencing used to mark the boundaries of allowable access routes to or work areas at these locations.

When accessing the CW-4 well cluster site, driving is to occur only in the active channel area of the wash. Due to recent rains, the access route to CW-4 has been slightly modified at the point where it first enters the wash. To the extent possible, all terrain support equipment (ATVs, "quadrunners," or "Gators") will be used for crew access to the CW-4 well cluster location to minimize rutting of the wash bottom, since the support vehicles typically make multiple trips in and out of the drilling area. For CW-2 and CW-3 well cluster locations, driving is to be one-way only on the access track and vehicles are to only use the established turnaround at CW-3. To minimize traffic to and from the drilling sites, fire hoses may be used to supply water as needed for drilling, and to transport water produced during well development to or from a remote tank located on the east mesa injection area. Any tanks and hoses will be located in areas previously cleared for cultural and biological resources. In addition, all well drilling, construction, and sampling work is to be conducted in accordance with the protective measures described in the *Transportation Management Plan for Cultural Resource Protection for Interim Measures No. 3* (CH2M HILL 2004a).

4.3 Drilling Requirements

Drilling and well installation shall conform to state and local regulations. CH2M HILL will obtain all permits, applications, and other documents required by state and local authorities. Utility clearances will also be obtained prior to commencement of drilling. The drilling, core/borehole logging, and well construction will be performed under the supervision of a California Professional Geologist. The drilling and well installation activities will be conducted in accordance with methods and procedures in the *Sampling, Analysis and Field Procedures Manual* (CH2M HILL 2005b).

4.3.1 Drilling Method

Sonic drilling methods will be used to install the compliance monitoring wells. Sonic drilling has been used for previous well drilling at the Topock site. It offers the advantages of minimal waste production, ability to penetrate through cobbles and caliche layers, and results in wells that are easier to develop than wells drilled by the mud rotary method. The drilling rig and drill casing/coring tools will be decontaminated prior to the start of the compliance well drilling program and prior to starting drilling at each well. Decontamination will be accomplished as outlined in Section 5.2.

In addition to the drilling rig, a large support/water truck and one or more 4-wheel drive pickup trucks, all terrain forklifts, or all-terrain vehicles (ATV) will be used for crew and equipment and material transfer to the drill sites. Short-term material storage in the area will be necessary to accommodate the drilling operations. Materials to be stored at the well site include drilling equipment and well construction materials (casing, sand, bentonite, cement grout, etc.). These materials will be stored on pallets near the drilling sites or in staging areas on the East Mesa.

The cuttings and excess core generated from drilling the borings will be transferred to lined steel roll-off soil bins temporarily stored at the drilling site or at the staging area on the East Mesa. The minimal water produced from sonic drilling will be contained in portable tanks at the drill site and transferred to larger storage tanks at the East Mesa. Disposal procedures for the investigation-derived waste (IDW) are discussed in Section 5.0.

4.3.2 Drilling Logs and Coring

A general drilling log will be prepared for each of the shallow compliance monitoring wells to document the drilling observations and activity. However, coring or detailed soil boring logs will not be performed since continuous coring and geophysical logging were performed at each of the compliance monitoring well clusters deep wells (CW-1D, CW-2D, CW-3D, and CW-4D) (CH2M HILL 2005d). The shallow well drilling logs will reference the existing core and geophysical logs obtained from the deep wells at the CW locations. The cores from the initial compliance well drilling program are currently stored on-site.

4.4 Compliance Monitoring Well Requirements

The compliance monitoring wells are to be installed in accordance with The *Final Design Plan for Groundwater Compliance Monitoring, PG&E Topock Compressor Station, Needles, California* (CH2M HILL 2005a). Monitoring wells will be installed and developed sequentially. The proposed shallow compliance monitoring wells will be named CW-1S, CW-2S, CW-3S, and CW-4S in accordance with the existing naming convention, with the S denoting the well is a shallow well. Table 4-1 lists the target depths of each planned soil boring/monitoring well. The final well constructions will be based on conditions encountered in the field and might deviate from details listed in Table 4-1. Figure 4-1 presents a schematic of the proposed shallow compliance monitoring well construction detail contrasted with the existing mid-depth and deep compliance monitoring wells.

TABLE 4-1
Target Depths of Planned Monitoring Wells
Work Plan for Installation of Shallow Compliance Monitoring Wells, PG&E Topock Compressor Station, Needles, California

Location/Property Owner	Well ID	Approximate Well Depth (ft bgs)	Approximate Screened Interval (ft bgs)
BLM	CW-1S	145	100-140
PG&E	CW-2S	128.5	83.5-123.5
PG&E	CW-3S	113	68-108
PG&E	CW-4S	98	53-93

Notes:

All monitoring wells will be 2-inch Schedule 40 PVC completed within an above-ground casing monument. Guard posts will be used for well monument CW-3S since the proposed location is adjacent to an access road.

All monitoring well screens will be 40 feet in length, made of 2-inch, slotted Schedule 40 PVC with 0.020-inch openings.

For compliance monitoring well CW-4S, surface steel casing to be installed a minimum of 8 feet bgs since the proposed location is in a wash.

ft = feet
bgs = below ground surface
BLM = Bureau of Land Management

4.4.1 3.3.1 Casing Requirements

The shallow compliance monitoring wells will be constructed with 2-inch diameter Schedule 40 PVC casing and screen. The well casing and screen will be installed in the borehole through the sonic drill casing (approximate 7-inch outside diameter). The anticipated total depth is anticipated between 98 to 145 feet for the shallow compliance monitoring wells.

- All casing will be new, unused, and decontaminated.
- Glue will not be used to join casing, and casings will be joined only with compatible threads that will not interfere with the planned use of the well.
- All polyvinyl chloride (PVC) will conform to American Society for Testing Materials (ASTM) Standard F 480-88A or the National Sanitation Foundation Standard 14 (Plastic Pipe System).
- The casing will be straight and plumb.

For compliance monitoring well CW-4S, surface steel casing will be installed to a minimum depth of 8 feet bgs, since the proposed location is in a wash.

4.4.2 Well Screen Requirements

Well screen requirements for the shallow compliance monitoring wells are as follows:

- 40-foot screen will be installed across the water table, with approximately 30 feet of screen installed below the water table and 10 feet installed above the water table. Depth to groundwater is estimated to be approximately 75 to 110 feet bgs for well clusters in upland areas (CW-1, CW-2, and CW-3) and approximately 60 feet bgs for the well cluster in the wash bottom (CW-4).
- All requirements that apply to casing will also apply to well screen, except for strength requirements.
- Screens will be factory slotted.
- Screen slot size will be 0.020 inch.
- The bottom of the screen will be capped with a threaded casing cap that will be joined to the screen by thread.

4.4.3 Annular Space Requirements

The annular space will be filled with a filter pack, a bentonite seal, or casing grout between the well casing and the borehole wall. In shallow-depth wells more than 50-feet deep, at least two stainless steel centralizers will be used, one at the bottom and one at the top of the screen.

4.4.4 Filter Pack Requirements

The filter pack will consist of No. 3 silica sand (consistent with other compliance monitoring wells) and will extend from the bottom of the hole to approximately 7 feet above the top of the well screen. The filter pack will be poured into the annulus from the ground surface and a weighted tape will be used to monitor the level of the filter to avoid bridging. The top of the sand pack will be surged with a surge block during placement. After surging, additional filter pack will be placed as required to return the level of the pack to 7 feet above the screen. A minimum 3-foot-thick layer of fine transition sand will be placed above the No. 3 sand filter pack to minimize the potential for the bentonite slurry (seal) material to invade the filter pack adjacent to the top of the well screen during well construction.

4.4.5 Bentonite Seal Requirements

A bentonite seal of at least 2 feet in thickness, composed of bentonite chips or pellets, will be placed over the filter pack. Only 100 percent sodium bentonite is to be used. Bentonite chips or pellets will be hydrated with potable water for at least 30 minutes before grouting.

4.4.6 Casing Grout Requirements

The casing grout will extend from the top of the bentonite seal to ground surface. The grout will consist of a Portland Type II cement slurry mixed with five percent bentonite powder. All grout will be pumped into place using a tremie pipe. The casing grout requirements are as follows:

- The casing grout will extend from the top of the bentonite seal to ground surface.
- The grout will be cement mixture in the following proportions:
  - 94 pounds of neat Type I or II Portland or American Petroleum Institute Class A cement per 6 gallons of potable water
  - 2 to 3 pounds of 100 percent sodium bentonite powder per bag of cement.
- All grout will be pumped into place using a tremie pipe.
- The expected volume of each ingredient in the grout mixture will be pre-calculated and documented.
- No accelerator compounds will be used in the grout mixture.

San Bernardino County will be notified in advance of grouting operations to provide them the opportunity to observe this activity.

4.4.7 Surface Completion Requirements

The shallow compliance wells will be completed with a steel, locking wellhead monument surface completion. A watertight expanding rubber seal type locking cap will be provided for each well. The wellhead monument (steel stovepipe) completion will be placed over the casing and cap and seated in a 3-foot by 3-foot by 4-inch-thick concrete pad. The ground surface will be freed of grass and scoured to a depth of 2 inches before setting the concrete pad. The diameter of the sleeve or stovepipe will be at least 4 inches greater than the diameter of the casing. The concrete pad will be sloped away from the well sleeve. The identity of the well will be permanently marked on the casing cap and the protective sleeve. Guard posts will be used for the CW-3S well monument since it is proposed to be installed adjacent to an access road.

All wells will be secured as soon as possible after drilling by using corrosion-resistant locks. The locks will be keyed for opening with one master key.

4.4.8 Well Development and Geophysical Logging

After well construction and annular seal placement, the compliance wells will be developed using a surge block, bailer, and submersible pump. Development will not be conducted until the grout in the wells has set for a minimum of 48 hours. During development, temperature, pH, specific conductance, and turbidity will be measured using field instruments. Well development will continue until at least 3 well volumes have been removed and field measurements of temperature, pH, and specific conductance stabilize within 10 percent between subsequent measurements, and turbidity is reduced to less than 50 nephelometric turbidity units. Geophysical logging is not planned for the shallow wells because geophysical logs were previously obtained from the nearby deep wells at each location.

4.4.9 Well Completion Diagrams

A completion diagram will be prepared for each monitoring well installed. It will include the following information:

- Well identification
- Drilling method
- Installation date(s)
- Elevations of ground surface and identification of the measuring point
- Total boring depth
- Lengths and descriptions of the screen and casing
- Lengths and descriptions of the filter pack, bentonite seal, casing grout, and any back filled material

4.5 Initial Groundwater Sampling

After well development, the new monitoring wells will be sampled for the initial water quality characterization. The sampling activity will follow the procedures, analytical methods, reporting limits, and quality control plan used for the Topock groundwater monitoring program as described in the Topock program *Sampling, Analysis and Field Procedures Manual* (CH2M HILL 2005b).

Samples from the new compliance monitoring wells will be analyzed for Cr(VI), Cr(T), Total Dissolved Solids (TDS), specific conductance, pH, aluminum, ammonia (as nitrogen), antimony, arsenic, barium, boron, calcium, chloride, carbonate/bicarbonate, copper, fluoride, lead, magnesium, manganese, molybdenum, nickel, nitrate/nitrate (as nitrogen), total Kjeldahl nitrogen, potassium, selenium, sodium, sulfate, total iron, and zinc. Groundwater samples for metals analyses will be filtered to obtain dissolved metals concentrations. Field water quality parameters (temperature, pH, specific conductance, oxidation-reduction potential, and turbidity) will also be measured.

SECTION 5.0

Waste Management

5.1 Waste Management

Several types of waste materials will be generated during the drilling, development, and sampling of the shallow compliance monitoring wells. Investigation-derived waste (IDW) materials that will be generated include drill cuttings, groundwater, decontamination water, and incidental trash. The incidental trash will consist of empty paper and plastic bags, cardboard boxes, wooden pallets, and miscellaneous debris. Figure 5-1 presents the proposed location of staging areas for the temporary storage of IDW. The area in between observation wells OW-1, OW-2 and OW-5 is proposed as the main temporary storage area for this material, with secondary storage being proposed at the CW-1 well site north of Route 66. The storage of material at the individual CW well drilling sites will be kept to the minimum needed for daily operations.

Water generated during drilling, development, and decontamination activity will be contained in temporary storage tanks and transferred by truck to storage bins or tanks located on the East Mesa for characterization, potential treatment, and appropriate disposal. Temporary storage of this IDW will be in the proposed areas presented in Figure 5-1. Based on available data, it is unlikely that groundwater from the proposed monitoring wells will contain chromium at concentrations above the 50 micrograms per liter California maximum contaminant level for drinking water. Therefore, secondary containment will not be necessary for tanks containing groundwater from the compliance wells. Water generated from the CW installations will be introduced to the IM No. 3 treatment facility, or transported offsite to a permitted disposal facility.

Drilling cuttings include the fragments of rock and soil that are removed to create the borehole. The cuttings will be contained in lined roll-off bins at the drill sites during drilling operations, and transferred to the proposed staging areas as filled, and at the completion of drilling activities. After sampling and characterization, all cuttings bins will be removed from the staging area for disposal at an appropriate facility. The cuttings will be screened for chromium, the main constituent of concern for the site. If the cuttings are characterized as having chromium above background levels, they will be transported offsite for disposal at a permitted waste disposal facility. It is estimated that the soil IDW bins will not remain on site for more than 45 days.

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

5.2 Equipment Decontamination

The back of the drilling rig and all downhole drilling tools will be decontaminated prior to starting each new borehole. Decontamination will be accomplished by steam cleaning the core barrel, drill stem, drive casing, and back of the drilling rig. Steam cleaning will be conducted on a decontamination pad located on PG&E Compressor Station property at the East Mesa staging area, so all rinsate can be contained and collected. Rinsate from the decontamination operation will be transferred to the cuttings bin or purge water tank that contains materials from the borehole last drilled by the rig. The decontamination rinsate will be managed along with the cuttings or purge water.

SECTION 6.0

Schedule and Reporting

The schedule for installation of the four shallow compliance monitoring wells at existing compliance monitoring wells clusters CW-1 through CW-4 will be 90 days after approval of this workplan. The schedule for the installation of the four shallow compliance monitoring wells is provided in Table 6-1. All drilling and development work associated with the compliance monitoring wells will be conducted during normal daylight hours, and therefore no night time work lighting will be required. The schedule assumes use of one rig for drilling and well installation. Permitting activities and schedules may be extended based on events not within PG&E control.

Following completion of the fieldwork, a summary report will be prepared to document the well installation, and the results of sampling and testing of the monitoring wells. The report will include the drilling, well completion, well development, and initial groundwater sampling records and results. The investigation report will be submitted approximately 8 weeks after the wells are installed and sampled.

TABLE 6-1
Anticipated Duration of Well Installation Activities
Work Plan for Installation of Shallow Compliance Monitoring Wells, PG&E Topock Compressor Station, Needles, California

Activity	Duration
DTSC Review of Draft Work Plan	As Necessary
Revise Draft Work Plan and Submit Final to DTSC	3 weeks
Permitting	9 weeks
Mobilization (including procurement)	2 weeks
Monitoring Well Drilling, Installation and Sampling (4 locations)	5 weeks
Summary Report	8 weeks

SECTION 7.0

Permits and Approvals Required

Table 6-1 provides a listing of permits and approvals that have been identified as applicable to the installation of the shallow compliance monitoring wells. All applicable and necessary permits/approvals will be obtained prior to moving drilling equipment to the site.

TABLE 7-1
Permits, Approvals, and Certifications for Compliance Monitoring Wells
Work Plan for the Installation of Shallow Monitoring Wells, PG&E Topock Compressor Station, Needles, California

Agency	Permits, Approval, Certifications, etc.
Federal BLM	Authorization was provided by BLM in a September 17, 2004 Action Memorandum, subject to subsequent approval of a work plan by the BLM Lake Havasu Field office.
California DTSC	CEQA Notice of Exemptions dated February 10, 2004 and June 30, 2004 (emergency project)
State Water Resources Control Board/ Colorado River Basin Regional Water Quality Control Board	Notice of Intent and Storm Water Pollution Prevention Plan for Construction Activities; covered under statewide general permit
United States Fish & Wildlife Service (USFWS)	BLM may consult with USFWS, pursuant to Section 7 of the Endangered Species Act (ESA).
State Historic Preservation Office (SHPO)	BLM may choose to consult with tribes for 30 days, followed by a 30 day consultation with SHPO, pursuant to Section 106 of the National Historic Preservation Act (NHPA).
San Bernardino County	Well Permits

SECTION 8.0

References

CH2M HILL. 2004a. *Transportation Management Plan for Cultural Resources Protection for Interim Measures No. 3*, Topock Compressor Station Expanded Groundwater Extraction and Treatment System, Needles, California. September.

___________. 2004b. Technical Memorandum: Selection of Locations for Compliance Monitoring Wells (Revised), Pacific Gas and Electric Company, Topock Project, November 9.

CH2M HILL. 2005a. *Final Design Plan for Groundwater Compliance Monitoring*, PG&E Topock Compressor Station, Needles, California. January 5.

__________. 2005b. *Sampling, Analysis and Field Procedures Manual, Topock Program, PG&E Topock Compressor Station, Needles, California.* March 11.

__________. 2005c. *Groundwater Compliance Monitoring Plan for Interim Measures No. 3 Injection Area*, WDR Order No. R7-2004-0103, *PG&E Topock Compressor Station, Needles, California.* June 17.

__________. 2005d. *Groundwater and Hydrogeologic Investigation Report for Interim Measures No. 3 Injection Area*, *PG&E Topock Compressor Station, Needles, California.* June 22.

__________. 2005e. Technical Memorandum: Review of Access Routes for Groundwater and Surface Water Data Collection Locations and Proposed Mitigation Measures, Pacific Gas and Electric Company, Topock Project, September 14.

__________. 2005f. *Compliance Monitoring Program Groundwater Monitoring Report Third Quarter 2005*, PG&E Topock Compressor Station, Needles, California. October 14.

Bureau of Land Management. 2004. Action Memorandum on Time Critical Removal Action No. 3: Mitigation Measures. September 17.

Figures

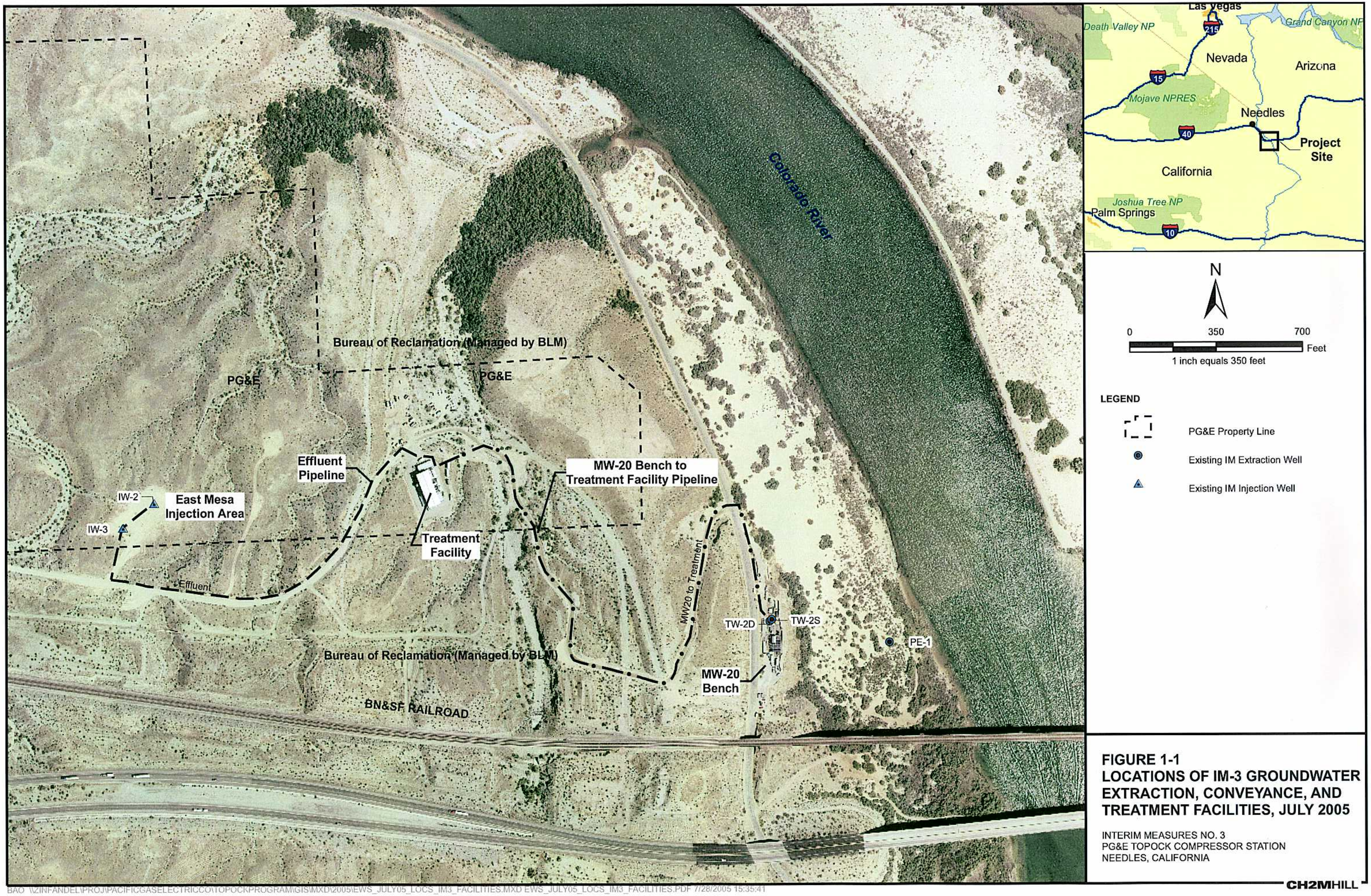

FIGURE 1-1
LOCATIONS OF IM-3 GROUNDWATER EXTRACTION, CONVEYANCE, AND TREATMENT FACILITIES, JULY 2005

INTERIM MEASURES NO. 3
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

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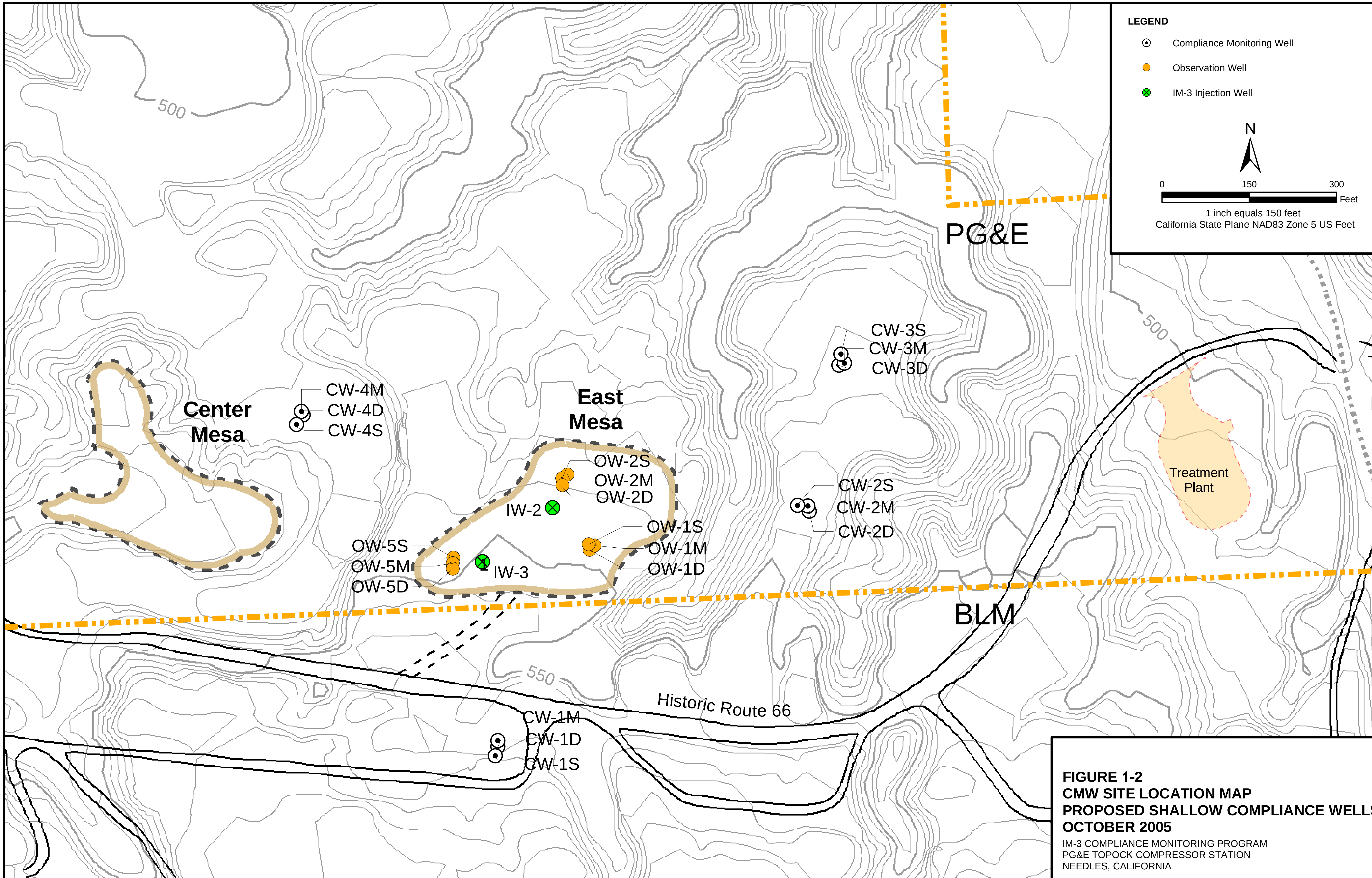

FIGURE 1-2
CMW SITE LOCATION MAP
PROPOSED SHALLOW COMPLIANCE WELLS
OCTOBER 2005

IM-3 COMPLIANCE MONITORING PROGRAM
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

CH2MHILL

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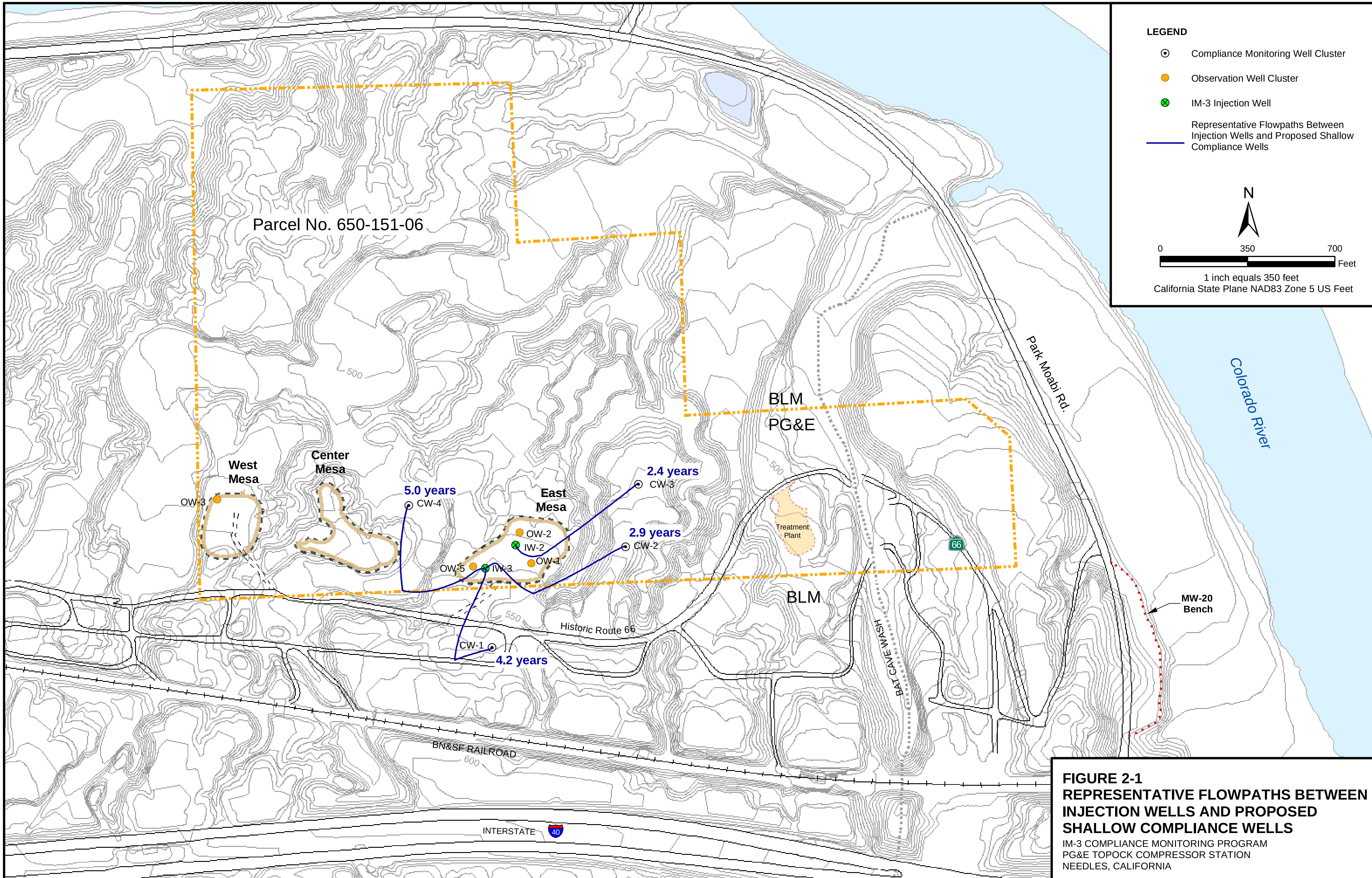

FIGURE 2-1
REPRESENTATIVE FLOWPATHS BETWEEN INJECTION WELLS AND PROPOSED SHALLOW COMPLIANCE WELLS
IM-3 COMPLIANCE MONITORING PROGRAM
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

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Revision 10/10/05

Proposed
Compliance Monitoring Well Cluster

Note 1 : For wells in washes, surface steel casing to be installed minimum 8 ft. bgs

Note 2: Guard posts will be used for well monuments installed adjacent to access roads

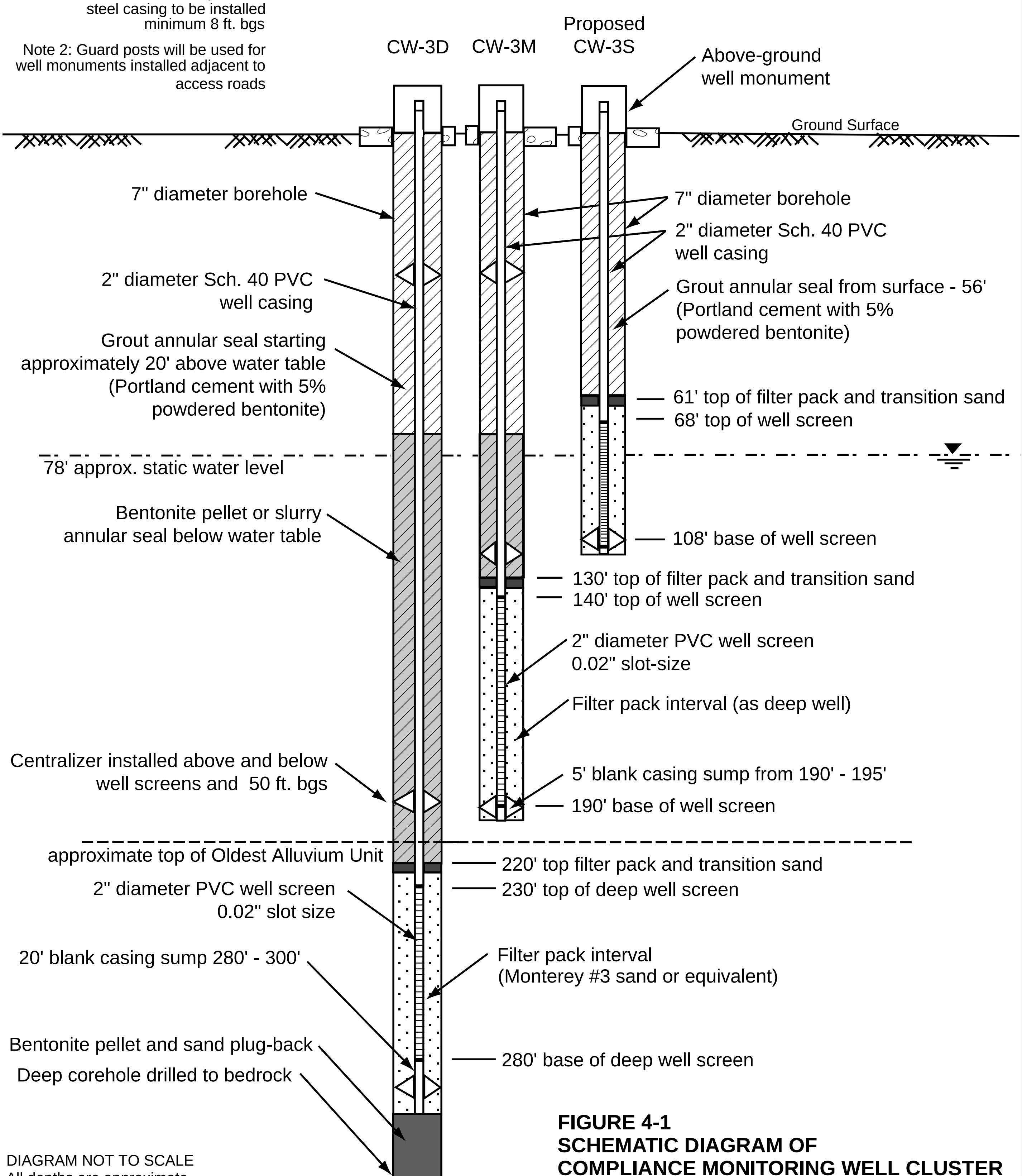

DIAGRAM NOT TO SCALE
All depths are approximate.

Actual depths for each well will be determined based on field conditions in consultation with DTSC and RWQCB.

FIGURE 4-1
SCHEMATIC DIAGRAM OF COMPLIANCE MONITORING WELL CLUSTER
INTERIM MEASURES NO. 3
PG&E TOPOCK COMPRESSOR STATION

CH2MHILL

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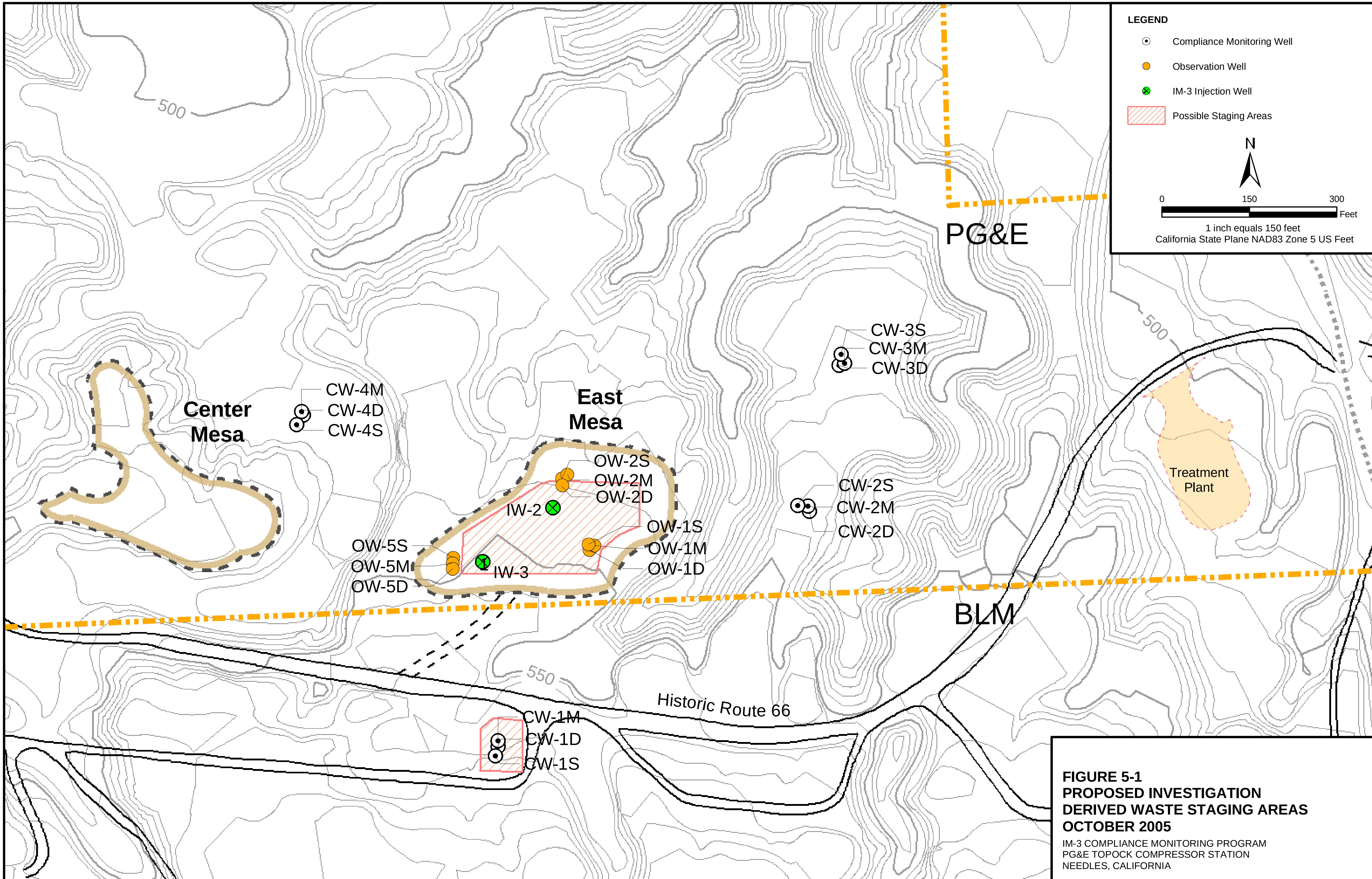

FIGURE 5-1
PROPOSED INVESTIGATION DERIVED WASTE STAGING AREAS
OCTOBER 2005
IM-3 COMPLIANCE MONITORING PROGRAM
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

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Attachment A

Selection of Locations for Compliance Monitoring Wells, Pacific Gas and Electric Company, Topock Project

PREPARED FOR: Department of Toxic Substances Control

DATE: November 9, 2004

Introduction

The purpose of this memorandum is to provide information on the potential locations for compliance monitoring wells associated with the planned injection wells on PG&E property at the Topock site. The compliance monitoring wells are designed to provide additional site characterization and baseline groundwater quality data and to meet the Waste Discharge Requirements for a compliance monitoring program after injection begins. This technical memorandum focuses on the issues regarding siting of the compliance monitoring wells. After the well locations are approved, a work plan will be prepared that will describe in detail the design, construction, sampling, and schedule for installation of these wells. This work plan is due to the Regional Water Quality Control Board (RWQCB) no later than November 27th, 2004. Consequently, PG&E is requesting an expedited review of this technical memorandum so that we may proceed with preparation of the work plan.

The presence of sensitive cultural and biological resources and the steep terrain provide significant constraints on siting monitoring wells in the vicinity of the injection wells. A site survey was conducted to identify potential well locations that could be made accessible to drilling equipment without the need for extensive road building or grading. A reconnaissance level archeological survey had previously identified several large areas of the site where injection well and observation well drilling activities could not be conducted without adverse impact to cultural resources. As such, these areas are not candidate sites for compliance monitoring well drilling. Due to frequent scouring by floods, significant cultural resources are typically not found in wash bottoms at this site. Washes do, however, provide wildlife corridors and habitat for several sensitive species of plants and animals. By careful selection of well sites, planning of access routes, and diligent monitoring of drilling activities we believe it is possible to conduct drilling activities in some wash bottoms without adverse impacts to the biological resources. Potential well locations in the wash bottoms were chosen to be out of the main flow channels and in areas accessible without cutting trees.

A total of 18 potential compliance monitoring well locations were identified. These potential locations, labeled A through R, are shown on Figure 1. Figure 1 also shows the areas of the site that were considered unavailable for well drilling due to inaccessible terrain, cultural resources, or wetland habitat. A more detailed archeological survey conducted after the initial selection of well locations showed that location labeled "I" on Figure 1 was in fact not accessible due to cultural resources not mapped in the original, reconnaissance level survey. The outline of the "Compliance Monitoring Well Project Site" shown on Figure 1 was determined based on distance from the injection well fields. There may be locations accessible for compliance monitoring wells outside the project site boundary, but groundwater travel times to wells at this distance would be greater than 10 years.

Colorado River Basin RWQCB Waste Discharge Requirements R7-2004-0103 require a minimum of one upgradient and two downgradient compliance monitoring wells associated with each injection well field. The DTSC has indicated that, where possible, compliance monitoring wells should be within a distance representing about 2 years of groundwater travel time from the injection well fields. The computer groundwater flow model developed for design of the Interim Measures 3 pump and treat system was used to simulate the groundwater flow patterns from the injection well fields. The travel time and direction from the injection well fields were considered the most important criteria for selection of preferred compliance monitoring well locations from among the 18 potential locations.

If both the East and West Mesa injection fields are developed, PG&E is proposing to install a total of 7 compliance monitoring wells in the "preferred" locations shown on Figure 1. If it is determined through aquifer testing that sufficient injection capacity can be provided by wells on the East Mesa alone, the West Mesa injection field may not be built. In that case, only 4 compliance monitoring wells would be installed in those preferred locations that surround the East Mesa, labeled as J, O, Q, and M on Figure 1. It is understood that the DTSC or the RWQCB may require additional compliance monitoring wells in the future based on the performance monitoring data collected during operation of the injection wells.

Model Simulations of Groundwater Travel Time

Groundwater modeling was conducted to estimate the travel times through the aquifer between the injection wellfields and the compliance monitoring well locations. To simplify the modeling task and to make the graphics more legible, the injection at each mesa was simulated as if it were a single injection well. Particle tracking was used to show groundwater flow paths in a steady state groundwater flow field.

The groundwater model can be used to simulate pumping rates needed to maintain an average monthly landward gradient throughout the year, based on the changing levels of the river. The projected average monthly pumping rate requirements in gallons per minute (gpm) are shown in the table below. These requirements are subject to change as the model calibration is refined.

TABLE 1
Model Projected Monthly Average Pumping Rates for 2004 in gpm.

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Avg
20	20	20	20	20	20	22	38	33	55	28	39	**28**

Although the model predicts that little or no pumping would be necessary to maintain landward gradients during the months of January through June, it was assumed that a minimum of 20 gpm would be pumped during these months, as directed by DTSC, to provide a margin of safety for possible system downtime in other months. To estimate groundwater travel times, the groundwater model was run in a steady state mode using the projected average annual pumping rate of 28 gpm.

The treatment system includes a reverse osmosis (RO) process that removes salts from the water. The byproduct of reverse osmosis is a concentrated salt solution known as RO concentrate. This concentrate, which may represent approximately 25 percent of the water passing through the RO unit, will not be re-injected to the aquifer. Consequently, the injection rate used in the model is only 21 gpm, 25 percent less than the average pumping rate.

Based on data available from drilling and testing of small diameter observation wells on the East and West Mesas, it appears likely that sufficient injection capacity will be obtained from a set of three injection wells on the East Mesa. If so, injection wells would not be drilled on the West Mesa. Until the injection wells have been drilled and tested, the option of injecting on both mesas is being retained. Consequently, two model simulations were conducted. The first projects groundwater flow paths from injection of 21 gpm only on the East Mesa. The second projects groundwater flow paths with the 21 gpm injection flow split evenly between the two mesas. Results of these two simulations are shown on Figures 2 and 3, respectively.

In the study area, much of the aquifer consists of relatively low-permeability silty and clayey sands with relatively thin layers of more permeable clean sands and gravels. Groundwater will travel much more rapidly through the clean sand and gravel zones than through the silty and clayey sand zones. The groundwater model simulates the average bulk properties of the aquifer and does not include the small scale preferential flow pathways represented by the clean sand and gravel layers. The model projections may therefore tend to underestimate the groundwater transport velocities. To account for model uncertainties, the average effective porosity in the model was set at 3 percent. Typical values of effective porosity of sand and gravel would be 15 percent. Using a value of 3 percent provides equivalent transport velocities to a condition where four-fifths of the aquifer is lower-permeability silty and clayey sands and groundwater is preferentially flowing through the higher-permeability clean sands and gravels that make up about one fifth of the saturated thickness.

The model uses 4 vertical layers to simulate a total aquifer thickness of about 250 feet near the injection wells. The hydraulic conductivity in this area is estimated to be about 35 ft/day. This estimate is consistent with results of aquifer testing in both the TW-1 well near the compressor station and the TW-2 wells near the floodplain. The pathlines shown on Figures 2 and 3 represent particles starting in Layer 3 of the 4-layer model. The pathlines and travel times are similar for particles started in other model layers. The injection wells were simulated as fully penetrating wells screened through all four model layers. The rate of injection into each layer is proportional to that layer’s contribution to total transmissivity.

To simplify the graphical presentation of model results, the model simulated injection through a single well on each mesa. Actually, there are three potential injection well locations on the East Mesa and two potential injection well locations on the West Mesa. If the model had simulated injection from multiple wells on each mesa, any resulting increases or decreases in travel times would not be expected to be significant.

Ranking of Potential Well Locations

The preferred compliance monitoring well locations were surveyed for cultural and biological resources by an archaeologist from Applied Earthworks and a wildlife biologist from CH2M HILL. These surveys indicated that, with proper mitigation measures in place, wells could be installed at all seven of the preferred locations without adverse impacts. A site-specific cultural resources survey also was conducted for Site I. This survey revealed that a well could not be installed at this location without adverse impact to cultural resources. Therefore, Site I is no longer considered to be a candidate site. Detailed cultural and biological surveys have not yet been completed on any other potential compliance well sites.

Table 1 provides a summary of the relative rankings of the potential well locations based on a set of criteria that include groundwater travel time from injection wells, ease of equipment access, and an initial screening for impacts to cultural and biological resources. The ranking criteria are somewhat subjective and meant only to provide insight into the process of selection of the preferred wells. An explanation of the ranking criteria is provided in Table 3.

Not included in Table 2 is the criterion of geographic location of the wells. It is desirable to have the compliance monitoring wells located in all four quadrants around each injection well field, rather than clustered together in one or two quadrants.

TABLE 2
Ranking of Potential Compliance Monitoring Well Locations

Well Location	Primary Monitoring Purpose	Ground-water Travel Time (yr.)	Equipment Access (ranking)	Cultural Resource Risk (ranking)	Biological Resource Risk (ranking)	Overall Score	Comments
A	Both Mesas	16	4	1	3	24	
B	East Mesa	31	4	1	4	40	Potential Willow Flycatcher habitat nearby
C	West Mesa	8	3	1	3	15	
D	**West Mesa**	**6**	**3**	**1**	**3**	**13**	
E	Both Mesas	13	3	1	3	20	
F	East Mesa	14	4	1	4	23	Potential Willow Flycatcher habitat nearby
G	West Mesa	6	3	1	3	13	
H	Both Mesas	10	3	1	3	17	
I	East Mesa	8	2	4	2	16	Site found to be inaccessible due to cultural resources
J	**East Mesa**	**6**	**2**	**2**	**2**	**12**	Travel time is 4 years if injection on East Mesa only
K	East Mesa	14	2	3	2	21	Use of Old Trails Highway needed for access
L	**West Mesa**	**3**	**3**	**1**	**3**	**10**	
M	**Both Mesas**	**9**	**3**	**1**	**3**	**16**	Travel time is 3 years if injection on East Mesa only
N	Both Mesas	12	3	1	3	19	
O	**West Mesa**	**3**	**2**	**2**	**2**	**9**	Travel time is 2 years if injection on East Mesa only
P	**East Mesa**	**2**	**1**	**1**	**1**	**5**	
Q	**East Mesa**	**3**	**1**	**1**	**1**	**6**	Travel time is 2 years if injection on East Mesa only
R	East Mesa	10	1	1	1	13	

Notes:
Travel time estimates based on injection of 21 gpm, divided between East and West Mesas as shown on Figure 3.
Bold text indicates preferred well locations.
Rankings are subjective with 1 being most desirable and higher numbers less desirable. Criteria used for rankings is explained in Table 3.

TABLE 3
Explanation of Ranking Criteria used in Table 2

Rank	Equipment Access	Cultural Resources	Biological Resources
1	Sites on or near established roads easily accessible to conventional truck-mounted drilling equipment	Sites in previously disturbed areas or in wash bottoms where significant cultural resources are unlikely to be present	Sites in previously disturbed upland areas where significant biological resources are unlikely to be present
2	Sites further from established roadways with some grading or filling needed to be accessible to truck-mounted drilling equipment	Sites on upland areas where significant cultural resources may exist but drilling likely can be conducted without adverse impact	Sites in undisturbed upland areas where there may be some sensitive species present
3	Sites in wash bottoms that will likely require all-terrain drilling equipment	Ranking given to Site K, indicating that blanketing of a section of Old Trails Highway likely would be required to allow access	Sites in wash bottoms, where sensitive species are known to be present but mitigation measures can prevent adverse impacts
4	Sites in wash bottoms far from established roads that will likely require all-terrain drilling equipment	Ranking given to Site I, indicating that site use would result in adverse impact to cultural resources	Sites near potential endangered species (Willow Flycatcher) habitat where mitigation to avoid adverse impacts may not be possible

Note – Ranking of 1 is considered to be most desirable and ranking of 4 least desirable

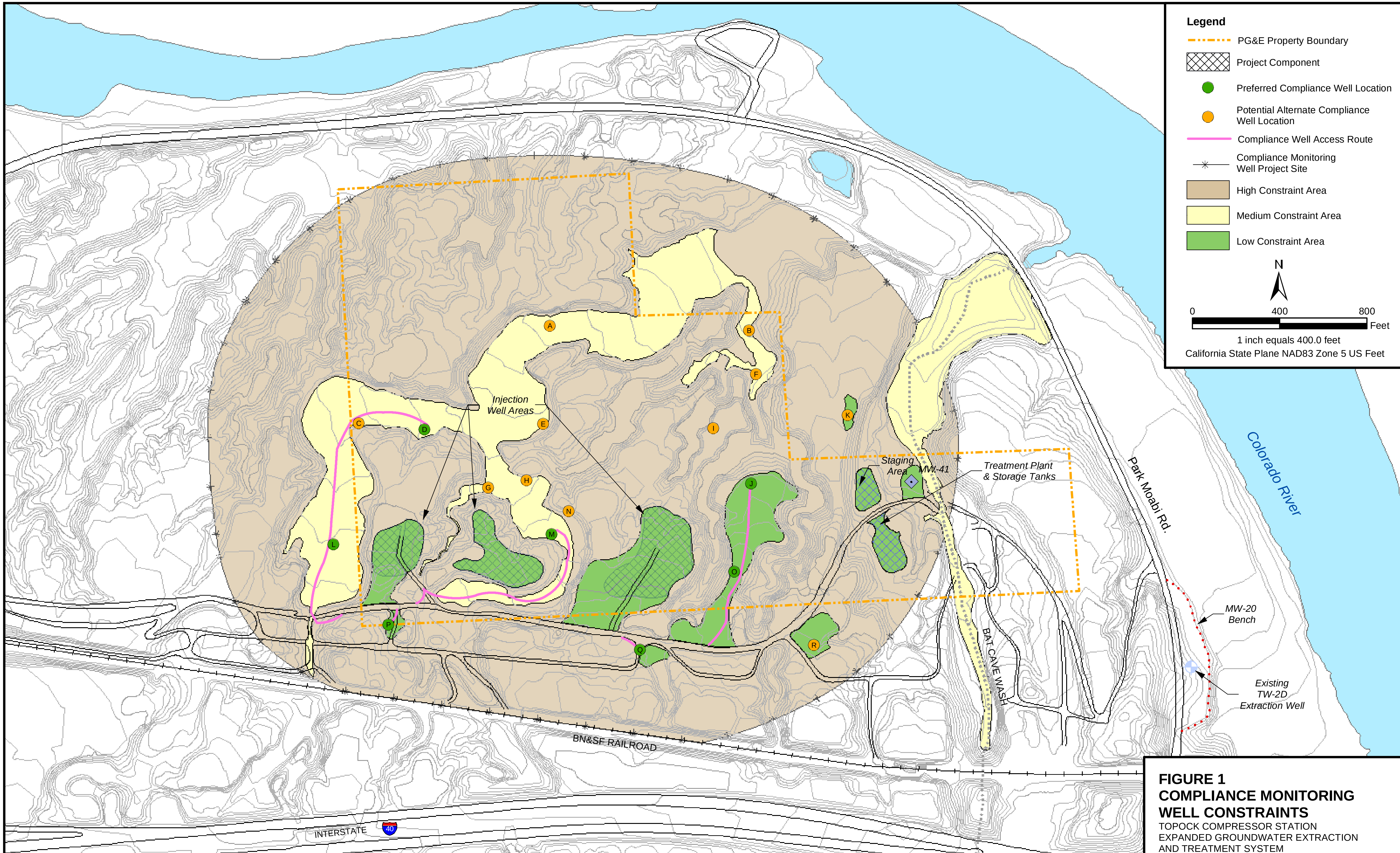

FIGURE 1
COMPLIANCE MONITORING WELL CONSTRAINTS
TOPOCK COMPRESSOR STATION
EXPANDED GROUNDWATER EXTRACTION
AND TREATMENT SYSTEM
CH2MHILL

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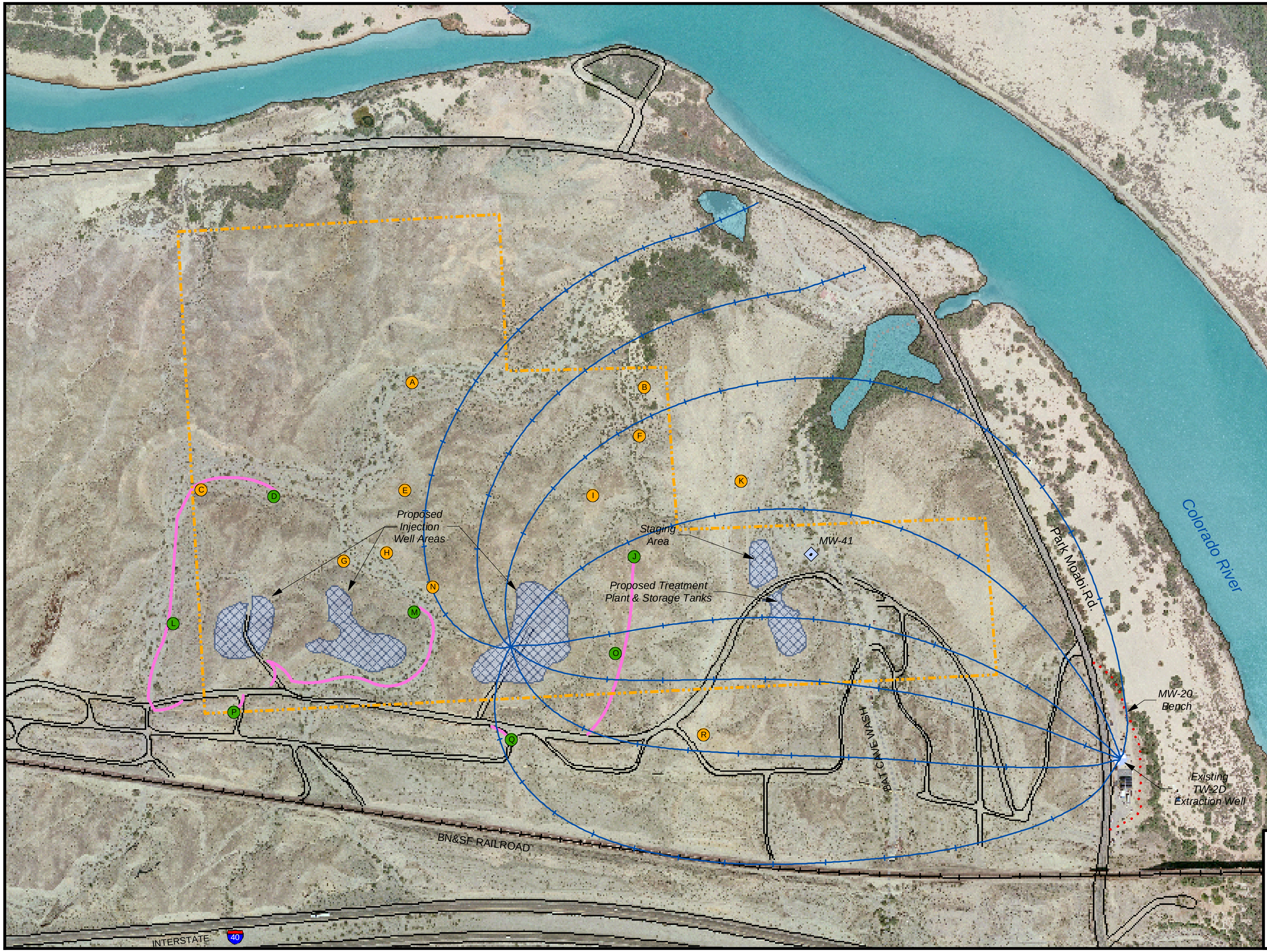

FIGURE 2
SIMULATED FLOWLINES WITH 21 GPM INJECTED AT EAST MESA
TOPOCK COMPRESSOR STATION
EXPANDED GROUNDWATER EXTRACTION
AND TREATMENT SYSTEM
CH2MHILL

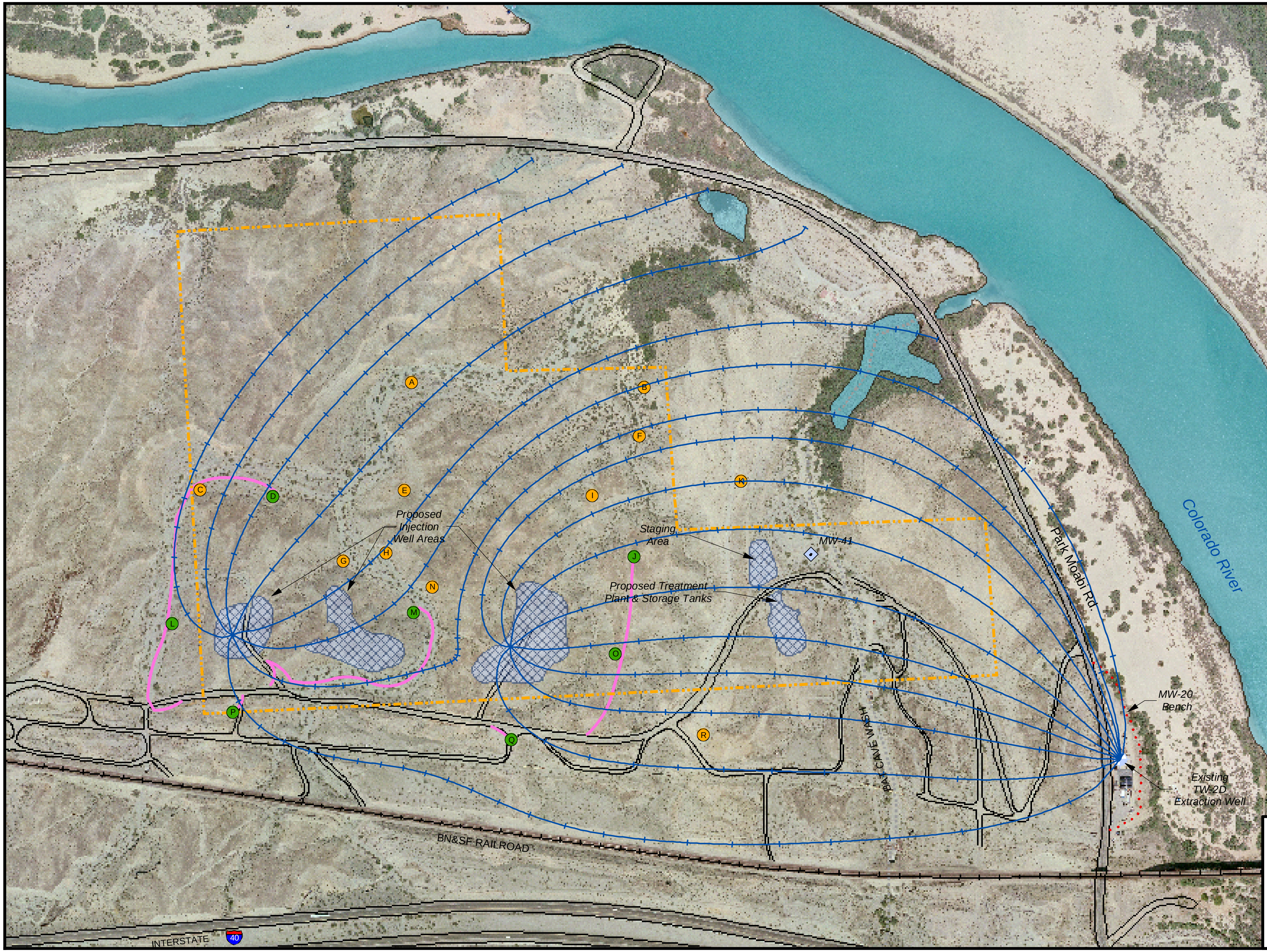

FIGURE 3
SIMULATED FLOWLINES WITH 21 GPM SPLIT BETWEEN EAST AND WEST MESAS
TOPOCK COMPRESSOR STATION
EXPANDED GROUNDWATER EXTRACTION AND TREATMENT SYSTEM

CH2MHILL

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