Operation and Maintenance Manual Volume 3

Contingency Plan
Pre-Final (90%) Design Submittal for the Final Groundwater Remedy
PG&E Topock Compressor Station
Needles, California

Prepared for

Pacific Gas and Electric Company

September 2014

CH2MHILL®

155 Grand Avenue
Suite 800
Oakland, California 94612

Contents

Tables

Appendices

Acronyms and Abbreviations

µg/L	micrograms per liter
ARAR	Applicable or Relevant and Appropriate Requirement
CEQA	California Environmental Quality Act
CIP	clean-in-place
Cr(III)	trivalent chromium
Cr(T)	total chromium
Cr(VI)	hexavalent chromium
DMRS	dissolved metals removal system
DOI	U.S. Department of the Interior
EIR	Environmental Impact Report
FMEA	Failure Mode Effect Analysis
FWPTS	freshwater pre-injection treatment system
gpm	gallons per minute
H&S	health and safety
HMI	human-machine interface
HNWR-1A	Havasu National Wildlife Refuge Well No. 1A
IRL	Inner Recirculation Loop
MG	million gallons
NTH IRZ	National Trails Highway In-Situ Reactive Zone
O&M	operation and maintenance
OIT	operator interface terminal
PG&E	Pacific Gas and Electric Company
PLC	programmable logic controller
RAOs	Remedial Action Objectives
SCADA	Supervisory Control and Data Acquisition
SWRCB	State Water Resources Control Board
TCS	Topock Compressor Station
UPS	uninterruptible power supply

1.0 Introduction

This volume of the Operation and Maintenance (O&M) Manual presents the contingency plans for the Pacific Gas and Electric Company (PG&E) Topock Compressor Station (TCS) groundwater remedy, as required by the 1996 Consent Agreement (California Department of Toxic Substances Control [DTSC] 1996) and the 2013 Consent Decree (U.S. Department of the Interior [DOI] 2013). Contingency planning is being conducted as a part of the final groundwater remedy design process to anticipate potential risks and organize plans to mitigate these risks. A contingency plan such as this one is typically used during the design phase as a tool to anticipate potential risks and to develop methods to mitigate these risks either within the design or as part of the future system operations. The contingency planning is done using a method termed Failure Mode Effect Analysis (FMEA). The FMEA tool provides an analytical and systematic approach to reviewing potential failure modes and their associated causes, and therefore helps to assess which risks pose the greatest concern and to prioritize risk management in order to prevent problems before they arise. The objective of the FMEA process is to outline possible failures that could cause unacceptable conditions in the groundwater remedy. Mitigation measures in design and operation are focused on these issues first and foremost. The FMEA also identifies conditions that, while not unacceptable, are issues that PG&E will strive to avoid or minimize. The following types of unacceptable conditions have been identified:

- **Category A: Unacceptable Remedy Performance** — The Remedial Action Objectives (RAOs) are not met. Specifically, this could include migration of unacceptable concentrations of constituents of concern to the Colorado River, permanent expansion of the target remediation area, or not achieving the numeric cleanup goals of the RAOs.
- **Category B: Schedule** — Failures that cause the schedule to achieving the groundwater remedy RAOs to be extended by more than 5 to 15 years.
- **Category C: Cost** — Failures that cause the cost of achieving the groundwater remedy RAOs to be increased by more than $10,000,000 to $50,000,000.
- **Category D: Significant Change to Impact** — Changes (such as visual impact) that necessitate additional California Environmental Quality Act (CEQA) analysis.
- **Category E: Significant Health and Safety (H&S) or Compliance Incident** — A health and safety incident that results in lost work time for remedy or Compressor Station staff or the public; an environmental compliance Notice of Violation (other than related to remedy performance); or violation of the requirements in the Applicable or Relevant and Appropriate Requirements (ARARs).

The mitigation measures described in the FMEA tables in this Contingency Plan are taken to minimize or eliminate the likelihood, or severity, of these unacceptable conditions. The FMEA also identifies potential failures that could cause conditions that, while not unacceptable as defined above, should be prevented or minimized.

Causes of potential failures are mitigated in the design process (e.g., select equipment to accommodate a range of anticipated operational conditions), in adaptive operations (e.g., adjusting flow rates and/or carbon substrate dosing; installation of future provisional remediation, freshwater supply, and/or monitoring wells; etc.), and/or in corrective action/contingency response planning (e.g., installing additional wells). Operational mitigation descriptions include the condition that an operator would observe and the action he/she would take. A preventative maintenance schedule is proposed as an overall mitigation step to minimize risk of unexpected failures.

Contingency planning has been prepared for six key elements of the groundwater remedy:

- In-Situ Remediation System (Section 2.1)
- Remedy-produced Water Management System (Section 2.2)
- Freshwater Supply (Section 2.3)

- Power Supply (Section 2.4)
- Remedy Supervisory Control and Data Acquisition (SCADA), Control Systems, and Instrumentation (Section 2.5)
- Enhanced Evaporation at TCS Evaporation Ponds (Section 2.6)

Each system's analysis in this FMEA includes an evaluation of the likelihood and severity of each type of potential failure to help prioritize mitigation. The severity scoring is shown in Table 1.0-1 (tables are presented at the end of each section). It should be noted that the "Severity of Effect" column denotes the implication of the effect if it were to occur, which should be unlikely since the mitigation measures are being taken. As shown in Table 1.0-1, unacceptable conditions are those with a severity score of 4 or above. The type of unacceptable condition is only indicated in the FMEA tables where there is a severity score of 4 or above. A potential failure may result in a 6-month schedule increase (severity score of 2), for example, without constituting an unacceptable condition and therefore the type of unacceptable condition would not be indicated in the FMEA table for this example. Quantifiable thresholds have not been defined for condition Categories A (remedy performance), D (change to impact), and E (H&S/compliance) to distinguish between different severity scores. Severity of effect for these categories is assessed qualitatively on a relative scale. For example, an H&S incident (Category E) with a severity score of 5 is expected to be the most serious with comparatively more lost work time, injury to personnel, etc. than a severity-level 4 H&S incident. The likelihood score is also relative, with 5 being the highest likelihood, though not necessarily highly likely.

The RAOs for the final groundwater remedy are to:

1. Prevent ingestion of groundwater as a potable water source having hexavalent chromium (Cr[VI]) in excess of the regional background concentration of 32 micrograms per liter (µg/L).
2. Prevent or minimize migration of total chromium (Cr[T]) and Cr(VI) in groundwater to ensure concentrations in surface water do not exceed water quality standards that support the designated beneficial uses of the Colorado River (11 µg/L Cr[VI]).
3. Reduce the mass of Cr(T) and Cr(VI) in groundwater at the site to achieve compliance with ARARs in groundwater. This RAO will be achieved through cleanup goal of regional background of 32 µg/L of Cr(VI).
4. Ensure that the geographic location of the target remediation area does not permanently expand following completion of the remedial action.

Compliance monitoring will include groundwater and surface water sampling and will focus on confirming that the final groundwater remedy is achieving these RAOs. Compliance monitoring is primarily designed to ensure that the remedy is meeting RAOs 2, 3, and 4, relating to controlling migration and reducing mass to an adequate degree.

The Contingency Plan anticipates potential issues that may occur with the remedy and identifies design and adaptive operations elements to mitigate those issues, which have been incorporated into the 90% Design Submittal. The adaptive operations framework is presented in data quality objectives in the Sampling and Monitoring Plan presented in Volume 2 of this O&M Manual (see also figures in Section 2 of Volume 2) and is referenced in the FMEA for the IRZ. Additional mitigations identified in the FMEA that may be required and are not covered by design or adaptive operations constitute contingency actions, as outlined in this plan.

TABLE 1.0-1
Severity Scoring Used in Failure Mode and Effects Analysis
Groundwater Remedy Operation and Maintenance Manual
Volume 3: Contingency Plan
PG&E Topock Compressor Station, Needles, California

	Category				
Severity of Effect	**A - Unacceptable Remedy Performance**	**B - Schedule**	**C - Cost**	**D - Change to Impact**	**E - H&S or Compliance**
Unacceptable Conditions					
5	Remedy does not meet RAOs, cleanup goals, design objectives, or otherwise perform as required.	Very significant schedule increase more than 15 years	Very significant cost increase more than $50M	Additional CEQA analysis required	• Serious H&S incident • ARARs, mitigation measures, or other compliance Notice of Violation event
4	Not defined	Schedule increase more than 5 years	Cost increase more than $10M	Not defined	Not defined
Other Conditions					
3	Remedy performance, operational, or other issue that prompts remedy (or portions thereof) to be temporarily shut down, but does not constitute unacceptable condition as defined above	Schedule increase 1-5 years	Cost increase $1M - $10M	Not defined	Not defined
2	Less significant/nuisance issues with remedy	Schedule increase 6 mo. - 1 year	Cost increase $0.5M - $1M	Not defined	Not defined
1	An incident that has an impact in one or more of the five categories, but less than defined above.				

Notes:
ARAR = applicable or relevant and appropriate requirement
H&S = health and safety
RAO = remedial action objective

2.0 Contingency Planning

2.1 In-Situ Remediation System

The in-situ remediation system includes the following components, as described above and in Section 3.2 of the 90% Basis of Design Report:

- National Trails Highway In-Situ Reactive Zone (NTH IRZ): line of wells that may be used as both injection and extraction wells to circulate groundwater and distribute an organic carbon source to promote reduction of the Cr(VI) to trivalent chromium (Cr[III]).
- Inner Recirculation Loop (IRL):
  - River Bank Extraction Wells along the Colorado River to provide hydraulic capture of Cr(VI) groundwater concentrations, accelerate cleanup of the floodplain, enhance the flow of contaminated groundwater through the NTH IRZ line, and control migration of IRZ-generated by-products toward the Colorado River.
  - IRL Injection Wells to re-inject groundwater extracted from the River Bank Extraction Wells (which may be amended with an organic carbon source) and/or fresh water into wells in the upgradient portion of the Cr(VI) plume to flush the plume through the NTH IRZ.
- Freshwater Injection Wells to inject fresh water into wells upgradient of the Cr(VI) plume to flush the plume through the NTH IRZ.
- TCS Recirculation Loop:
  - East Ravine Extraction Wells in the eastern (downgradient) end of the East Ravine to provide hydraulic capture of contaminated groundwater in bedrock.
  - TCS Injection Wells located upgradient of the TCS for the re-injection of groundwater extracted from the East Ravine Extraction Wells and Transwestern Bench Extraction Wells, which will be amended with an organic carbon source, to promote reduction of the Cr(VI) to Cr(III) and remove elevated Cr(VI) groundwater concentrations from the alluvial aquifer in the vicinity of the TCS.

Table 2.1-1 presents the results of the FMEA for the in-situ remediation system.

Potential failures identified include possible ways in which the remedy may not perform per the original intent. This risk is mitigated through design (including pilot testing, predictive simulations/modeling, additional design efforts, and designing in flexibility) and operational flexibility (as described in the Decision Rules/Operational Framework included in Volume 2 of this O&M Manual). The FMEA includes references to elements of the 90% design submittal that provide additional details on how remedy risks are being mitigated in the design and operational strategy. Other potential failures include operational and safety issues involved with mechanical equipment and chemicals for which PG&E has set as a design criterion that two levels of protection would have to fail simultaneously for a failure to be considered significant enough to be included in the FMEA.

2.2 Remedy-produced Water Management System

The final groundwater remedy is reliant on several dozen wells used for the IRZ, freshwater and carbon-amended injection, and groundwater extraction. For all wells, especially the injection and IRZ wells, regular maintenance such as backwashing and rehabilitation is vital to ensure efficient and effective operations during the 30-year projected life of the remedy. Well maintenance will also prevent or reduce the need for drilling new replacement wells. These maintenance activities will produce an ongoing water stream that must be managed as part of the remedial action. Other types of produced water with smaller volumes will also need to be managed, such as monitoring well sampling purge water, equipment decontamination wastewater, and rainfall that collects in remedy facility secondary containment. Providing a reliable means of managing this wastewater is a necessary supporting component of the overall remedy.

The Remedy-produced Water Management System includes the generation, transportation, conditioning, reuse and disposal of conditioned water. The system is described in Section 2.3 of the Operation and Maintenance Plan (Volume 1 of this O&M Manual).

Table 2.2-1 presents the FMEA matrix for the Remedy-produced Water Management System. Two main failure types were identified. The first type of failure is the system a) not having capacity to condition the produced water due to produced water flow being greater than forecasted, or b) experiences downtime which could be caused by a range of events (vandalism, acts of God, equipment failure, etc.). This would result in having to truck some or all of the produced water off-site for management. This would increase costs and traffic-related impacts of the remedy. However, it would not impact remedy performance. To mitigate this risk, the conditioning system has been conservatively sized and space has been reserved for build-out of additional equipment if needed. Also, multiple disposal/reuse options are being established to reduce the risk of disposal/reuse limiting produced water management.

The second type of failure is the conditioning system effluent causing performance problems with wells or pipelines used for re-injecting the water. Problems could range up to the possibility of well fouling or scaling requiring replacement of the wells. Water quality issues that could hurt well performance include high suspended solids, high pH, or constituents/ions that precipitate out and scale the well. Loss of wells due to fouling or scaling could slow the remedy performance until the wells are rehabilitated or replaced. This risk is mitigated by designing in fine-particle filtration and in-line monitoring of pH and turbidity. Operational mitigations will include frequent monitoring of the conditioning system performance and of the injectivity of the wells used for re-injecting treated water.

In response to comments on the 60% design documents (RTC #757 DTSC-239, Tribes' comment #341 [see Appendix I of the 90% BOD Report]), a contingent system is included in this Contingency Plan to remove scale-forming ions from remedy-produced water prior to injecting, if needed. The design basis for the contingent system, referred to herein as the dissolved metals removal system (DMRS), is included in Appendix A. The DMRS would be integrated into the remedy-produced water treatment A-side process, downstream of the A-side filters (see Volume 1, O&M Plan, of the O&M Manual, Sections 2.5 and 3.3). Effluent water from the DMRS would be sent to the remedy-produced A-side conditioned water storage tanks (TNK-401 and TNK-402), pumped from there to the conditioned water storage tank (IRZ00-T720) at the MW-20 Bench, and then returned to the NTH IRZ injection wells via the conditioned water injection pump (IRZ00-P747) and piping.

The implementation of the contingent DMRS could be triggered by significant performance losses in pipelines and wells due to heavy scaling of calcium, iron, magnesium, and/or manganese that cannot be adequately mitigated using planned preventative measures including the clean-in-place (CIP) loop for the removal of biological films and mineral scale depositions that accumulate within the NTH IRZ pipelines (see Section 5.1 of Volume 1), routine pipeline maintenance procedures (Sections 5.2 and 5.3 of Volume 1), and the well maintenance program (Section 4 of Volume 1).

The DMRS is designed to be fully integrated into the planned conditioning process for remedy-produced water and has space allocated for it in the 90% design, thereby allowing for installation without expansion of the building footprint if required in the future. The DMRS would be primarily located on the second floor of the planned Remedy-produced Water Conditioning Building. Certain treatment chemicals will be stored on the first floor of the planned Remedy-produced Water Conditioning Building.

2.3 Freshwater Supply

The Freshwater Supply Water System will provide water for the freshwater injection wells used in the groundwater remedy. The freshwater injection is to assist with flushing the chromium plume through the IRZ located along the NTH. The objective of the freshwater supply system is to provide sufficient water of acceptable quality for successful implementation of the remedy. The quantity and quality requirements are defined in Section 3.3 of the 90% Basis of Design Report. Fresh water for the remedy will be supplied from well HNWR-1A located in Arizona. For well quality protection, Volume 2 of the O&M Manual discusses in detail the proposed monitoring plan for the HNWR-1A well and results of a recent source assessment. Table 2.3-1 presents the FMEA matrix for the supply of fresh water.

Per DTSC direction (comment RTC #21 DTSC-2 on the 60% design), a contingent arsenic treatment system is included in the 90% design and is identified herein as the freshwater pre-injection treatment system (FWPTS). The design basis for the FWPTS is included in Appendix B of this Contingency Plan. Space is reserved for the FWPTS next to the planned Remedy-produced Water Conditioning Building.

The triggering step for implementation of this contingency system was outlined in a letter from the California State Water Resources Control Board (SWRCB) (2013) to DTSC. The State Board letter requires that if the leading edge of the arsenic plume, i.e., arsenic concentrations at the concentration in the injected fresh water, extend more than 150 feet away from injection locations, PG&E must immediately reassess its modeling calculations and quickly identify interim actions it can take to limit the migration of the arsenic plume. The letter further directs the cessation of the injection of untreated fresh water if the arsenic concentration caused by injection of fresh water is detected above the water quality objective (10 parts per billion [10 μg/L]) at 225 feet from the injection locations. The letter states that at this point, DTSC should either (i) require pretreatment to remove arsenic prior to injection or (ii) require another source of fresh water in order to meet the water quality objective.

2.4 Power Supply

The power supply system will provide electricity for the groundwater remedy. The design objective of the system is to reliably provide sufficient electricity to power the groundwater remedy's electrically driven components such as pumps, controls, and lighting.

The primary power supply source for the remedy facilities in California will be power generated by the PG&E Topock Compressor Station. For the freshwater supply well (HNWR-1A) in Arizona, the power supply source will be power provided by Mohave Electric Cooperative. Secondary power supply will be power generated from small photovoltaic solar panels at various locations such as at the Operations Building at the Transwestern Bench, the Remedy-produced Water Conditioning Building at TCS, and at select remote well locations.

A potential failure is the temporary loss of power to the groundwater remedy infrastructure such as pumps and control systems. This could be caused by damage to the power generation equipment or transmission system. The failure modes anticipated would all be repairable in a period of days to weeks. Because the remedy performance is not anticipated to be affected by equipment outages of that duration, the power supply failure modes evaluated are not anticipated to significantly affect remedy schedule or performance.

To mitigate the risk of even temporary power outages, the electrical equipment used in the remedy is designed for the site conditions; site security is provided to minimize risk of vandalism, and an uninterruptible power supply (UPS) is provided for key equipment such as control systems.

Table 2.4-1 presents the FMEA matrix for the power supply system.

2.5 Remedy SCADA, Control Systems, and Instrumentation

The Remedy SCADA system provides operator control, remote access, data logging, and alarm notification for the groundwater remedy. Field instrumentation measures various process data and transmits these data to local programmable logic controllers (PLCs). PLCs are industrial computerized controllers that gather this process data and use process-specific algorithms to provide automated control of the groundwater remedy system. Additionally PLCs are used to concentrate hardwired data signals and transmit them to the central SCADA control center via communications network links. The operator interface terminals (OITs) or human/machine interfaces (HMIs) provide graphical displays representing current and historical process data and provides for operator interaction with the process, adjustment to the automation system, and trending of historical data. The final remedy will contain field instrumentation and local PLCs for each process area or well site tied together via fiber optic cabling, as well as multiple OITs/HMIs to allow operators to interact with various aspects of the groundwater remedy system.

The design objectives of the Remedy SCADA, instrumentation, and control systems are to reliably provide automatic and remote control/monitoring of the groundwater remedy system components, and to reliably record data that are needed for operations and compliance reporting.

A potential failure evaluated is damage to the Remedy SCADA system that causes temporary loss of the ability to view system performance, send/receive control signals from the control room, and log system data. This could have various causes such as hardware or software failures due to site environmental conditions or vandalism, power outages, or damage to communication wiring. Such potential failures are not anticipated to significantly affect remedy schedule or performance.

To mitigate the risk of even temporary loss of control from the central control area, the Remedy SCADA and instrumentation equipment used in the remedy will be designed for the site conditions, equipment spares will be stocked on-site for critical control equipment, site security to protect against vandalism will be provided, and externally powered instruments will be connected to UPS-fed circuits.

Table 2.5-1 presents the FMEA matrix for the Remedy SCADA system.

2.6 Enhanced Evaporation at TCS Evaporation Ponds

One of the management options identified for remedy-produced water is disposal at the existing TCS evaporation ponds (other options include injection into the IRZ wells, re-use in cooling towers, and off-site disposal). Water accumulated in the ponds will evaporate over time. In the event the ponds are full (i.e., water level in the ponds reaches the maximum level allowed by the Regional Water Quality Control Board), and the other options mentioned above are not feasible or available, water can also be trucked off-site via the truck loading station at the ponds. The preferred method of water disposal is evaporation; therefore, a new drip system and agitators will be installed to enhance evaporation at the ponds. Further, the existing truck loading station will also be improved to support off-site trucking of water, if needed. Table 2.6-1 presents the FMEA matrix for the evaporation pond enhancements system.

TABLE 2.1-1
Failure Mode Effect Analysis Matrix - In-Situ Remediation System
Groundwater Remedy Operation and Maintenance Manual
Volume 3: Contingency Plan
PG&E Topock Compressor Station, Needles, California

Potential Failure and Effect without Mitigation	Potential Cause	Mitigation - Design	Mitigation - Operations				Severity (1 Low - 5 High)	Likelihood (1 Low - 5 High)	Severity x Likelihood	Type of Unacceptable Condition					Notes
			Mitigation	Observable Condition: PLC	Observable Condition: Human	Action if Cause Occurs				A. Unacceptable Remedy Performance	B. Significant Schedule Increase	C. Significant Cost Increase	D. Change to Impact	E. H&S or Compliance NOV (other than related to remedy performance)	
Conveyance (General)															
Release from conveyance pipeline. <u>Effect Without Mitigation:</u> Potential release of water with Cr(VI), carbon substrate, and/or well/pipeline maintenance chemicals.	Differential thermal expansion or settlement, deterioration, vandalism, puncture; pressure exceedance; fabrication failure.	Overall pipeline design for durability over project lifetime; secondary containment (double-wall pipe or concrete trench box) with appropriately-designed leak detection systems (see Appendix C - Design Criteria, Section C.5.1 - Piping); redundant/spare pipe installed (or spare space provided for additional pipe); pipe installed within concrete trench box or direct buried without stacking to facilitate access.	Flow monitoring	Alarm conditions - secondary containment sump alarms; out-of-range process alarms (i.e., pipeline flows or pressures)	Observe leak	Stop pipeline operation, switch to spare pipeline and/or repair /replace pipeline, resume operation.	4	1	4					X	Type E unacceptable condition associated with potential environmental release.
Conveyance fouling/clogging. <u>Effect without Mitigation:</u> Potentially insufficient capacity to support remedy.	Solids buildup (i.e., scaling, biofouling).	Overall system/pipeline design to minimize solids buildup; clean-in-place system and cleanouts for pipeline maintenance (see Operations and Maintenance Plan, Section 5 - Pipeline Maintenance); redundant/spare pipe installed (or spare space provided for additional pipe); pipe installed within concrete trench box or direct buried without stacking to facilitate access.	Pipeline pressure/flow monitoring	Pipeline pressure/flow monitoring and data-logging	Significant increase in pipeline pressure or decrease in flow; observed clogging	Stop pipeline operation, switch to spare pipeline and/or clean/repair /replace pipeline, resume operation.	2	3	6						
Pipeline maintenance chemical/fluid release to wells. <u>Effect without Mitigation:</u> Release of chemicals, solids, etc. into wells and groundwater.	Valving between wells and conveyance not closed during pipeline maintenance.	Clean-in-place system programmed to require automated wellhead valves to be closed prior to operation.	Operator training; wellhead/pipeline inspection during maintenance	Well pressure/flow monitoring and data-logging; wellhead valve position monitoring	Loss of pipeline maintenance solution; observed well flows during pipeline maintenance	Well rehab (Operations and Maintenance Plan, Section 4 - Well Maintenance)	2	2	4						

TABLE 2.1-1
Failure Mode Effect Analysis Matrix - In-Situ Remediation System
Groundwater Remedy Operation and Maintenance Manual
Volume 3: Contingency Plan
PG&E Topock Compressor Station, Needles, California

Potential Failure and Effect without Mitigation	Potential Cause	Mitigation - Design	Mitigation - Operations: Mitigation	Observable Condition: PLC	Observable Condition: Human	Action if Cause Occurs	Severity (1 Low - 5 High)	Likelihood (1 Low - 5 High)	Severity x Likelihood	Type of Unacceptable Condition: A. Unacceptable Remedy Performance	B. Significant Schedule Increase	C. Significant Cost Increase	D. Change to Impact	E. H&S or Compliance NOV (other than related to remedy performance)	Notes
Remediation Wells (General) - see also Table 2.2-1, Failure Mode Effect Analysis Matrix - Remedy-produced Water Management System															
Extraction well failure. <u>Effect without Mitigation:</u> The well will not be able to contribute to meeting extraction rate/remedy goals.	Capacity declines over time due to fouling or other well issues.	See Appendix C - Design Criteria (Remediation Well Design and Field Construction Approach) and Operations and Maintenance Plan, Section 4 - Well Maintenance - Extraction wells designed to optimize performance - Extraction wells designed to facilitate periodic well rehab - Remedy operations to minimize substrate and remedial by-product concentrations at extraction wells to minimize fouling	Remediation/monitoring well performance monitoring; periodic well rehab (Operations and Maintenance Plan, Section 4 - Well Maintenance)	Well water level/flow monitoring and data-logging	Insufficient capacity of produced water based on remediation/ monitoring well performance monitoring and evaluation	If well maintenance efforts ineffective - stop well operation, repair or replace, resume operation.	2	3	6						
	Well collapse or casing/screen failure (from deterioration, corrosion, etc.), vandalism, accidental damage, etc.	See Appendix C - Design Criteria (Remediation Well Design and Field Construction Approach) - Overall well design for durability over project lifetime - materials selection for resistance against corrosion, deterioration, and damage during routine operation and well rehab - Wells secured within vaults for protection	Visual well inspections	Alarm condition - out-of-range well operation	Observe damage	Stop well operation, repair or replace, resume operation.	2	1	2						
Injection well failure. <u>Effect without Mitigation</u>: The well will not be able to contribute to meeting injection rate/remedy goals.	Capacity declines over time.	See Appendix C - Design Criteria (Remediation Well Design and Field Construction Approach) and Operations and Maintenance Plan, Section 4 - Well Maintenance - Injection wells designed to optimize performance - drop tubes to minimize air entrainment - Injection wells designed to facilitate routine backwashing and periodic well rehab	Remediation/monitoring well performance monitoring; periodic well backwashing and rehab (Operations and Maintenance Plan, Section 4 - Well Maintenance)	Well water level/pressure/flow monitoring and data-logging	Insufficient capacity of injected water based on remediation/ monitoring well performance monitoring and evaluation	If well maintenance efforts ineffective - stop well operation, repair or replace, resume operation.	2	3	6						
	Well collapse or casing/screen failure (from deterioration, corrosion, etc.), vandalism, accidental damage, etc.	See Appendix C - Design Criteria (Remediation Well Design and Field Construction Approach) - Overall well design for durability over project lifetime - materials selection for resistance against corrosion, deterioration, and damage during routine operation and well rehab - Wells secured within vaults for protection	Visual well inspections	Alarm condition - out-of-range well operation	Observe damage	Stop well operation, repair or replace, resume operation.	2	1	2						
Release from wellhead, piping, or vault. <u>Effect Without Mitigation:</u> Potential release of water with Cr(VI), carbon substrate, and/or well/pipeline maintenance chemicals.	Differential thermal expansion, deterioration, vandalism, puncture; pressure exceedance; fabrication failure.	Overall wellhead design for durability over project lifetime; wells secured within vaults for protection; leak detection level switch in vault sump to alarm/stop well operation	Visual well/vault inspections	Alarm condition - well vault sump level switch; out-of-range well operation	Observe leak	Stop well operation, repair, resume operation.	4	1	4					X	Type E unacceptable condition associated with potential environmental release.
	Injection well overflows.	Downwell pressure transducer to shut off well if excessive water level/pressure increase; leak detection level switch in vault sump to alarm/stop well operation; overall injection system designed for flow/pressure balancing across network to minimize potential for well overflow	Visual well/vault inspections; preventative well maintenance (Operations and Maintenance Plan, Section 4 - Well Maintenance)	Alarm condition - well vault sump level switch; out-of-range well operation	Observe leak	Stop well operation, make repairs (as necessary), troubleshoot injection well capacity issues, as necessary - rehab/redevelop well (Operations and Maintenance Plan, Section 4 - Well Maintenance)	4	1	4					X	
Remediation well equipment, valving, instrumentation failure (other than above). <u>Effect without Mitigation:</u> Potential well damage or undesired operation.	Mechanical or electrical failure; general wear and tear; temperature.	Valves/instruments designed to fail in safest position; redundant controls/alarms; well casing relief valves to protect injection wells in case of excess pressure; common equipment/onsite spares for wells to facilitate troubleshooting	Preventative maintenance schedule; visual well/vault inspections	Alarm condition - well vault sump level switch; out-of-range well operation	Observe leak or out-of-range well operation	Stop well operation, repair, resume operation.	2	2	4						

TABLE 2.1-1
Failure Mode Effect Analysis Matrix - In-Situ Remediation System
Groundwater Remedy Operation and Maintenance Manual
Volume 3: Contingency Plan
PG&E Topock Compressor Station, Needles, California

Potential Failure and Effect without Mitigation	Potential Cause	Mitigation - Design	Mitigation - Operations: Mitigation	Mitigation - Operations: Observable Condition: PLC	Mitigation - Operations: Observable Condition: Human	Mitigation - Operations: Action if Cause Occurs	Severity (1 Low - 5 High)	Likelihood (1 Low - 5 High)	Severity x Likelihood	Type of Unacceptable Condition: A. Unacceptable Remedy Performance	B. Significant Schedule Increase	C. Significant Cost Increase	D. Change to Impact	E. H&S or Compliance NOV (other than related to remedy performance)	Notes
Carbon Amendment Systems (MW-20 and TW Benches)															
General carbon amendment system failure. <u>Effect without Mitigation:</u> Unable to operate parts or all of groundwater recirculation and carbon amendment systems to support remedy.	Equipment, valving, instrumentation failure	Valves/instruments that can result in a release if a fail-safe return is not provided are designed to fail in safest position; redundant controls/alarms; common equipment/onsite spares to facilitate troubleshooting; secondary containment at bench systems.	Visual inspections and preventative maintenance schedule	Alarm condition - out-of-range system operation; sump level alarm	Observed failure condition	Stop system operation, repair, resume operation.	3	2	6						
Carbon substrate storage and/or feed system failure. <u>Effect without Mitigation</u>: Potential release of flammable liquid; unable to amend recirculated groundwater with carbon substrate; potential over-dosing of carbon substrate to injection wells.	Human error Physical impact from vehicles Equipment, valving, instrument failure Corrosion, puncture, deterioration, accidental damage Vandalism	See Appendix C - Design Criteria, C.5.7 - Fire Protection Equipment and Draft Basis of Design Report, Section 3.2.1.1 - Description - NTH IRZ (Organic Carbon Substrate Amendment System [MW-20 Bench]) and Section 3.2.3.1 - Description - TCS Recirculation Loop (Organic Carbon Substrate Amendment System [Transwestern Meter Station]) - System designed in accordance with all applicable codes for flammable liquids - Overall system design for durability over project lifetime, including materials selection for compatibility, corrosion control, impact/damage protection - Storage tank has impact-resistant construction and double-wall construction with integral interstitial zone for leak detection monitoring - Instrumentation to include: tank interstitial space fluid level sensors, primary tank level transmitter with manual gauging port for operator verification, primary tank fluid temperature sensor, visible beacon/audible alarm within bench areas to notify operators of high level during tank filling, pipeline secondary containment leak detection system - Double-wall tank and piping systems with additional secondary containment in process/filling area - Valves/instruments designed to fail in safest position - Redundant controls/alarms - Fire extinguishers to be located at bench systems in accordance with applicable codes - Security fencing/traffic bollards	Visual inspections and preventative maintenance schedule; operator training	Alarm condition - leak detection/ secondary containment alarm; tank overfill alarm; out-of-range system operation (i.e., over- or under-dosing)	Observe failure condition	Stop system operation, repair, replace, or otherwise resolve failure, resume system operation; manual carbon substrate dosing at system or individual wells, if necessary	5	2	10			X		X	Type C/E unacceptable conditions associated with potential cost/H&S issues with flammable liquid storage and handling.

TABLE 2.1-1

Failure Mode Effect Analysis Matrix - In-Situ Remediation System

Groundwater Remedy Operation and Maintenance Manual

Volume 3: Contingency Plan

PG&E Topock Compressor Station, Needles, California

Potential Failure and Effect without Mitigation	Potential Cause	Mitigation - Design	Mitigation - Operations				Severity (1 Low - 5 High)	Likelihood (1 Low - 5 High)	Severity x Likelihood	Type of Unacceptable Condition					Notes
			Mitigation	Observable Condition: PLC	Observable Condition: Human	Action if Cause Occurs				A. Unacceptable Remedy Performance	B. Significant Schedule Increase	C. Significant Cost Increase	D. Change to Impact	E. H&S or Compliance NOV (other than related to remedy performance)	
NTH IRZ															
IRZ is not effective at removing Cr(VI) from groundwater as designed. <u>Effect without Mitigation:</u> Potential schedule/cost increase or other issues with achieving RAOs as designed.	More rapid utilization of carbon substrate after injection than anticipated.	Design included pilot testing, predictive simulations/modeling, and additional design efforts; system designed with flexibility for range of operating flow rates and carbon substrate types and dosing strategies; future provisional wells have been included in the design, if needed; flexibility retained in the design to adjust locations of provisional wells; manual carbon substrate dosing can target individual wells if needed to supplement IRZ-wide dosing; River Bank extraction wells are designed to capture downgradient Cr(VI), TOC, and/or byproducts, as needed; system designed with flexibility to re-direct extracted water from TCS Recirculation Loop to NTH IRZ (if system is flow limited)	See Sampling and Monitoring Plan, Decision Rules/Operational Framework (Figures 2.2-2 and 2.2-3) for IRZ performance troubleshooting and operational adaptability philosophy to be conducted based on remedial performance monitoring/evaluation and using the designed system flexibility - operational adjustments may include flow rates, carbon substrate type and dosing strategy, number and location of operating wells, injection of water from the TCS Recirculation Loop into the NTH IRZ (if system is flow limited), etc. River Bank extraction, Inner Recirculation Loop extraction, and Freshwater injection wells may be slowed or shut down to slow groundwater flow rate during NTH IRZ troubleshooting.		See Sampling and Monitoring Plan and Operations and Maintenance Plan for summary of remedy monitoring and how data will be evaluated/applied to remedy system optimization	If operational adjustments outlined in Sampling and Monitoring Plan, Decision Rules/Operational Framework (Figures 2.2-2 and 2.2-3) are not successful in establishing IRZ effectiveness - additional extraction/injection wells or water sources (if system is flow limited) will be considered	4	2	8	X	X	X	X		Unacceptable conditions associated with potential increased level of effort required to achieve remedy performance objectives.
	Well spacing or screen placement is inadequate.						4	2	8	X	X	X	X		
	Recalcitrant mass in immobile porespace.						4	2	8	X	X	X	X		
	Unexpected hydrogeologic conditions (e.g., preferential flow paths allow water to pass through IRZ without adequate treatment).						4	3	12	X	X	X	X		
	Extraction/injection flow limited.						4	2	8	X	X	X	X		
Extraction of organic carbon and/or significant byproducts. <u>Effect without Mitigation:</u> Potential to increase well/pipeline maintenance required to meet remedy goals.	Carbon substrate dosing greater than required.					If operational adjustments outlined in Sampling and Monitoring Plan, Decision Rules/Operational Framework (Figures 2.2-2 and 2.2-3) are not successful in managing organic carbon or by-product concentrations at extraction wells - additional wells or water sources (if system is flow limited) will be considered; treatment of River Bank extracted groundwater prior to re-injection will be considered.	4	2	8			X			
	By-product generation greater than expected/attenuation slower than expected						4	2	8			X			

TABLE 2.1-1

Failure Mode Effect Analysis Matrix - In-Situ Remediation System

Groundwater Remedy Operation and Maintenance Manual

Volume 3: Contingency Plan

PG&E Topock Compressor Station, Needles, California

Potential Failure and Effect without Mitigation	Potential Cause	Mitigation - Design	Mitigation - Operations: Mitigation	Mitigation - Operations: Observable Condition: PLC	Mitigation - Operations: Observable Condition: Human	Mitigation - Operations: Action if Cause Occurs	Severity (1 Low - 5 High)	Likelihood (1 Low - 5 High)	Severity x Likelihood	Type of Unacceptable Condition: A. Unacceptable Remedy Performance	B. Significant Schedule Increase	C. Significant Cost Increase	D. Change to Impact	E. H&S or Compliance NOV (other than related to remedy performance)	Notes
Inner Recirculation Loop - see also Table 2.3-1, Failure Mode Effect Analysis Matrix - Freshwater Supply															
Unacceptable migration of Cr(VI) or byproducts. Effect without Mitigation: Potential for Cr(VI) or byproducts to enter the Colorado River; potential plume expansion.	Unexpected hydrogeologic conditions.	Design included pilot testing, predictive simulations/modeling, and additional design efforts; system designed with flexibility for range of operating flow rates and carbon substrate type and dosing strategy; IRL injection wells designed for flexibility to inject freshwater and/or River Bank extracted groundwater[1]; future provisional wells have been included in the design, if needed; flexibility retained in the design to adjust locations of provisional wells	See Sampling and Monitoring Plan, Decision Rules/Operational Framework (Figures 2.2-4 and 2.2-5) for IRL performance troubleshooting and operational adaptability philosophy to be conducted based on remedial performance monitoring/evaluation and using the designed system flexibility - operational adjustments may include flow rates, carbon substrate type and dosing strategy, number and location of operating wells, injection of freshwater and/or River Bank extracted groundwater into IRL injection wells[1], etc.		See Sampling and Monitoring Plan and Operations and Maintenance Plan for summary of remedy monitoring and how data will be evaluated/applied to remedy system optimization	If operational adjustments outlined in Sampling and Monitoring Plan, Decision Rules/Operational Framework (Figures 2.2-4 and 2.2-5) are not successful in establishing adequate plume control or plume flushing - additional extraction/injection wells (including wells to the south of RB-5), River Bank extraction well pumping from shallow zones, or additional water sources (if system is flow limited) will be considered; institutional controls will be considered, as needed, to limit new large-capacity extraction wells; additional mitigation measures, including potential treatment of River Bank extracted groundwater prior to re-injection, will be considered	4	3	12	X		X	X		Unacceptable conditions associated with potential increased level of effort required to achieve remedy performance objectives.
	Well spacing or screen placement is inadequate.						4	2	8	X		X	X		
	New large-capacity wells (e.g., water supply wells) are installed near the site (e.g., at Park Moabi or elsewhere along the Colorado River).						4	2	8	X		X	X		
Flushing of plume through NTH IRZ not as effective as designed. Effect without Mitigation: Potential schedule delay.	Unexpected hydrogeologic conditions.						4	3	12		X	X	X		
	Well spacing or screen placement is inadequate.						4	2	8	X		X	X		
	Lack of adequate supply of injection water (e.g., River Bank Extraction Well produced water contains unacceptably high concentrations of byproducts/other constituents).						4	2	8		X	X	X		
Natural reducing rind near river is negatively-impacted by pumping resulting in inadequate reducing buffer in floodplain. Effect without Mitigation: Could affect ability to rely on MNA for residual contamination when active remediation ends.	Oxic water from the river being pulled into floodplain by extraction wells near the river	Design included pilot testing, predictive simulations/modeling, and additional design efforts; system designed with flexibility for range of operating flow rates; River Bank extraction well pumping planned for deeper zones only				If operational adjustments are not successful in adequately maintaining the natural reducing rind - assess potentially required remedy modifications	2	2	4						

TABLE 2.1-1

Failure Mode Effect Analysis Matrix - In-Situ Remediation System

Groundwater Remedy Operation and Maintenance Manual

Volume 3: Contingency Plan

PG&E Topock Compressor Station, Needles, California

Potential Failure and Effect without Mitigation	Potential Cause	Mitigation - Design	Mitigation - Operations: Mitigation	Mitigation - Operations: Observable Condition: PLC	Mitigation - Operations: Observable Condition: Human	Mitigation - Operations: Action if Cause Occurs	Severity (1 Low - 5 High)	Likelihood (1 Low - 5 High)	Severity x Likelihood	Type of Unacceptable Condition: A. Unacceptable Remedy Performance	B. Significant Schedule Increase	C. Significant Cost Increase	D. Change to Impact	E. H&S or Compliance NOV (other than related to remedy performance)	Notes
TCS Recirculation Loop															
TW Bench extraction well network does not provide adequate volume or mass removal. <u>Effect without Mitigation:</u> Potential schedule delay as impacted water near TCS not treated as rapidly as planned.	Unexpected hydrogeologic conditions.	Design included pilot testing, predictive simulations/modeling, and additional design efforts; system designed with flexibility for range of operating flow rates and carbon substrate type and dosing strategy; TCS injection wells designed for flexibility to inject freshwater and/or extracted groundwater; future provisional wells have been included in the design, if needed; flexibility retained in the design to adjust locations of provisional wells; River Bank extraction wells are designed to capture downgradient Cr(VI), TOC, and/or byproducts, as needed; system designed with flexibility to re-direct extracted water from TCS Recirculation Loop to NTH IRZ (if system is limited by ability to inject into TCS injection wells)	See Sampling and Monitoring Plan, Decision Rules/Operational Framework (Figures 2.2-6 to 2.2-8) for TCS Recirculation Loop performance troubleshooting and operational adaptability philosophy to be conducted based on remedial performance monitoring/evaluation and using the designed system flexibility - operational adjustments may include flow rates, carbon substrate type and dosing strategy, number and location of operating wells, etc.; TW Bench and East Ravine extracted groundwater may be injected into NTH IRZ (if system is limited by ability to inject into TCS injection wells).		See Sampling and Monitoring Plan and Operations and Maintenance Plan for summary of remedy monitoring and how data will be evaluated/applied to remedy system optimization	If operational adjustments outlined in Sampling and Monitoring Plan, Decision Rules/Operational Framework (Figures 2.2-6 to 2.2-8) are not successful in achieving design objectives - additional extraction/injection wells or water sources (if system is flow limited) will be considered.	4	3	12		X	X	X		Unacceptable conditions associated with potential increased level of effort required to achieve remedy performance objectives.
	Well spacing or screen placement is inadequate.						4	2	8		X	X	X		
	Extraction/injection flow limited.						4	2	8		X	X	X		
East Ravine extraction well network does not provide capture of targeted groundwater, as designed. <u>Effect without Mitigation:</u> Potential expansion of plume or Cr(VI) release to Colorado River.	Unexpected hydrogeologic conditions.						4	3	12	X	X	X	X		
	Well spacing or screen placement is inadequate.						4	2	8	X	X	X	X		
	Extraction/injection flow limited.						4	2	8	X	X	X	X		
Cr(VI) treatment by TCS injection well network not as effective as designed. <u>Effect without Mitigation:</u> Potential schedule delay.	Unexpected hydrogeologic conditions.						4	3	12		X	X	X		
	More rapid utilization of carbon substrate after injection than anticipated.						4	2	8		X	X	X		
	Well spacing or screen placement is inadequate.						4	2	8		X	X	X		
	Extraction/injection flow limited.						4	2	8		X	X	X		

TABLE 2.1-1
Failure Mode Effect Analysis Matrix - In-Situ Remediation System
Groundwater Remedy Operation and Maintenance Manual
Volume 3: Contingency Plan
PG&E Topock Compressor Station, Needles, California

Potential Failure and Effect without Mitigation	Potential Cause	Mitigation - Design	Mitigation - Operations: Mitigation	Mitigation - Operations: Observable Condition: PLC	Mitigation - Operations: Observable Condition: Human	Mitigation - Operations: Action if Cause Occurs	Severity (1 Low - 5 High)	Likelihood (1 Low - 5 High)	Severity x Likelihood	Type of Unacceptable Condition: A. Unacceptable Remedy Performance	B. Significant Schedule Increase	C. Significant Cost Increase	D. Change to Impact	E. H&S or Compliance NOV (other than related to remedy performance)	Notes
Freshwater Injection System - see also Table 2.3-1, Failure Mode Effect Analysis Matrix - Freshwater Supply															
Flushing of plume through NTH IRZ not as effective as designed. Effect without Mitigation: Potential schedule delay.	Unexpected hydrogeologic conditions.	Design included pilot testing, predictive simulations/modeling, and additional design efforts; system designed with flexibility for range of operating flow rates	See Sampling and Monitoring Plan, Figure 2.2-9 Freshwater Injection System Decision Rules/Operational Framework for freshwater injection performance troubleshooting and operational adaptability philosophy to be conducted based on remedial performance monitoring/evaluation and using the designed system flexibility - operational adjustments may include flow rates, number and location of operating wells, etc.; TCS injections may be adjusted or shut down if FW-02 is not operating as intended		See Sampling and Monitoring Plan and Operations and Maintenance Plan for summary of remedy monitoring and how data will be evaluated/applied to remedy system optimization	If operational adjustments outlined in Sampling and Monitoring Plan, Figure 2.2-9 Freshwater Injection System Decision Rules/Operational Framework are not successful in achieving design objectives - additional injection wells will be considered	4	3	12		X	X	X		Unacceptable conditions associated with potential increased level of effort required to achieve remedy performance objectives.
	Well or screen placement is inadequate.						4	2	8		X	X	X		
	Lack of adequate supply of injection water.						4	2	8		X	X	X		
Insufficient FW-02 performance to maintain control of southwestern plume margin. Effect without Mitigation: Potential plume expansion.	Unexpected hydrogeologic conditions.						4	3	12	X					
	Well or screen placement is inadequate.						4	2	8	X					
	Lack of adequate supply of injection water.						4	2	8	X					
Analytical data collected from freshwater arsenic monitoring wells located 225 feet from freshwater injection locations indicate arrival of arsenic plume above the water quality objective. Effect without Mitigation: Per the California State Water Resources Control Board (SWRCB) letter to DTSC (SWRCB 2013), PG&E is required to cease injection of untreated water and either 1) add pre-treatment or 2) use a freshwater source without arsenic if data collected from freshwater arsenic monitoring wells located 225 feet from freshwater injection locations indicate arrival of arsenic plume above the water quality objective. Modeling calculations will be re-assessed and these or other actions may also be considered for implementation if data collected from freshwater arsenic monitoring wells located 150 feet from freshwater injection locations indicate arrival of the leading edge of the arsenic plume, defined as arsenic concentrations at the concentration in the injected freshwater.	Unexpected hydrogeologic/ geochemical conditions.	Design included pilot testing, predictive simulations/modeling and additional design efforts; system designed with flexibility for range of operating flow rates	Sampling of freshwater arsenic monitoring wells located 150 feet from freshwater injection locations. If data from these wells indicate arrival of the leading edge of the arsenic plume, defined as arsenic concentrations at the concentration in the injected freshwater, modeling calculations will be re-assessed and operational adjustments may include flow rates, number and location of IRL injection wells operating with freshwater versus River Bank extracted groundwater[1], aeration of freshwater prior to injection to reduce arsenic mobility, etc. (see Sampling and Monitoring Plan, Section 2.2.4)		See Sampling and Monitoring Plan and Operations and Maintenance Plan for summary of remedy monitoring and how data will be evaluated/applied to remedy system optimization	If operational adjustments/interim actions discussed in Sampling and Monitoring Plan, Section 2.2.4 are not successful in achieving design objectives - implementation of the freshwater pre-injection treatment system (see also Section 2.3) for freshwater arsenic treatment and/or additional/alternative freshwater sources will be implemented per the SWRCB letter to DTSC (SWRCB 2013).	4	2	8		X	X			Type B/C unacceptable condition associated with potential schedule/cost increases.

TABLE 2.1-1
Failure Mode Effect Analysis Matrix - In-Situ Remediation System
Groundwater Remedy Operation and Maintenance Manual
Volume 3: Contingency Plan
PG&E Topock Compressor Station, Needles, California

Potential Failure and Effect without Mitigation	Potential Cause	Mitigation - Design	Mitigation - Operations: Mitigation	Mitigation - Operations: Observable Condition: PLC	Mitigation - Operations: Observable Condition: Human	Mitigation - Operations: Action if Cause Occurs	Severity (1 Low - 5 High)	Likelihood (1 Low - 5 High)	Severity x Likelihood	Type of Unacceptable Condition: A. Unacceptable Remedy Performance	B. Significant Schedule Increase	C. Significant Cost Increase	D. Change to Impact	E. H&S or Compliance NOV (other than related to remedy performance)	Notes
In-Situ Remediation System (General)															
Aerial or vertical extent of Cr(VI) plume greater than currently defined. <u>Effect without Mitigation</u>: Potential expansion of remedy footprint.	Inadequate characterization of Cr(VI) in groundwater	Groundwater characterization efforts to date indicate it is unlikely that significant Cr(VI) concentrations exist outside of currently-defined plume footprint. Remedy system design includes some flexibility to expand outside of planned footprint, if needed. See Chapter 5 of the Construction/Remedial Action Work Plan for the Construction Contingency Plan/Procedures.	Installation of remediation and monitoring wells will be conducted in a step-wise manner with a focus on first gathering lithologic data, then water quality data, before finalizing well locations/well screen intervals and installing wells. Well construction will also consider previous well data to ensure the latest data is used in the well installation process.		See Sampling and Monitoring Plan and Operations and Maintenance Plan for summary of remedy monitoring and how data will be evaluated/applied to remedy system optimization	Assess potentially required remedy modifications, including system expansion	4	2	8			X	X		Unacceptable conditions associated with potential cost increase/additional CEQA analysis required due to expansion of remedy footprint.
Cr(III) re-oxidation to Cr(VI) after in-situ treatment. <u>Effect without Mitigation:</u> Potential issues with achieving RAOs as designed.	Unexpected high availability of reactive MnO$_2$ surfaces along groundwater flow path.	Design included pilot testing, predictive simulations/modeling, and additional design efforts that indicated significant re-oxidation of Cr(III) to Cr(VI) is unlikely	See Sampling and Monitoring Plan, Decision Rules/Operational Framework (Figures 2.2-2 to 2.2-9) for remedy performance troubleshooting and operational adaptability philosophy to be conducted based on remedial performance monitoring/evaluation and using the designed system flexibility such as adjusting operational flow rates, organic carbon dosing strategy, etc.			Assess potentially required remedy modifications	1 to 4	1	1 to 4	X	X	X	X		Unacceptable conditions associated with potential increased level of effort required to achieve remedy performance objectives.
Changes in aquifer pH not adequately buffered. <u>Effect without Mitigation:</u> Potential issues with achieving RAOs as designed.	Inadequate groundwater and/or biogeochemical characterization	Design included pilot testing and predictive simulations/modeling that indicated significant change in pH is unlikely				Assess potentially required remedy modifications	1 to 3	1	1 to 3						
In-situ remedy byproduct (arsenic) concentrations do not sufficiently attenuate. <u>Effect without Mitigation</u>: Potential issues with achieving RAOs as designed.		Design included pilot testing, predictive simulations/modeling, and additional design efforts that indicate sufficient byproduct attenuation following remedy operation				Assess potentially required remedy modifications, including potential treatment of extracted River Bank groundwater prior to re-injection	1 to 3	1	1 to 3						
In-situ remedy byproduct (manganese) concentrations do not sufficiently attenuate. <u>Effect without Mitigation</u>: Potential issues with achieving RAOs as designed.							1 to 3	1	1 to 3						
In-situ remedy byproduct (iron) concentrations do not sufficiently attenuate. <u>Effect without Mitigation</u>: Potential issues with achieving RAOs as designed.							1 to 3	1	1 to 3						

TABLE 2.1-1

Failure Mode Effect Analysis Matrix - In-Situ Remediation System

Groundwater Remedy Operation and Maintenance Manual

Volume 3: Contingency Plan

PG&E Topock Compressor Station, Needles, California

Potential Failure and Effect without Mitigation	Potential Cause	Mitigation - Design	Mitigation - Operations				Severity (1 Low - 5 High)	Likelihood (1 Low - 5 High)	Severity x Likelihood	Type of Unacceptable Condition					Notes
			Mitigation	Observable Condition - PLC	Observable Condition - Human	Action if Cause Occurs				A. Unacceptable Remedy Performance	B. Significant Schedule Increase	C. Significant Cost Increase	D. Change to Impact	E. H&S or Compliance NOV (other than related to remedy performance)	
Natural Disaster															
Seismic damage. Effect without Mitigation: Damage to remedy infrastructure may cause shutdown of parts or all of remedy.	Earthquake	See Appendix C - Design Criteria, C.3.5 - Seismic Loads - Structures will be designed in accordance with applicable seismic codes		Alarm conditions will shut system down if significant damage	Observed failure condition		varies	1	varies		X	X			Type B/C unacceptable condition associated with potential schedule/cost increases.
Flooding. Effect without Mitigation: Damage to remedy infrastructure may cause shutdown of parts or all of remedy; potential loss of access.	Rising water levels in Colorado River	Remedy infrastructure located outside of ordinary high water mark and 100-year floodplain to the extent possible; system can be operated/shutdown remotely if access limited	Preventative system shutdown or other action if flood conditions predicted	Alarm conditions will shut system down if significant flooding (sump levels)/ damage	Observed failure condition		varies	1	varies		X	X			Type B/C unacceptable condition associated with potential schedule/cost increases.
Fire damage. Effect without Mitigation: Damage to remedy infrastructure may cause shutdown of parts or all of remedy.	Wildfires/vegetation fires; Compressor station or gas pipeline explosion	System can be operated/shutdown remotely if access limited	Routine vegetation clearing/housekeeping in remedy facility areas; preventative system shutdown or other actions if fires in area	Alarm conditions will shut system down if significant damage	Observed failure condition	Stop system operation, inspect system, repair/replace system infrastructure (as needed), resume system operation	varies	1	varies		X	X			Type B/C unacceptable condition associated with potential schedule/cost increases.
Freezing conditions. Effect without Mitigation: Potential damage to remedy infrastructure may cause shutdown of parts or all of remedy.	Cold temperatures	Site conditions/temperatures unlikely to be cold enough to cause issues.	Preventative system shutdown and system/pipeline draining if freezing temperatures predicted	Alarm conditions will shut system down if significant freezing/ damage	Observed failure condition		1	1	1						
Wind-blow dust damage. Effect without Mitigation: Potential damage to remedy infrastructure may cause shutdown of parts or all of remedy.	Dust, sands, etc. blown by high desert winds	Most remedy infrastructure located within enclosed buildings or vaults.	Preventative maintenance and visual inspection schedule to observe damage	Alarm conditions will shut system down if equipment failure due to dust damage	Observed damage or failure condition		1	2	2						

Abbreviations:

PLC - process logic controller
DOI - United States Department of the Interior
DTSC - Department of Toxic Substances Control
EIR - environmental impact report
H&S - health and safety
NOV - notice of violation
RAO - remedial action objective
TW - Transwestern
IRZ - In-Situ Reactive Zone
NTH - National Trails Highway
TCS - Topock Compressor Station
IRL - Inner Recirculation Loop
MNA - monitored natural attenuation
Cr(VI) - hexavalent chromium
Cr(III) - trivalent chromium
MnO_2 - manganese dioxide
P/V - pressure/vacuum
SWRCB - State Water Resources Control Board
TOC - total organic carbon

Notes:

1. Under the nominal operational scenario, River Bank extracted groundwater will be injected into the lower two-thirds of the saturated interval at IRL-1 and IRL-2. Changes in the wells and/or intervals into which River Bank extracted groundwater is injected will first be discussed with the DTSC and DOI.

TABLE 2.2-1
Failure Mode Effect Analysis Matrix — Remedy-produced Water Management System
Groundwater Remedy Operation and Maintenance Manual
Volume 3: Contingency Plan
PG&E Topock Compressor Station, Needles, California

			Mitigation - Operations							Type of Unacceptable Condition					
				Observable Condition											
Potential Failure and Effect without Mitigation	**Potential Cause**	**Mitigation - Design**	**Mitigation**	**Remedy SCADA**	**Human**	**Action if Cause Occurs**	**Severity (1 Low - 5 High)**	**Likelihood (1 Low - 5 High)**	**Severity x Likelihood**	**A. Unacceptable Remedy Performance**	**B. Significant Schedule Increase**	**C. Significant Cost Increase**	**D. Significant Change to Impacts (Additional CEQA Analysis).**	**E. H&S or Compliance NOV (other than related to remedy performance)**	**Notes**
1. Conditioning System Capacity Insufficient [2,3] Effect without Mitigation: Some water will not be able to be conditioned or re-used/ disposed on-site.	a. Generate more water that must be managed in a single backwash event – Short- term capacity condition	Plant designed for 35 gpm capacity and safety factor applied in sizing storage tanks	Temporarily decrease backwash frequency which would cause an increase in water level in the injection well	Influent flow measurements	N/A	Adjust operations to reduce backwash Investigate root cause and re-evaluate well O&M procedures	1	1	1						In cases resulting in loss of well performance, see the SOPs in the O&M Manual for diagnostic and maintenance procedures.[4]
	b. Wells need more maintenance then anticipated – Long-term capacity condition	Plant designed for 35 gpm capacity and safety factor applied in sizing storage tanks. Process is divided into 2 sides (Remedy A-side and Freshwater B-side) to allow for flexibility in managing conditioned water.	Investigate root cause, re-evaluate well operations, and maintenance procedures (see Section 4). If needed, evaluate the need and methods to increase plant capacity.	Flow transmitters, High well operating level	N/A	Adjust operations to reduce backwash Investigate root cause and re-evaluate well O&M procedures	3	2	6						See Note [1]. Severity depends on downtime and cost.
	c. Excessive load of solids on filters. Frequent filter change-outs	Install tanks to settle solids and turbidity analyzers on conditioned water tanks. Design coarse, then fine filter and standby filters on each train and instrumentation to measure pressure across the filters.	Conduct jar testing for alternative coagulants, to improve settling in tanks. Normal operation is flow through 2-stage filters. Standby filters put into service if operating filter is fouled. Stock spare filters on site	Quick increase in differential pressure across cartridge filters Alarms	Scheduled inspections, check water chemistry for scaling conditions	Well sampling to evaluate influent solids concentrations; Replace cartridges. If scaling, change pH target or add antiscalant	2	1	2						In cases resulting in loss of well performance, see the O&M Manual, Volume 1, Section 4 for diagnostic and maintenance procedures.[4]
	d. Grit build-up in tank	Design capability to pump solids from these tanks to phase separators. Design capability to use vac truck to remove solids.	Operators to monitor solids level	N/A	Operators to monitor solids level	Operators to hose down solids so they'll pump out, or remove by vac truck	1	1	1						
	e. Phase separator bins cannot be removed due to problems with hauling contractor and solids fill up in system. Plant capacity limited or stopped.	N/A	Have backup destination for disposal planned	N/A	N/A	Store full bins on site or at other PG&E facilities	1	1	1						

TABLE 2.2-1
Failure Mode Effect Analysis Matrix — Remedy-produced Water Management System
Groundwater Remedy Operation and Maintenance Manual
Volume 3: Contingency Plan
PG&E Topock Compressor Station, Needles, California

Potential Failure and Effect without Mitigation	Potential Cause	Mitigation - Design	Mitigation - Operations: Mitigation	Observable Condition: Remedy SCADA	Observable Condition: Human	Action if Cause Occurs	Severity (1 Low - 5 High)	Likelihood (1 Low - 5 High)	Severity x Likelihood	A. Unacceptable Remedy Performance	B. Significant Schedule Increase	C. Significant Cost Increase	D. Significant Change to Impacts (Additional CEQA Analysis).	E. H&S or Compliance NOV (other than related to remedy performance)	Notes
	f. IRZ and other on-site reuse/disposal options do not have the capacity to take all treated water – Short term condition	N/A	Storage	N/A	N/A	Adjust operations	2	1	2						
	g. IRZ and other on-site reuse/disposal options do not have the capacity to take all treated water – Long term condition	N/A	Evaluate alternative re-use options	N/A	N/A	Trucking	3	1	3						.
	h. More wells or higher flow rates are needed to achieve RAOs, which produces more water to manage	Reserve space for additional storage and/or conditioning equipment	N/A	N/A	N/A	N/A	2	1	2						See Note 3.
2. Poor Quality Water to Wells: High or low pH Effect without Mitigation: Out of Spec Water may cause increased well or formation fouling or geochemical changes releasing minerals which could affect IRZ performance or plume composition. Excessive pH either high or low could reduce or change microorganism populations, which in turn could also reduce IRZ performance.	a. Tank eductor failure, and poor mixing of conditioning chemicals	Install redundant tank eductors	N/A	N/A	If chemical addition loses effectiveness at altering pH. Will do periodic visual inspections of educators	Repair or replace	1	1	1						
	b. pH Analyzer Failure	Install analyzers on influent and conditioned water tanks	Periodic calibration and system inspections	High and low alarm	Scheduled inspections and monitoring with handheld meter	N/A	1	1	1						
3. Poor Quality Water to Wells: High Suspended Solids Effect without Mitigation: Increase potential for well fouling which could result in increased well maintenance	Cartridge filter rupture or operator not install cartridge	Install turbidity analyzers on conditioned water tanks	Injection well performance monitoring SOP and RPWC System SOPs.[4] Normal operation is flow through 2-stage filters. Standby filter put into service if operating filter is fouled	Alarms on analyzers	Equipment inspections	Follow well maintenance procedures (Section 4), replace cartridges	2	1	2						

TABLE 2.2-1
Failure Mode Effect Analysis Matrix — Remedy-produced Water Management System
Groundwater Remedy Operation and Maintenance Manual
Volume 3: Contingency Plan
PG&E Topock Compressor Station, Needles, California

Potential Failure and Effect without Mitigation	Potential Cause	Mitigation - Design	Mitigation - Operations: Mitigation	Observable Condition: Remedy SCADA	Observable Condition: Human	Action if Cause Occurs	Severity (1 Low - 5 High)	Likelihood (1 Low - 5 High)	Severity x Likelihood	A. Unacceptable Remedy Performance	B. Significant Schedule Increase	C. Significant Cost Increase	D. Significant Change to Impacts (Additional CEQA Analysis).	E. H&S or Compliance NOV (other than related to remedy performance)	Notes
4. Poor Quality Water to Wells: Presence of scaling ions: (Ca, Mg, Mn, Fe, etc.) or high pH water Effect without Mitigation: Scaling in pipelines and wells	Presence of ions in well water	Reserve space to add conditioning units, if needed. These contingent units are described in Section 2.2 of this Contingency Plan. Pipe blowoffs and cleanouts are included in the pipelines. May need to add anti-scalants continuously or use other chemical cleaners.	Monitor effluent quality and injection well performance (see additional information in the Notes column).	N/A	N/A	Follow well maintenance procedures (Section 4)	2	2	4						System is not designed for removing dissolved metals. Modify conditioning process if dissolved ions and metals pose or are causing declining well performance. Addition of conditioning methods may be required if pH increase is not effective in removing constituents. More frequent rehabs or backwash at wells that are fouling due to poor effluent water quality.
5. Equipment Failure Effect Without Mitigation: Leak, contamination, personnel exposure	a. Pipe rupture	Select piping material that is appropriate for the liquid being conveyed and is rated for the anticipated operating pressure.	N/A	N/A	Visual	Follow SOPs,[4] and perform repair	2	1	2						
	b. Tank Failure	Install tank vents, barriers to prevent vehicle impact, seismic supports, coatings, corrosion protection system, and secondary containment for tanks	Preventive maintenance	N/A	Visual	Follow SOPs,[4] and perform repair	2	1	2						
	c. Pump Failure	Mech. seals, drainage for leaks and drips, evaluate seal flush system destination, evaluate cavitation potential on low suction head pumps.	Preventive maintenance	Run fail indication	N/A	Follow SOPs[4] for pump and seals, and perform repair	1	1	1						
	d. Filter failure	Install instrumentation to measure pressure across the filters and alarm. Install 2-stage filters (coarse and fine). Set vessel pressure rating to contain “deadhead” pump condition.	Preventive maintenance	Increased pressure across filters	N/A	Follow SOPs,[4] and perform repair/ replace cartridges	1	1	1						
	e. Eductor failure	Install multiple tank eductors. Monitor vacuum on educator to evaluate erosion or fouling.	Preventive maintenance and inspection. Do routine maintenance and adjust procedures and equipment accordingly.	N/A	Visual inspections/ maintenance	Follow SOPs[4] and perform repair/ replace educators.	1	1	1						

TABLE 2.2-1
Failure Mode Effect Analysis Matrix — Remedy-produced Water Management System
Groundwater Remedy Operation and Maintenance Manual
Volume 3: Contingency Plan
PG&E Topock Compressor Station, Needles, California

			Mitigation - Operations							Type of Unacceptable Condition					
				Observable Condition											
Potential Failure and Effect without Mitigation	**Potential Cause**	**Mitigation - Design**	**Mitigation**	**Remedy SCADA**	**Human**	**Action if Cause Occurs**	**Severity (1 Low - 5 High)**	**Likelihood (1 Low - 5 High)**	**Severity x Likelihood**	**A. Unacceptable Remedy Performance**	**B. Significant Schedule Increase**	**C. Significant Cost Increase**	**D. Significant Change to Impacts (Additional CEQA Analysis).**	**E. H&S or Compliance NOV (other than related to remedy performance)**	**Notes**
6. Freezing Effect without mitigation: No fluid flow	Low ambient temperature	Install heat trace for some chemical piping and storage tanks.	Drain system. Other responses include heat tape, wrapping lines with cloth or rags, or placing heat lamps.	N/A	Weather forecast and anticipated outage schedule.	Upgrade freeze protection or change chemical strength or type	2	1	2						Not been a problem historically at TCS or IM-3
7. Spills Effect without Mitigation: Exposure and contamination of soil	Equipment or pipe failure	Provide adequate secondary containment	SOP[4] and training and alarms (also in HMBP, BMPs, SWPPP)	Alarm for pump running and no flow. Secondary containment level alarms	Visual inspections	Drain system, pump to influent storage tanks. Repair leak.	2	1	2						
8. Unexpected constituents/ material by-product in conditioned water Effect without Mitigation: Carry over contaminant to cooling tower or injection wells	a. Not following RPWC SOPs[4]	N/A	Follow the Operation and Maintenance Manual and SOPs	N/A	N/A	Reinforce/training	1	1	1						Examples include, iron, manganese, silica, calcium, magnesium, and biological materials
	b. Unexpected material enters system	N/A	Investigate root cause, re-evaluate well operations, and maintenance procedures (see Section 4)	N/A	N/A	Revise SOPs[4] or process as needed, could modify monitoring procedures.	2	1	2						
9. Lightning Strike Effect without mitigation: Damage to plant may cause shutdown of system. May cause release of produced water or conditioning chemicals	Lightning	Provide lightning protection and adequate secondary containment for tanks and equipment	Maintain appropriate spare parts to minimize downtime. If necessary, can truck offsite or stop backwashing to mitigate downtime of conditioning system.	N/A	Add inspections into SOPs[4] to watch for leaks or overfilling after a strike	Inspect and assess site for damage / mechanical integrity or repair. If necessary, can truck offsite or stop backwashing until repair is done.	2	1	2						
10. Seismic Damage Effect without Mitigation: Damage to plant may cause shutdown of system	Earthquake	Design in accordance with structural design criteria in 90% Basis of Design Report, Appendix C. Provide adequate secondary containment for tanks and equipment	If necessary, can truck offsite or stop backwashing to mitigate downtime of conditioning system.	N/A	N/A	Inspect and assess site for damage / mechanical integrity or repair. If necessary, can truck offsite or stop backwashing until repair is done.	3	1	3						
11. Fire Effect without Mitigation: Damage to plant may cause shutdown of system	Fire	Fire hydrant in proximity of building. Provide adequate secondary containment for equipment and tanks.	Fire water/pumps at station. If necessary, can truck offsite or stop backwashing to mitigate downtime of conditioning system.	N/A	N/A	Contact Fire Dept. Inspect, assess damage, begin repairs, startup. If necessary, can truck offsite or stop backwashing until repair is done.	2	1	2						

TABLE 2.2-1
Failure Mode Effect Analysis Matrix — Remedy-produced Water Management System
Groundwater Remedy Operation and Maintenance Manual
Volume 3: Contingency Plan
PG&E Topock Compressor Station, Needles, California

Potential Failure and Effect without Mitigation	Potential Cause	Mitigation - Design	Mitigation - Operations: Mitigation	Mitigation - Operations: Observable Condition: Remedy SCADA	Mitigation - Operations: Observable Condition: Human	Mitigation - Operations: Action if Cause Occurs	Severity (1 Low - 5 High)	Likelihood (1 Low - 5 High)	Severity x Likelihood	Type of Unacceptable Condition: A. Unacceptable Remedy Performance	B. Significant Schedule Increase	C. Significant Cost Increase	D. Significant Change to Impacts (Additional CEQA Analysis).	E. H&S or Compliance NOV (other than related to remedy performance)	Notes
12. System is damaged due to vandalism Effect without Mitigation: Damage to wells could result in increased trucking or well repair/ replacement. Plant is off-line for weeks to months while being re-built.	Vandalism	Facilities within the TCS will be secured by current TCS security system. Controls built into the system (alarms, containment, automatic cutoffs and shutdowns) are designed to help mitigate uncontrolled releases or discharges following several types of due to vandalism	Periodic inspections of all equipment inside and outside conditioning system and wells. TCS access control and security will help protect plant.	N/A	N/A	Inspect and assess site for damage / mechanical integrity or repair.	2	1	2						

Notes:

[1] Anticipated annual remedy-produced water volume is 7.6 million gallons (MG) per year. With provisional wells this volume could increase to 10 MG per year. The automated backwashing and conditioning system has been designed to accommodate this range of anticipated volume of wastewater. If the system functions as designed, the amount of trucking needed during O&M would be minimal, and within the range analyzed in the certified EIR (DTSC 2011; see Section 3.5.3, page 3-26).

[2] Current estimated annual flow is 7.6 MG; with provisional wells could be 10 MG/yr. Peak design flow is 35 gpm (18.4 MG/yr).

[3] Space is reserved to allow for increase storage and system conditioning capacity if needed.

[4] Standard Operating Procedures are presented in O&M Manual Volume 1, Operation and Maintenance Plan, Appendix C.

Acronyms and Abbreviations:

ARAR = Applicable or Relevant and Appropriate Requirements
BMP = Best Management Practices
EIR = Environmental Impact Report
H&S = Health & Safety
HMBP = Hazardous Materials Business Plan
IM-3 = Interim Measure No. 3
NOV = Notice of Violation
N/A = Not Applicable
O&M = Operation and Maintenance
RAO = Remedial Action Objective
RPWC = Remedy-Produced Water Conditioning
SCADA = Supervisory Control and Data Acquisition
SOP = Standard Operating Procedure
SWPPP = Storm Water Pollution Prevention Plan
TCS = Topock Compressor Station

TABLE 2.3-1
Failure Mode Effect Analysis Matrix — Freshwater Supply
Groundwater Remedy Operation and Maintenance Manual
Volume 3: Contingency Plan
PG&E Topock Compressor Station, Needles, California

	Failure Mode	Likely Causes for Failure	Effects of Failure	Operational Actions	Possible Contingency Measures
Failure Modes Associated with HNWR-1A Source	Well yield declines below the minimum required for optimal remedy operation	• Pump failure • Extraction well fouling • Excessive drawdown due to competing water users	• Delay in reaching Remedial Action Objectives	• Replace pump • Rehab well • Replace well • Bring HNWR-1 online	• Bring Site B well online.
	Quality of water in freshwater well declines over time	• Pumping draws in saline water from below or geochemically reduced water containing iron and manganese	• Could result in shutting down remedial action if water quality is not suitable for injection	• Isolate the upper well screen interval from the lower screen interval (e.g., using an in-well packer) • Aerate freshwater prior to injection (note that this option requires a small amount of piping changes and addition of fittings) • Increase riverbank extraction (note that this option could only be used to offset a marginal reduction in freshwater supply)	• Bring Site B well on line. • Implement contingent arsenic treatment system per State Water Resources Control Board letter (SWRCB 2013)[1]
	Freshwater pumping causes adverse effects on water quality or capacity in nearby wells	• Over pumping of aquifer in areas with marginal groundwater quality / transmissivity	• Could result in shutting down remedial action if affected water users cannot be made whole	• None	• Bring Site B well on line

Note:

[1] The referenced letter provides the SWRCB's findings and conditions for allowing injection of fresh water containing naturally occurring arsenic above the maximum contaminant level (MCL) without pre-treatment. The letter requires that if the leading edge of the arsenic plume, i.e., arsenic concentrations at the concentration in the injected fresh water, extend more than 150 feet away from injection locations, PG&E must immediately reassess its modeling calculations and quickly identify interim actions it can take to limit the migration of the arsenic plume. The letter further directs the cessation of the injection of untreated fresh water if the arsenic concentration caused by injection of fresh water is detected above the water quality objective (10 parts per billion [10 µg/L]) at 225 feet from the injection locations. The letter states that at this point, DTSC should either (i) require pretreatment to remove arsenic prior to injection or (ii) require another source of fresh water in order to meet the water quality objective.

TABLE 2.4-1
Failure Mode Effect Analysis Matrix — Power Supply
Groundwater Remedy Operation and Maintenance Manual
Volume 3: Contingency Plan
PG&E Topock Compressor Station, Needles, California

Potential Failure and Effect without Mitigation	Potential Cause	Mitigation – Design	Mitigation - Operations: Mitigation	Mitigation - Operations: Observable Condition: Remedy SCADA	Mitigation - Operations: Observable Condition: Human	Mitigation - Operations: Action if Cause Occurs	Severity (1 Low - 5 High)	Likelihood (1 Low - 5 High)	Severity x Likelihood	Type of Unacceptable Condition: A. Unacceptable Remedy Performance	Type of Unacceptable Condition: B. Significant Schedule Increase	Type of Unacceptable Condition: C. Significant Cost Increase	Type of Unacceptable Condition: D. Significant Change to Impacts (e.g., Additional CEQA Analysis)	Type of Unacceptable Condition: E. H&S or Compliance NOV (other than related to remedy performance)	Notes
1. Utility or generated power supply failure Effect Without Mitigation: Loss of equipment function and eventual loss of control system functionality. May prohibit systematic shutdown of processes	Raptor entanglement, lightning strike on line, high wind, post insulator destroyed by gunshot, traffic collision with pole, or external customer causes distribution circuit trip	Uninterruptible Power Supplies (UPS) for control circuits	Maintain site security.	N/A	N/A	Repair, replace	1	2	2						
	Generator mechanical, electrical, or controller failure	Interconnection to other source(s) of generated electrical power, connection point for dedicated portable generator (note that a portable, rental backup generator of similar make and model of the existing generator [Isuzu Model 6WG1X] will be mobilized onsite as needed during project implementation to provide power).	N/A	N/A	N/A	Repair, replace	2	1	2						
2. Electrical distribution equipment failure Effect Without Mitigation: Loss of power downstream of failed equipment. May prohibit systematic shutdown of processes	Manufacturing defects, age, and heat exposure, or ingress of dirt/sand into electrical equipment	Use utility-grade equipment, rated for installation environment. Utilize common equipment styles for quick replacement	Periodic electrical testing, including transformer dissolved gas analysis	N/A	N/A	Repair, replace	3	1	3						
3. Damage from direct or nearby lightning strikes Effect Without Mitigation: Loss of power downstream of failed equipment. May prohibit systematic shutdown of processes	If power is from utility: Connection to utility overhead lines which attract lightning	Use of Surge Protective Devices	Periodic inspection of SPD indicators	N/A	N/A	Repair, replace	3	1	3						
	Direct strike on equipment	None	None	Loss of Power Detected	Charred Enclosure	Repair, replace	3	2	6						
4. Cable damage/fault/failure Effect Without Mitigation: Loss of power downstream of failed equipment. May prohibit systematic shutdown of processes	Digging near underground lines, rodents in termination cabinets, over temperature leading to insulation failure	Protect power cabling in raceway and enclosures. Minimize sun exposure to insulation systems and size circuits conservatively	Keep enclosure doors closed, use proper bolt torques	Loss of Power Detected	N/A	Repair, replace	3	1	3						
5. Externally caused equipment failure Effect Without Mitigation: Loss of power downstream of failed equipment. May prohibit systematic shutdown of processes	Vandalism, theft, force majeure	Provide secure, robust, and lockable system enclosures	Inspect accessible equipment for damage	N/A	Inspect accessible equipment for damage	Repair, replace	3	1	3						

TABLE 2.4-1
Failure Mode Effect Analysis Matrix — Power Supply
Groundwater Remedy Operation and Maintenance Manual
Volume 3: Contingency Plan
PG&E Topock Compressor Station, Needles, California

Potential Failure and Effect without Mitigation	Potential Cause	Mitigation – Design	Mitigation - Operations: Mitigation	Mitigation - Operations: Observable Condition: Remedy SCADA	Mitigation - Operations: Observable Condition: Human	Mitigation - Operations: Action if Cause Occurs	Severity (1 Low - 5 High)	Likelihood (1 Low - 5 High)	Severity x Likelihood	Type of Unacceptable Condition: A. Unacceptable Remedy Performance	Type of Unacceptable Condition: B. Significant Schedule Increase	Type of Unacceptable Condition: C. Significant Cost Increase	Type of Unacceptable Condition: D. Significant Change to Impacts (e.g., Additional CEQA Analysis)	Type of Unacceptable Condition: E. H&S or Compliance NOV (other than related to remedy performance)	Notes

Notes:
ARAR = applicable or relevant and appropriate requirement
H&S = health and safety
N/A = not applicable
NOV = Notice of Violation
PLC = programmable logic controller

TABLE 2.5-1
Failure Mode Effect Analysis Matrix — Remedy SCADA, Control Systems, and Instruments
Groundwater Remedy Operation and Maintenance Manual
Volume 3: Contingency Plan
PG&E Topock Compressor Station, Needles, California

Potential Failure and Effect without Mitigation	Potential Cause	Mitigation - Design	Mitigation - Operations: Mitigation	Mitigation - Operations: Observable Condition: Remedy SCADA	Mitigation - Operations: Observable Condition: Human	Mitigation - Operations: Action if Cause Occurs	Severity (1 Low – 5 High)	Likelihood (1 Low – 5 High)	Severity x Likelihood	Type of Unacceptable Condition: A. Unacceptable Remedy Performance	B. Significant Schedule Increase	C. Significant Cost Increase	D. Significant Change to Impacts (e.g., Additional CEQA Analysis etc.)	E. H&S or Compliance NOV (other than related to remedy performance)	Notes
1. PLC hardware failure Effect Without Mitigation: Lose ability to send/ receive control signals from control room. Lose ability to collect data.	a. Over-temperature	Keep cooled, design includes shade or active cooling where required for equipment longevity.	Keep spares on-site in stock	Remedy SCADA monitors communication and PLC health, and alarms in failure event	Failure may result in unchanged or frozen process variable	Repair, replace	1	3	3						Would be fixed before would cause RAO or schedule issues
	b. Dust/Rainfall/Spray from washdown or pipe break	Design utilizes industrial-grade equipment, housing in National Electrical Manufacturers Association (NEMA)-rated enclosures appropriate for environment. For open enclosures include filters.													Would be fixed before would cause RAO or schedule issues
	c. Power supply irregularity (lightning, shifting generator power, utility's overvoltage, harmonics, temporary power loss)	UPS provided for each PLC.													Would be fixed before would cause RAO or schedule issues
2. Cabling or termination damage/failure Effect Without Mitigation: Lose ability to send/ receive control signals from control room. Lose ability to collect data.	Mechanical damage by backhoe or shovel for underground circuits, traffic or vandalism for above-ground circuits, or temperature changes loosen terminations	Provide conduit for mechanical protection of circuits, route fiber optic cables in protected areas of panels, monitor communications, detection tape, rigid conduit, concrete cap, pipe markers.	Use proper torque on cable terminations	Remedy SCADA monitors communications network, alarms in failure event	Routine patrols of utility corridors and facilities	Repair, replace	1	2	2						

TABLE 2.5-1
Failure Mode Effect Analysis Matrix — Remedy SCADA, Control Systems, and Instruments
Groundwater Remedy Operation and Maintenance Manual
Volume 3: Contingency Plan
PG&E Topock Compressor Station, Needles, California

Potential Failure and Effect without Mitigation	Potential Cause	Mitigation - Design	Mitigation - Operations: Mitigation	Mitigation - Operations: Observable Condition: Remedy SCADA	Mitigation - Operations: Observable Condition: Human	Mitigation - Operations: Action if Cause Occurs	Severity (1 Low – 5 High)	Likelihood (1 Low – 5 High)	Severity x Likelihood	Type of Unacceptable Condition: A. Unacceptable Remedy Performance	B. Significant Schedule Increase	C. Significant Cost Increase	D. Significant Change to Impacts (e.g., Additional CEQA Analysis etc.)	E. H&S or Compliance NOV (other than related to remedy performance)	Notes
3. Field instrumentation damage/failure Effect Without Mitigation: Lose ability to receive accurate control signals from control room or at local controllers. Diminished process data accuracy.	a. Thermal or physical damage to instrument or aging of internal parts or circuits, drifting of instrument output signal(s)	Provide sun protection and mechanical protection where instruments are vulnerable to damage	Calibrate instruments according to manufacturer's recommended schedules	Reduced control system and process performance	Test critical alarms as part of O&M procedure and field verification (e.g., water levels)	Adjust, repair, replace	1	1	1						For severities upon loss of critical instrumentation, see Process FMEAs.
	b. Power supply irregularity (lightning, shifting generator power, utility's overvoltage, harmonics, temporary power loss)	Connect externally powered instruments to UPS-fed circuits	Routine testing of battery capacity or regular replacement	Erroneous alarms, reduced control system and process performance	N/A	Repair, replace	1	1	1						
4. SCADA controls software failure: Effect without Mitigation: Control system commands lock themselves into last state	Software bug, OS or applications software	Use HMI software suited for size of system, rigorous testing of applications software prior to and during startup	Keep backup files onsite and offsite for all OS and application software programs	N/A	Loss of real-time monitoring and/or control	Reboot system, potential reload of software	2	2	4						
5. Valve fails in non-safe state. Effect without Mitigation: Water or chemical may flow not per design.	a. Power failure	Valves that are important to fail in safe position will be designed or configured with a fail safe mode or passive valves (checks), alarm at PLC	N/A	Detection of undesirable process condition	N/A	Repair, replace	2	2	4						
	b. Electrically actuated valves - power loss at valve	Program to fail to safe position	N/A	Objectionable flow condition	N/A	Repair, replace	2	2	4						

TABLE 2.5-1
Failure Mode Effect Analysis Matrix — Remedy SCADA, Control Systems, and Instruments
Groundwater Remedy Operation and Maintenance Manual
Volume 3: Contingency Plan
PG&E Topock Compressor Station, Needles, California

			Mitigation - Operations							Type of Unacceptable Condition					
				Observable Condition											
Potential Failure and Effect without Mitigation	**Potential Cause**	**Mitigation - Design**	**Mitigation**	**Remedy SCADA**	**Human**	**Action if Cause Occurs**	**Severity (1 Low – 5 High)**	**Likelihood (1 Low – 5 High)**	**Severity x Likelihood**	**A. Unacceptable Remedy Performance**	**B. Significant Schedule Increase**	**C. Significant Cost Increase**	**D. Significant Change to Impacts (e.g., Additional CEQA Analysis etc.)**	**E. H&S or Compliance NOV (other than related to remedy performance)**	**Notes**
6. Radio Communication interruption Effect Without Mitigation: Lose ability to send/ receive control signals from control room. Lose ability to collect data.	Vegetation or other obstruction in radio path	Antennas on towers with clear line of sight, use appropriate carrier frequency for link, program communications heartbeat	Vegetation management	Communication loss for radio link	N/A	Clear obstruction	1	2	2						
7. Externally caused SCADA equipment failure Effect Without Mitigation: Lose ability to send/ receive control signals from control room. Lose ability to collect data.	Vandalism, theft, force majeure	Provide secure and robust system enclosures, bollards where required, installations above flood plain	Periodic inspections of all equipment inside and outside conditioning system and wells. TCS access control will help protect plant.	Loss of equipment functionality	Visibly damaged or missing equipment	Repair, replace	1	1	1						
8. pH probe or other analytical probe/device fouling Effect Without Mitigation: Lose ability to monitor pH/parameter. Lose ability to collect data.	Contact with process liquid over time	Make pH probes or other devices accessible to operators	Routine inspection of cleaning of pH probes or devices	N/A	Rapid loss of calibration, visual fouling	Clean and re-calibrate	1	1	1						

TABLE 2.5-1
Failure Mode Effect Analysis Matrix — Remedy SCADA, Control Systems, and Instruments
Groundwater Remedy Operation and Maintenance Manual
Volume 3: Contingency Plan
PG&E Topock Compressor Station, Needles, California

			Mitigation - Operations							Type of Unacceptable Condition					
				Observable Condition											
Potential Failure and Effect without Mitigation	Potential Cause	Mitigation - Design	Mitigation	Remedy SCADA	Human	Action if Cause Occurs	Severity (1 Low – 5 High)	Likelihood (1 Low – 5 High)	Severity x Likelihood	A. Unacceptable Remedy Performance	B. Significant Schedule Increase	C. Significant Cost Increase	D. Significant Change to Impacts (e.g., Additional CEQA Analysis etc.)	E. H&S or Compliance NOV (other than related to remedy performance)	Notes
9. Cyber-security: Software security, remote access security, or operating system update errors. Effect Without Mitigation: Lose ability to send/ receive control signals from control room. Lose ability to collect data.	Not keeping software up to date, remote hack	Design in site access security, and remote access security, password protected access	Maintain software license, password protection	N/A	N/A		2	1	2						
10. Remedy SCADA does not get alarms Effect Without Mitigation: Systems are shut down	Loss of communications which results in loss of status, control, and alarms.	Design includes layers of protection against such consequences. Such a failure would result in an alarm indicating loss of communication. See control scheme for the PLC in Appendix E of the 90% BOD Report, Section Number 26 79 15.	Periodic verification of SCADA/PLC communications	No communication	No communication		3	1	3						

Notes:
ARAR = applicable or relevant and appropriate requirement
BOD = Basis of Design
CEQA = California Environmental Quality Act
H&S = health and safety
FMEA = Failure Mode Effects Analysis
N/A = not applicable
NOV = Notice of Violation
O&M = operation and maintenance
OS = operating system
PLC = programmable logic controller
RAO = remedial action objective
SCADA = supervisory control and data acquisition
TCS = Topock Compressor Station
UPS = uninterruptible power supply

TABLE 2.6-1
Failure Mode Effect Analysis Matrix — Enhanced Evaporation at TCS Evaporation Ponds
Groundwater Remedy Operation and Maintenance Manual
Volume 3: Contingency Plan
PG&E Topock Compressor Station, Needles, California

	Failure Mode	Likely Causes for Failure	Effects of Failure	Operational Actions	Possible Contingency Measures
Failure Modes Associated with Evaporation Ponds	Discharge rate will cause ponds to exceed capacity	• Compressor station wastewater discharge needs are high • Remedial waste water production rates are high	• Potential overflow of evaporation ponds	• Utilize portable pumps to transfer water to ponds with available capacity • Storage water in temporary tanks • Truck water offsite • Identify operational adjustments at compressor station to reduce station waste water generation	• Add drip system to Pond 1 and/or 2
	Flow rates through drip evaporation system decline	• Pump failure • Build-up in the circulation piping • Clogging of the circulation pipe perforations	• Potential overflow of evaporation ponds	• Rehab pump • Replace pump • Flush pipe or perform mechanical cleaning • Inspect and clean perforations	• Add drip system to Pond 1 and/or 2

3.0 References

California Department of Toxic Substances Control (DTSC). 1996. *Corrective Action Consent Agreement (Revised), Pacific Gas and Electric Company's Topock Compressor Station, Needles, California.* EPA ID No. CAT080011729. February 2.

_______. 2011. *Final Environmental Impact Report for the Topock Compressor Station Groundwater Remediation Project*. January 31.

California State Water Resources Control Board (SWRCB). 2013. Letter from Jon Bishop/SWRCB to Stewart Black/DTSC. Subject: Topock Compressor Station: Remedy Requirements Associated with Injection of Groundwater Containing Naturally Occurring Arsenic. November 20.

U.S. Department of the Interior (DOI). 2013. Remedial Action/Remedial Design Consent Decree (CD) between the United States of America and Pacific Gas & Electric Company. Case 5:13-cv-00074-BRO-OP, Document 23. Entered November 21.

Appendix A
Contingent Dissolved Metals Removal System
Conceptual Design Basis

Contingent Dissolved Metals Removal System Conceptual Design Basis
PG&E Topock Compressor Station, Needles, California

PREPARED FOR: Pacific Gas and Electric Company

PREPARED BY: CH2M HILL

DATE: August 14, 2014

1.0 Introduction

In response to the California Department of Toxic Substances Control's (DTSC's) comment #757 DTSC-239 and the Tribes' comment #341 on the 60% Basis of Design Report for Pacific Gas and Electric Company's (PG&E's) Final Groundwater Remedy for the Topock Compressor Station (TCS), a contingency plan to remove scaling ions from remedy-produced water is presented in this technical memorandum (TM). The information contained herein includes a description of the contingent removal system along with an estimate of the system footprint, chemical use, electricity use, and waste generation.

The contingent system, referred to herein as the dissolved metals removal system (DMRS), will be located entirely in the planned Remedy-produced Water Conditioning Building inside the TCS. No additional footprint is required for installation of this contingency system. The DMRS is designed to be fully integrated into the currently planned conditioning process for remedy-produced water, thereby allowing for easy installation if required in the future.

The DMRS will be primarily located on the second floor of the Remedy-produced Water Conditioning Building. Certain treatment chemicals will be stored on the first floor of the planned Remedy-produced Water Conditioning Building. For additional information on Remedy Produced Water management, see Appendix F of the Basis of Design Report (CH2M HILL, 2014).

2.0 Water Quality, Treatment Goals, and Design Flow Rates

This conceptual basis of design is based on Topock-specific groundwater data collected from Floodplain Area monitoring wells and in-situ pilot test wells, as well as experience in designing and operating iron, manganese, calcium, and magnesium groundwater treatment systems on non-Topock projects. Once the Final Groundwater Remedy is up and running, this basis of design should, at a minimum, be verified with actual water quality information and any adjustments to the conceptual design should be made accordingly.

Prior to implementation, bench-scale and pilot-scale tests should be conducted using actual remedy-produced water to determine the final design of the DMRS and finalize equipment selection.

2.1 Design Influent Water Quality

For the purpose of this conceptual design, it is assumed that the quality of remedy-produced water generated from the future National Trails Highway (NTH) In-situ Reactive Zone (IRZ) injections wells will be similar to the groundwater quality data of the existing Floodplain Area monitoring wells that are considered to be anoxic (that is, low oxygen concentrations representative of anticipated groundwater during IRZ operations). Table 1 (presented at the end of this TM) summarizes the groundwater quality for these Floodplain Area anoxic monitoring wells (data collected through November 2013). The mean concentrations of the parameters in the anoxic Floodplain Area monitoring wells are the primary basis of the "expected" concentrations of DMRS influent water quality parameters. Exhibit 1 summarizes the DMRS influent water quality and flow design basis.

EXHIBIT 1
Conceptual Design Flow Rate, Influent Water Quality, and Treatment Goals
Contingent Dissolved Metals Removal System Conceptual Design Basis TM
PG&E Topock Compressor Station, Needles, California

Parameter	Units	Expected Influent Value [a]	Upper Expected Influent Value [a]	Target Effluent Value
Process Flow Rate	Gallons per minute	20-35		
pH	pH units	7.4	7.9	6.5-8.5
Alkalinity	mg/L (as $CaCO_3$)	160	330	--
Total Dissolved Solids	mg/L	6,000	12,000	--
Temperature	degrees Celsius	29.0	30.5	--
Iron	mg/L	2.6	8.6	< 0.15
Manganese	mg/L	1.8	2.7	< 0.02
Calcium	mg/L	304	500	< 200[b]
Magnesium	mg/L	99	150	--
Chloride	mg/L	2,600	4,050	--
Sulfate	mg/L	790	1,550	--
CCPP [c]	mg/L	21.2	121	< 0

Notes:

[a] Values are estimated on the basis of existing groundwater data and anticipated changes in groundwater conditions at injection wells. Remedy-produced water quality data collected after the Final Groundwater Remedy is implemented should be compared to these expected values, and the final design should be adjusted accordingly. Bench-scale tests for equipment components should also be conducted using remedy-produced water in the final design.

[b] The target effluent value of calcium is the concentration threshold determined using WaterPro for which the calcium carbonate precipitation potential (CCPP) is less than zero when all other water quality parameters are at their expected concentrations.

[c] CCPP is used as the indicator to evaluate the potential for scaling to occur for this memorandum. CCPP is estimated using WaterPro.

-- = No target value specified

Sources:
2013 Annual Monitoring Report for the Floodplain Reductive Zone In-Situ Pilot Test, Tables 3 and 4 (ARCADIS, 2013)
Concentrations in Floodplain Area monitoring wells (see Table 1 at the end of this TM).

2.2 Design Flow Rate and Treatment Goals

The design flow rate is equivalent to the design flow rates of the Remedy-produced Water Conditioning System. The DMRS will be designed to treat “A-side” remedy-produced water only, as this is the water that is likely to have high concentrations of scaling compounds. The goal of the DMRS is to minimize precipitation of iron, manganese, calcium, and magnesium in the piping system and the injection wells by removing the metals. Exhibit 1 shows the DMRS design flow rates and the treatment goals.

Concentrations of iron and manganese that will not cause adverse aesthetic effects are defined as secondary maximum contaminant levels (MCLs). Aesthetic effects include such things as scaling and discoloration, but do not cause adverse health effects. The target effluent concentration values for iron and manganese shown in Exhibit 1 are about 50% lower than their respective secondary MCLs in order to provide more protection from scaling. Calcium and magnesium contribute to water “hardness,” and the influent water quality conditions shown in Exhibit 1 are considered "very hard"(typically water with combined hardness concentrations greater than 300 milligrams per liter [mg/L] as calcium carbonate ($CaCO_3$) is considered very hard [American Water Works Association, 1995]). Under these influent water quality conditions, calcium and magnesium will likely scale the piping and wells, and thus the treatment goal would be to reduce the magnesium and calcium concentrations so they do not precipitate. The degree to which calcium and magnesium precipitate depends on pH, temperature, and dissolved salt concentrations, and the calcium carbonate precipitation potential (CCPP) will be used as the indicator in this conceptual design.

Water!Pro™ [1](WaterPro) modeling software was used to evaluate the design water quality and establish a design treatment goal. The treatment goal for calcium is the concentration threshold determined by WaterPro for which the CCPP is less than zero when all other water quality parameters are at their expected concentrations (note that a measure of CCPP below zero indicates that calcium carbonate is under-saturated in solution, therefore not likely to precipitate).

3.0 Evaluation and Selection of Removal Technologies

For this conceptual design basis, PG&E has identified and evaluated proven treatment technologies for iron, manganese, calcium, and magnesium that have been successfully used by municipalities and industry. Unproven technologies or technologies that have not been widely used in full-scale applications were not considered.

The initial technologies considered included the following:

- For iron and manganese:
  - Oxidation with several oxidants followed by filtration
  - Biological removal
  - Chemical precipitation softening (with lime or caustic)
  - Ion (cation) exchange
  - Adsorption onto manganese oxide-containing media such as manganese dioxide (MnO_2) or greensand
- For calcium and magnesium:
  - Ion (cation) exchange
  - Chemical precipitation softening (with lime, soda ash and/or caustic [sodium hydroxide])
  - Membrane softening with reverse osmosis or nanofiltration membranes

Descriptions of the considered technologies and a discussion of the preferred technology that was selected are presented in the subsections below; the conceptual design is then presented in Section 4.0.

3.1 Iron and Manganese Removal

There are many effective iron and manganese treatment methods available, including oxidation and filtration, chemical precipitation softening, adsorptive filtration, ion exchange, membrane filtration (e.g., reverse osmosis), and biological filtration (Odell, 2009). Membrane filtration was not considered for the DMRS due to the anticipated high energy usage and large volume of wastewater generated. Biological filtration was eliminated because of the potential for treatment upsets with influent pH changes. The methods of oxidation and filtration and ion (cation) exchange were ruled out because they are typically less effective at the relatively high expected concentrations of iron and manganese in influent water. In addition, ion (cation) exchange for iron and manganese removal was eliminated because all of the iron and manganese must be in the reduced form for this process to be effective and some of the iron and manganese in the remedy-produced water is likely to be oxidized.

[1] Corrosion Control & Treatment Process Modeling Program developed by Schott Engineering Associates for use with Microsoft Excel.

Chemical precipitation softening—typically done with lime and less so with caustic—is effective in removing iron and manganese from water, but not typically used due to higher capital costs than other proven technologies; however, it was retained for further consideration as a feasible option.

Adsorptive filtration is a method where the iron and manganese are oxidized, then adsorbed onto one of several available types of high-content manganese oxide-containing mineral surface. Adsorptive filtration with MnO_2 was considered for removing iron and manganese in this conceptual design because of its proven performance, high efficiency, low energy use, low waste generation, and small amount of space needed for equipment.

In this removal method, an oxidant (such as chlorine) is injected just upstream of the filtration vessels. After a short contact time of 15 to 30 seconds, iron and manganese will be oxidized and adsorb onto the surface of the MnO_2 media. The excess chlorine in the process water keeps the MnO_2 media catalytically active by converting the iron and manganese to oxides (ferric hydroxide [$Fe(OH)_3$] and MnO_2), thereby providing additional adsorption sites for oxidation to take place (MWH, 2005). These rapid reactions allow the removal system to be designed with relatively high hydraulic loading rates (i.e., ratio of flow rate to filter cross section area) and small footprint. Any residual chlorine oxidant will be removed to prevent adverse effects when re-injected to the IRZ wells. The filtration vessels are backwashed periodically and any solids that are removed can be settled in a clarifier or decant tank by gravity. Polymers or other settling aids may be needed to improve solids formation. Solids are dewatered before being disposed of off-site. Water can be decanted and recycled back to the head of the process up to 95 percent of the backwash flow.

Another technology that operates using the same principle of oxidation followed by adsorption that has often been used to remove iron and manganese is potassium permanganate oxidation and greensand filtration. However, relative to oxidation followed by MnO_2 adsorption, this technology requires longer contact times, slower loading rates, and larger diameter vessels, and the manganese effluent concentration are more difficult to control (AdEdge, 2004). Potassium permanganate is also not an ideal oxidant because the unreacted permanganate produces pink discoloration of the water and would require removal following treatment. Similar to MnO_2 filtration, the filter beds are backwashed periodically and solids are dewatered and then disposed of off-site.

3.2 Calcium and Magnesium Removal

The technologies considered for calcium and magnesium removal included ion exchange, chemical precipitation softening (with lime, soda ash and/or caustic), and membrane softening with reverse osmosis or nanofiltration membranes. The adsorptive filtration method is effective at removing iron and manganese but ineffective in removing calcium and magnesium, so was discarded.

Ion exchange softening is typically carried out using strong acid cation exchange resins. Using the sodium form of strong acid resin, the sodium ions (Na^+) enter solution and divalent ions such as calcium (Ca^{2+}) and magnesium (Mg^{2+}) are adsorbed to the resin. After a resin bed becomes loaded with Ca^{2+} and Mg^{2+}, it is regenerated with high strength sodium chloride brine solution. The resin bed regeneration involves a sequence of steps consisting of backwashing, brine injection, slow rinse displacement, and fast rinsing. Ion exchange for the anticipated remedy-produced water would result in a large wastewater stream (more than 20 percent of influent flow) and is therefore rejected from further consideration.

Membrane softening with reverse osmosis and nanofiltration membranes was eliminated from consideration because of the high operational costs and the large amount of concentrated brine produced by this alternative (20 percent to 50 percent of the entire plant production).

Chemical softening involves coagulation, flocculation, and sedimentation; these steps occur in one basin, called a solids contact clarifier or reactor clarifier with sludge recirculation (MWH, 2005) or in a package treatment unit. Produced water treated by any of the chemical softening processes needs to be filtered before injecting back into the subsurface.

Lime-soda ash softening, partial (i.e., not fully softened) lime softening, and partial caustic softening are forms of chemical softening in which calcium (Ca^{2+}), magnesium (Mg^{2+}), and a combination of Ca^{2+} and Mg^{2+} along with iron (Fe^{2+}) and manganese (Mn^{2+}) are precipitated by chemical addition to the stream being treated. The chemical reactions are complex but result in primarily solid forms of calcium carbonate, ferric carbonate, and oxides of manganese or manganese hydroxide. If magnesium is precipitated, it would form magnesium hydroxide. Lime-soda ash softening is the most common of these softening processes. Partial (lime or caustic) softening relies on naturally occurring alkalinity in the stream being treated, so no additional soda ash (sodium carbonate) needs to be added.

In the case of the expected influent water quality, the alkalinity (160 to 330 mg/L as $CaCO_3$) is sufficient to precipitate most of the calcium as calcium carbonate using either partial lime or caustic softening. Partial caustic softening has a number of advantages over partial lime softening for calcium removal; for one, addition of caustic, unlike lime, does not introduce additional calcium to the stream that would also need to be removed, and all the alkalinity is used to precipitate calcium from the raw water. Using liquid caustic eliminates the difficulties in handling dry chemical feeding of lime or lime and soda ash. Although caustic is more expensive than lime, the higher cost is partially offset by the reduced labor needed to maintain an all-liquid system. Partial caustic softening also produces less by-product sludge than partial lime softening. Taking all of this into account, partial caustic softening would be the most suitable chemical softening option for calcium and magnesium removal in the DRMS.

3.3 Selected Process

After ruling out all treatment technologies for removal of either iron and manganese or calcium and magnesium that are unsuitable for the DMRS under the anticipated water quality conditions, it is determined that partial caustic softening is the best available option for removing calcium and magnesium as well as iron and manganese. Although not necessarily the least costly alternative for either of the two pairs of target constituents when considered individually, partial caustic softening is the best alternative that will be effective at removing all four constituents from the remedy-produced water stream, obviating the additional costs and design challenges that would be posed by providing two different treatment trains to handle the four constituents. Therefore partial caustic softening was the process selected to carry into the conceptual design stage for removal of calcium and magnesium as well as iron and manganese.

4.0 Contingent Dissolved Metals Removal Process and System Description

This section describes the design philosophy, the removal process, and the conceptual system configuration for a partial chemical softening process using caustic. The process flow diagram (PFD) is shown on Figure 1a and the corresponding mass balance is shown in Figure 1b (figures are presented at the end of this TM).

4.1 System Description

The DMRS is a potential future process addition for the A-side stream of the remedy-produced water conditioning process. The contingent system would be installed downstream of the influent tanks (where batch conditioning including pH adjustment, coagulant addition, solids settling, and sludge draw-off occurs) and the cartridge filters (where suspended solids are removed from the process stream). Exhibit 2 illustrates the contingent dissolved metals removal process and its integration into the planned Remedy produced Water Conditioning System.

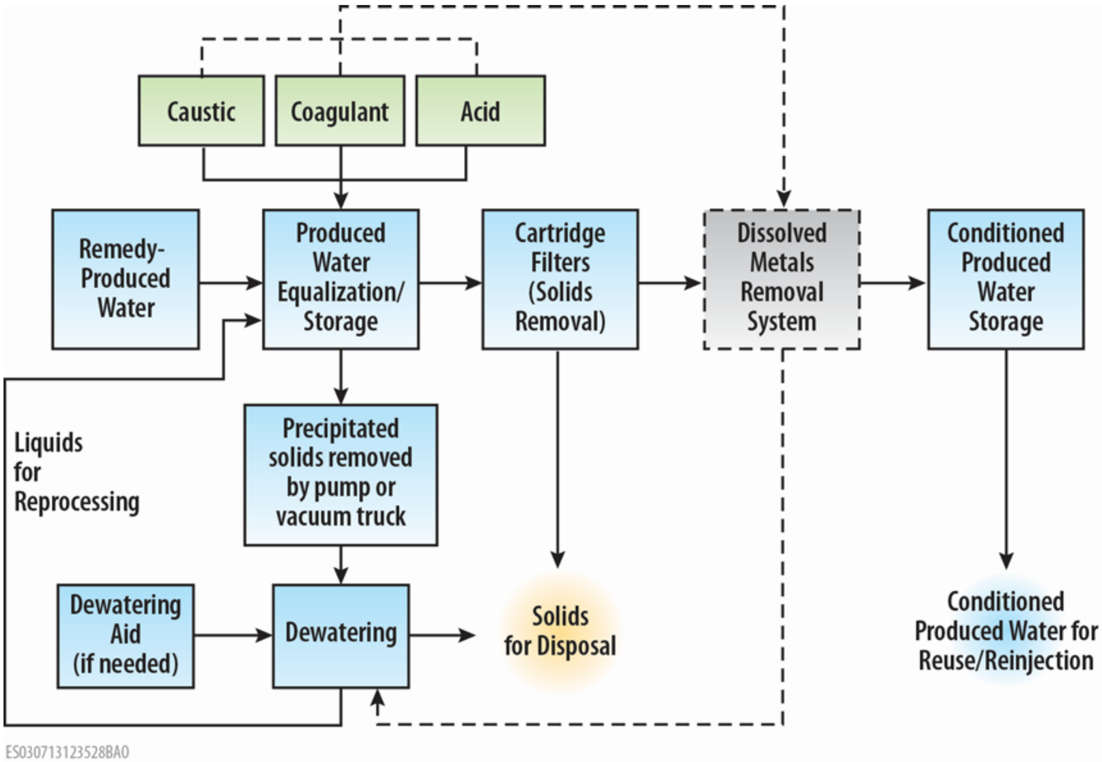


EXHIBIT 2
Dissolved Metals Removal System Schematic Diagram
Contingent Dissolved Metals Removal System Conceptual Design Basis TM
PG&E Topock Compressor Station, Needles, California

After filtration, the produced water would be fed into a process unit to improve the coagulation/flocculation and enhance solids removal. This unit combines several steps including:

1. Rapid mixing of the chemical agents – Rapid mixing is used to quickly and uniformly disperse the chemical agents throughout the water. Chemical agents will include 25 percent caustic and possibly a coagulant. The need for coagulant would be confirmed during bench-scale testing. Caustic addition would result in a solution pH of 9.7 to 10 to enable sufficient calcium to be removed to achieve a desired CCPP level.

2. Chemical reactions – Calcium forms calcium carbonate, a solid precipitate, by reacting with caustic or sodium carbonate (formed by reaction of carbonic acid with caustic). Magnesium is soluble up to a pH of 11 and so would not be removed to a great extent. Additional residence time is needed in the reaction chamber due to the high dissolved solids concentrations which slow the reaction rate (estimated to be 35 to 40 minutes).

3. Solids formation –The carbonate solids will form as tiny particles initially. A coagulant and also a flocculant may be needed to aid in forming larger masses so as to settle more easily. The use of these chemical agents would be confirmed during bench scale testing

4. Effluent clarification – Carbonate solids would be allowed to settle by gravity to clarify the water. Gravity clarification is often enhanced by the use of parallel plates or tubes to aid in settling the solids. The tubes and plates interfere with the rising solid particles, increasing the rate of agglomeration, thereby causing the solids to settle to the bottom of the process unit. Flocculants can also help with clarification, and if needed would be identified during bench scale testing. A portion of the solids would be recycled

to “seed” the reaction and improve solids settling efficiency. Periodically, solids would be pumped out of the process unit to a dewatering device – in this case the phase separators located in the 1st floor.

As shown on the process flow diagram (Figure 1a), effluent water flows to a clear well and then is pumped through two single or media filter vessels sized for 4 to 6 gallons per minute per square foot (gpm/sq. ft.) hydraulic loading. Both vessels would be in service and the flow would be evenly split between them (parallel configuration). The media beds would be expected to capture any solids escaping the clarifier (15 to 30 mg/L is typical). Iron and manganese removal will be accomplished in the softening step. The filtered water would flow through cartridge filters to a treated water tank and from there be pumped to the conditioned water tank farm. Acid would be added upstream of the media filter vessels to neutralize the pH (to approximately pH 7.5) and to mitigate precipitation of calcium carbonate in the media filters. The neutralized water would be re-injected to the IRZ wells via the clean-in-place (CIP) pump located at the MW-20 Bench.

Filters would be backwashed periodically using filtered water for 10 minutes using a loading rate of 15 gpm/sq. ft. (47 gpm) or 5 minutes using a loading rate of 30 gpm/sq. ft. (94 gpm), depending on the media. The backwash stream would flow to a cone bottom decant tank. The liquid stream would be returned to the influent tanks and solids would be pumped to the phase separators.

4.1.1 Reserved Space for the Contingent DMRS within the Planned Remedy-produced Water Conditioning Plant

Many equipment manufacturers offer solids contact clarifiers with different configurations. These units are sized for larger flows (typically 500,000 gallons per day and larger) than what is anticipated for the DMRS. Some manufacturers offer package treatment units geared for small communities or small industrial facilities for different treatment processes including chemical softening. Solids contact clarifiers typically require a large vertical space to have sufficient mixing, solids accumulation and installation/maintenance for the unit mixers. For the purposes of this conceptual design, a package unit suitable for softening processes (supplied by companies such as Evoqua [formerly Siemens], Veolia, and Infilco Degremont) would be installed in the 2nd floor of the Remedy-produced Water Conditioning Building. The 1st floor has chemical storage and the phase separators for solids dewatering and would be used to support DMRS operations. The general arrangement is shown on Figure 2.

4.1.2 Solid Waste & Wastewater Generation

Solid wastes are generated largely from the solids contact clarifier, with lesser amounts from the filter backwash. Wastewater is generated by daily backwashing of the filter media to reduce pressure losses and maintain uniform bed flow profiles to maintain system performance. Daily backwashing removes precipitated non-hazardous suspended solids including calcium carbonate and precipitated iron and manganese from the media bed. Backwashing is anticipated to occur daily. The solid and liquid portions of the backwash water are separated in the cone bottom decant tank. The liquid portion of the backwash water is expected to have similar qualities to the treated water, with very little soluble scaling ions present. A summary of the waste generation calculations is shown in Exhibit 3.

EXHIBIT 3
Summary of Waste Generation
Contingent Dissolved Metals Removal System Conceptual Design Basis TM
PG&E Topock Compressor Station, Needles, California

Item	Amount, Units
Backwash wastewater [a]	9,800 gallons per year
Sludge [a]	168 tons per year
Spent filter media	2.6 tons over project life (assume 30 years)

Notes:
[a] Based on assumed volume of 4.67 million gallons per year that would be processed in this system.

The volume of wastewater was estimated based on the following assumptions:

- Backwash rate is 15 to 30 gpm/sq. ft. and vessel cross section area is 3.1 sq. ft, depending on the media provided with the filters.
- Backwashing time is 5 to 10 minutes (5 minutes for the media requiring 30 gpm/sq. ft. and 10 minutes for the media requiring 15 gpm/sq. ft.) resulting in 470 gallons per backwash per vessel.
- Two vessels are backwashed daily.
- 95 percent of the backwash water is recycled to the influent tank farm with the remainder pumped to the evaporation ponds.

The backwash volume of 470 gallons/backwash x 2 vessels/day x 4 days of operation/week x 52 weeks of operation/year x 5% remaining after recycling = 9,800 gallons /year. This volume is small enough that it could be disposed of in the Compressor Station ponds if necessary.

Wastewater sludge is mostly calcium carbonate ($CaCO_3$); for this calculation all of the sludge from the clarifier and backwash filter stream is considered to be $CaCO_3$: 104 mg/L Ca x (1/40 mg/millimole [mmol] Ca) x 1 mmol $CaCO_3$ / mmol Ca x 100 mg $CaCO_3$ /mmol = 260 mg/L.

Pounds of dry solids/million gallons (MG): 260 mg/L x 8.34 lb/MG = 2,170 lb/MG. Assumes the sludge can be dewatered to 3 percent solids.

The amount of dry solids generated per year based on the calculated annual flow (Table 2) is 4.67 MG/yr x 2,170 lb/MG / 0.03 = 337,000 lb / yr = 168 tons/yr.

At 10 tons per phase separator, this results in about 17 phase separator bins being disposed of annually.

The possible disposal of the worn filter media would as also produce a solid waste stream. The filter media has a long service life of typically 10-15 years, but the actual lifespan is project- and system-specific. The mass of solid waste to be managed is estimated based on the following assumptions:

- The media has a specific gravity of 1.92 with water density of 62.4 pounds per cubic foot (cf)
- Each vessel has 11 cf of media
- Two vessels need replacement twice during the project life

Therefore the estimated solid waste generated per year for the DMRS is 2 vessels x 11 cf x 2 replacements = 44 cf x 1.92 x 62.4 lb/cf = 5,270 lb = 2.6 tons.

4.2 Chemical and Media Use

Chemicals will be used in the treatment system for pH adjustment in the partial softening process. WaterPro was used to calculate caustic and hydrochloric acid use. In addition a coagulant and/or flocculent may be necessary for efficient solids removal, and these would be selected during bench-scale testing. The estimated chemical usage is shown in Exhibit 4.

4.3 Electricity Usage

Electricity usage was estimated based on the power consumption from equipment (primarily pumps) usage. The estimated electricity usage of the DMRS is 3,200 kilowatt-hours per year.

EXHIBIT 4
Estimated Chemical Usage
Contingent Dissolved Metals Removal System Conceptual Design Basis TM
PG&E Topock Compressor Station, Needles, California

Item, Units	25% Caustic	19% Hydrochloric Acid	Coagulant (If needed)	Polymer[b] (If needed)
Calculated dose, mg/L	93	3.6	TBD	1
Pure chemical used, pounds/year[a]	3,600	140	TBD	39
Chemical product usage, gallons/year	340	15	TBD	3.4

Notes:
[a] Based on assumed volume of 4.67 million gallons per year that would be processed in this system.
[b] A polymer if required would be used as a flocculating agent. Its need would be determined during bench scale testing.
mg/L – milligrams per liter
TBD = to be determined

4.4 Controls Philosophy

The system will be automated to reduce the need for continuous operator oversight. Electronic notifications will be sent automatically to on-site operators that notify them of system alarms, shutdown, or other issues. System automation will be controlled using a programmable logic controller that will communicate with the groundwater remedy supervisory control and data acquisition system (SCADA). Remotely controlled valves will have pneumatic actuators if possible for diverting water or stopping flow. Online pH will be incorporated to enable remote process monitoring and control. Iron, manganese, calcium and magnesium cannot be monitored directly using an online analyzer. Grab samples will be collected periodically from sample ports and analyzed using bench-top colorimetric instruments in the sample room (located in the Remedy-produced Water Conditioning Building) to monitor iron, manganese, calcium and magnesium levels.

4.5 Supporting Facilities

As discussed previously, the DMRS would be installed in the Remedy-produced Water Conditioning Building. Electricity will be provided to the Remedy-produced Water Conditioning Building from the Compressor Station. The building will have a heating, ventilation, and air conditioning system for the sample room and electrical equipment room. A programmable logic controller located at the Remedy-produced Water Conditioning Building will control the DMRS with remote monitoring and control accomplished by the groundwater remedy SCADA.

4.6 Contingent DMRS in Relation to the Overall Well Maintenance Program for the Groundwater Remedy

The DMRS, if required, would be a part of the Remedy-produced Water Conditioning System. Effluent water from the DMRS is sent to the A-side conditioned water storage tanks, and from there can be pumped to tank TNK-720 at the MW-20 Bench and returned to the NTH IRZ injection wells via the CIP injection pump and piping that feeds the North and South NTH IRZ headers. If implemented, the blending ratio of the DMRS effluent to total injected water flow is 20-35 gpm to 200-400 gpm. Therefore, the DMRS effluent could account for 5-18 percent of the injected water into the IRZ wells, which is small compared to the amount of groundwater to be injected into the wells. Therefore, routine and non-routine well maintenance procedures will continue to be the primary means to mitigate the effects of scaling/fouling in wells due to dissolved metals. Procedures for well maintenance are described in detail in the Operations and Maintenance (O&M) Plan for the Groundwater Remedy (Volume 1 of the O&M Manual, Section 4 and Appendix B).

4.7 Design Philosophy/Uncertainties in Design

Because this conceptual design was developed absent the actual water quality information of the future groundwater and remedy-produced water and without bench testing the selected equipment and chemicals using remedy-produced water, various uncertainties exist in the design that will need to be confirmed after the Final Remedy is implemented. The design of the DMRS and expected chemical usage, waste production, and electricity usage should be adjusted based on actual water quality information and bench-scale testing results. Some or all of the following testing and bench-scale tests may be needed to confirm the design of the Contingent DMRS:

- Water quality testing of A-side remedy-produced water; this should include testing for key parameters listed in Exhibit 1, as well as other constituents that are prone to causing scaling/fouling of the remedy system.
- Bench-scale testing the process of caustic additions should be conducted using 25 percent caustic (or the final strength/type of caustic selected for the Remedy-produced Water Conditioning Plant) to determine the dose needed to drive the pH of the treated water to the optimal pH between 9.7 and 10 for the chemical softening process.
- Bench-scale testing of the reactor clarifier to determine the effectiveness of the chemical softening processes (coagulation, flocculation, and sedimentation), and what the optimal pH and additional hydraulic residence time is. This testing should also be used to determine if a coagulant or flocculant is needed to aid with solids settling and any possible benefits of solids recycling.
- Bench-scale testing with single or multimedia filters (such as a column test) to determine the effectiveness of the media in lowering levels of iron, manganese, and solids in the clarifier effluent, and to verify the filter sizing, loading rates, and backwash regimen. These results could also affect the size of the treated water tank and cone bottom decant tank.
- Bench-scale testing the process of acidification should be conducted using 19 percent hydrochloric acid (or the final strength/type of acid selected for the Remedy-produced Water Conditioning Plant) to determine the dose needed to drive the pH of the treated water to 7.5 (or an alternative target pH determined from other bench-scale testing).
- Bench-scale testing of media filters backwash water using the Imhoff Cone Test to determine the effectiveness and rate of solids settling in the cone bottom decant tank. Based on these testing results, further analysis should be conducted to determine the necessity of a polymer addition to aid in solids settling. Testing should then be further conducted to determine the appropriate polymer and regimen for use. If the cone bottom decant tank and polymer are unsuccessful, an alternative option such as a low-profile clarifier may be considered.
- Bench-scale testing the process of acidification should be conducted using 19 percent hydrochloric acid (or the final strength/type of acid selected for the Remedy-produced Water Conditioning Plant) to determine the dose needed to drive the pH of the treated water to 7.5 (or an alternative target pH determined from other bench-scale testing).

Based on the results of the tests listed above, the need for additional and/or alternative testing may be determined and should be conducted as warranted. The conceptual design is conservative in assuming that iron, manganese, calcium and magnesium will all contribute to scaling in pipelines. However, if bench-scale testing determines that one or more or the constituents are not affecting remedy performance, equipment and process steps may need to be modified accordingly.

5.0 Design Information

Process calculations used to develop the design criteria were prepared using the estimated water quality in the NTH IRZ injection wells. Conceptual design information is presented in Tables 2 and 3 and on Figures 1a, 1b, and 2 attached at the end of this TM.

6.0 References

AdEdge Technologies, Inc. 2004. *AD26 Systems for Iron, Manganese, Sulfide and Arsenic Removal*. February.

American Water Works Association. 1999. *Water Quality & Treatment*. R. Letterman, Editor.

ARCADIS. 2013. *PG&E Topock Compressor Station, Needles, California, Floodplain Reductive Zone In Situ Pilot Test, 2013 Annual Monitoring Report*. October 11.

CH2M HILL. 2013. *Basis of Design Report/Intermediate (60%) Design Submittal for the Final Groundwater Remedy, PG&E Topock Compressor Station, Needles, California*. April.

CH2M HILL. 2014. *Basis of Design Report/Pre-Final (90%) Design Submittal for the Final Groundwater Remedy, PG&E Topock Compressor Station, Needles, California*. In preparation.

MWH. 2005. *Water Treatment: Principles and Design*. 2nd ed. Hoboken, New Jersey, John Wiley & Sons, Inc.

Odell, Lee. 2009. *Optimizing Iron and Manganese Removal*. Unpublished Technical Memorandum.

Tables

TABLE 1
Summary of Floodplain Water Quality
Contingent Dissolved Metals Removal System Conceptual Design Basis TM
PG&E Topock Compressor Station, Needles, California

		Floodplain Anoxic Wells[1]				In-Situ Pilot Test[3]			IM-3 Influent[4]			Dissolved Metals Removal System					
Parameter	**Units**	**Minimum Detected Value**	**Mean Value**	**Maximum Detected Value**	**BTV[2]**	**Minimum Detected Value**	**Mean**	**Maximum Detected Value**	**Minimum Value**	**Mean**	**Maximum Value**	**Minimum Value**	**Expected Influent Value[5]**	**Upper Expected Influent Value[5]**	**Maximum Value**	**Justification for Expected Value**	**Justification for Upper-Expected Value**
Calcium	mg/L	26.2	304	1220	NC	78.9	241	432	200	230	260	26.2	304	432	1,220	Mean value of Floodplain Anoxic Wells data	Maximum of In-Situ Pilot Test data
Iron	mg/L	0.09	2.6	13.9	14.6	0.058	3.80	34.3	0.02	0.064	0.5	0.02	2.56	14.6	34.3	Mean value of Floodplain Anoxic Wells data	BTV of Floodplain Anoxic Wells data
Magnesium	mg/L	6.43	99	586	NC	9.58	47.1	214	29	32	35	6.43	99	214	586	Mean value of Floodplain Anoxic Wells data	Maximum of In-Situ Pilot Test data
Manganese	mg/L	0.006	NC	2.2	2.5	0.002	1.74	11.3	0.0078	0.0098	0.01	0.002	1.74	2.5	11.3	Mean value of In-Situ Pilot Test data	BTV of Floodplain Anoxic Wells data
Alkalinity	mg/L (as $CaCO_3$)	--	--	--	--	27.5	160	880	140	156	210	27.5	160	880	880	Mean value of In-Situ Pilot Test data	Maximum of In-Situ Pilot Test data
Chloride	mg/L	104	2,600	12,600	NC	798	2,558	5,210	2,100	2,260	2,500	104	2,600	5,210	12,600	Mean value of Floodplain Anoxic Wells data	Maximum of In-Situ Pilot Test data
Sulfate	mg/L	240	789	2,420	2,360	1	488	1,130	500	532	550	0.931	789	2,360	2,420	Mean value of Floodplain Anoxic Wells data	BTV of Floodplain Anoxic Wells data
pH	pH units	6.88	NC	8.05	8.05	--	--	--	7.1	7.4	7.9	6.88	7.4	8.05	8.05	Mean value of IM-3 Influent data and calculated midpoint of Floodplain Anoxic Wells data	BTV of Floodplain Anoxic Wells data
Temperature	degrees Celsius	--	--	--	--	--	--	--	--	--	--	--	29	31	--	Estimated from IM-3 field records	Estimated from IM-3 field records
Total Dissolved Solids (TDS)	mg/L	736	NC	21,500	25,000	1,820	5,524	11,400	4,000	4,520	5,100	736	6,000	11,400	21,500	Mean of In-Situ Pilot Test data rounded up to the nearest thousand	Maximum of In-Situ Pilot Test data

Notes:

[1] Data collected from Topock monitoring wells located in the Floodplain Area that are situated in anoxic groundwater conditions, through November 2013. Remedy-produced water entering the DMRS will largely be extracted from wells in the Floodplain Area or wells in anoxic conditions.

[2] The background threshold value (BTV) is the upper limit estimate of the background concentration of the constituent based on statistical analysis.

[3] Data collected from Floodplain Reductive Zone In-Situ Pilot Test from March 2006 to July 2013 (ARCADIS, 2013). Data represent the changing groundwater conditions over time due to the injection of a food-grade reagent mixture into groundwater, which is what will be implemented in the final groundwater remedy.

[4] Data collected from the influent of the Topock Interim Measure 3 (IM-3) groundwater treatment system. Data are from a total of 11 samples collected between June 2009 and June 2012. Wells that feed IM-3 are situated in generally more oxic groundwater conditions than the expected anoxic conditions of the remedy-produced water. Therefore, IM-3 influent data are the least significant of the datasets presented. Nondetect concentrations are included in the minimum, maximum, and mean value calculations at their reporting limits.

NC = Not calculated

-- = Not available

TABLE 2
Conceptual Design Criteria for Contingent Dissolved Metals Removal System
Contingent Dissolved Metals Removal System Conceptual Design Basis TM
PG&E Topock Compressor Station, Needles, California

Subject	Criteria	Comments/Reason
OPERATIONAL CRITERIA		
Maximum Process Flow Capacity	35 gpm	
Average Process Flow Capacity	20 gpm	
Average Daily Flow – Well Rehabilitation Period (22 weeks/year)	29,645 gallons	A side water is processed 4 days of the week. Assume annual well rehabilitation takes place for continuous period of time limiting the number of days routine backwashing can occur..
Average Daily Flow – Rest of the year (30 weeks/year)	17,145 gallons	A side water is processed 4 days of the week during normal backwashing operations.
Annual Flow	4,670,000 gallons	
SITE CIVIL		
Location	Remedy-produced Water Conditioning Plant at PG&E Topock Compressor Station near Needles, California.	
Building Finish Floor Elevation	Finished first floor, Elevation 626 feet (NGVD88). Finished second floor, Elevation 640 feet (NGVD88)	
Grading	Longitudinal Slopes: Minimum 1% away from structures (2% desirable).	
Vehicle Access	WB 50 (turning radius for semi-truck and trailer with 50-foot wheel base). Highway truck (wheel loading on access roadways and parking areas). 50-foot minimum turning radius. Designated site accommodates truck circulation. Roads will be constructed at new facility for maintenance activities.	Required for delivery of chemicals, pumps, motors, and fire vehicles.
Site Constraints	Proposed facility located within the boundary of the compressor station. Access to all critical compressor station facilities must be maintained.	No modifications to the perimeter site fence or entrance gate will be made.
Parking	No parking will be required for new facility.	
Pedestrian Traffic	Limited to paved roadways, sidewalks are not located between existing facilities.	
PROCESS EQUIPMENT, MOTORS, VALVES, AND ANCILLARIES		
Treatment Process	Partial caustic softening to remove calcium and magnesium hardness and iron and manganese. This will be accomplished largely in a solids contact clarifier or package treatment unit. Process steps include rapid chemical mixing, softening reaction, coagulation, flocculation, settling, sludge recirculation, and sludge withdrawal. Effluent is filtered in media and cartridge filters to achieve desired effluent quality.	Design criteria listed below are what is expected from planned pre-purchase bid, but not a guarantee of what equipment will be selected. The information in this section will be verified during the detailed design.

TABLE 2
Conceptual Design Criteria for Contingent Dissolved Metals Removal System
Contingent Dissolved Metals Removal System Conceptual Design Basis TM
PG&E Topock Compressor Station, Needles, California

Subject	Criteria	Comments/Reason
Softening Treatment		
Treatment Objective	Hardness and iron and manganese removal	Primary iron and manganese removal will be through media filters, but some removal will be accomplished in softening step.
Number of Clarifier Units	One	Package treatment unit designed for chemical softening
Number of Media Vessels	Two	Single or multimedia vessels designed for solids removal
Reaction Zone Residence Time	35 to 40 minutes	Allow additional time to counteract reduced rate caused by salty (high TDS) groundwater
Rise Rate	0.75 gpm/square foot	
Materials of Construction	Carbon steel vessels with internal epoxy lining skid-mounted on structural steel frame	
Performance Targets		
Effluent Iron Concentration	< 0.15 mg/L	This performance target is for media filter effluent. Empirical evidence shows that Fe concentrations > 0.15 mg/L cause scaling
Effluent Manganese Concentration	< 0.02 mg/L	This performance criterion is for media filter effluent. Empirical evidence shows that Mn concentrations > 0.02 mg/L cause scaling
Effluent Calcium Concentration	< 200 mg/L	By definition, calcium carbonate precipitation potential (CCPP) < 0 mg/L indicates that calcium carbonate is undersaturated in solution. The WaterPro™ model indicates that CCPP < 0 when calcium concentrations <200 mg/L and with the remaining parameters are at their "expected" values.
Caustic Feed System		
Chemical Feed System	One chemical feeder system— high-density cross-link polyethylene (HDXLPE) tank and pump skid with duplex pumps, controller, and panel with 120 volt receptacle. Sized for up to 10 gph. Tank sized for minimum one month's storage (approximately 55 gallons)	Assumed able to use all of planned Remedy-produced Water Conditioning caustic feed system.
Safety Equipment	One eyewash and shower unit	Use planned 2nd floor unit
Coatings/Finishes	Chemical resistant coatings in chemical areas	
Controls	Chemical feed pump speed control and tank level controls	

TABLE 2
Conceptual Design Criteria for Contingent Dissolved Metals Removal System
Contingent Dissolved Metals Removal System Conceptual Design Basis TM
PG&E Topock Compressor Station, Needles, California

Subject	Criteria	Comments/Reason
Acid Feed System		
Chemical Feed System	One chemical pump system —Pump skid with duplex pumps, controller, and panel with 120 volt receptacle. Sized for up to 0.01 gph. Tank not needed due to low demand of 15 gallons per year.	Assumed able to use all of planned Remedy-produced Water Conditioning acid feed system.
Safety Equipment	One eyewash and shower unit	Use planned 2nd floor unit
Coatings/Finishes	Chemical resistant coatings in chemical areas	
Controls	Chemical feed pump speed control and tank level controls	
Backwash Tank and Treated Water Tank		
Number	Two	One cone bottom tank (Backwash Tank) and one flat bottom tank (Treated Water Tank).
Material	Fiberglass Reinforced Plastic (FRP)	An ultra-high molecular weight coating may be considered for the inside surface of the cone bottom tank (Backwash Tank) to improve the slickness of the surface for solids to settle onto.
Capacity	1,000-gallon tanks	Backwash is anticipated to be approximately 470 gallons per vessel (940 gallons total per day) – 10 minutes of backwashing at 15 gpm/ft^2 or 5 minutes of backwashing at 30 gpm/ft^2 depending upon filter media. Backwash tank will have cone bottom to aid in solids recovery and improve backwash recycle rate.
Static Mixer		
Number	As required	
Diameter	2-inch	
Type	Wafer style with integral injection ports	
Piping Materials		
Process	HDPE SDR 11 or CPVC Schedule 80, per ASTM D1784, ASTM D1785, and NSF/ANSI 14 and NSF 61 listed	
Potable Water	Buried: Copper, Type K, per ASTM B88 Exposed: Copper, Type L, per ASTM B88 or CPVC Sch. 80	
Process Piping Installation	Major process piping headers will be installed in pipe trenches inside the treatment building and buried outside the building. Media vessel piping will be aboveground. Actuated valves will be installed above grade whenever possible.	

TABLE 2
Conceptual Design Criteria for Contingent Dissolved Metals Removal System
Contingent Dissolved Metals Removal System Conceptual Design Basis TM
PG&E Topock Compressor Station, Needles, California

Subject	Criteria	Comments/Reason
YARD PIPING		
Design Criteria	Appendix C, 90% Basis of Design Report (CH2M HILL, 2014)	
CORROSION CONTROL		
Design Criteria	Appendix C, 90% Basis of Design Report (CH2M HILL, 2014)	
ARCHITECTURAL/STRUCTURAL		
Building Code	Appendix C, 90% Basis of Design Report (CH2M HILL, 2014)	
Building Construction Materials	Appendix C, 90% Basis of Design Report (CH2M HILL, 2014)	
Loads	Appendix C, 90% Basis of Design Report (CH2M HILL, 2014)	
HVAC		
Codes/Standards	Appendix C, 90% Basis of Design Report (CH2M HILL, 2014)	
Design Conditions		
Site Elevation	See Section C.2 Civil, Appendix C, 90% Basis of Design Report (CH2M HILL, 2014)	
Cooling Load Basis	Building envelope heat gain and internal heat gains from equipment.	
System Type		
Process Building	None.	
PLUMBING		
Lavatory/Toilet Room	No facilities provided.	
Potable Water	Existing emergency shower/eye wash station available on 2nd floor of building.	Per 2010 California Plumbing Code, and ANSI Z358.1.
Non-potable Water	The non-potable water supply will have a reduced pressure backflow preventer. Non-potable water will be supplied for wash down water. Wash down hose valves, hoses and hose racks will be furnished in the area as required.	Per 2010 California Plumbing Code.

TABLE 2
Conceptual Design Criteria for Contingent Dissolved Metals Removal System
Contingent Dissolved Metals Removal System Conceptual Design Basis TM
PG&E Topock Compressor Station, Needles, California

Subject	Criteria	Comments/Reason
ELECTRICAL		
Electrical Load	The electrical load will consist of process pumps, motor operated valves, filter system, control panel and instrumentation. Power distribution will be sized in accordance with NFPA 70 (National Electric Code) to operate process and facility loads. Short-circuit current interrupting capacity of power distribution equipment will be coordinated with existing power distribution system.	.
Service Voltage	480V, 3-phase, 3-wire power will be supplied from XFMR 099	
Utilization Voltage	Appendix C, 90% Basis of Design Report (CH2M HILL, 2014)	
Redundancy Requirements	Power distribution system redundancy will be limited to equipment supporting the operation of back-up process and facility equipment (i.e. motor control combination starters, and breakers,). Power distribution system will incorporate spare breakers and fuses. Supporting quick replacement of failed components.	.
Manufacturers of Electrical Equipment, Grounding, Lightning Protection, Illumination, Emergency Lights, Stand-by/Backup Power, Raceways, and Duct Banks	Appendix C, 90% Basis of Design Report (CH2M HILL, 2014)	
SECURITY		
Security	None	All security covered through TCS main facility
CONTROL AND TELEMETRY		
Control and Telemetry Design Criteria	The treatment vessels will be a packaged system with the equipment manufacturer providing a fully configured programmable logic controller based system control panel with panel-mounted operator interface terminal. The control panel will be specified with an uninterruptible power supply to provide true online conditioned power sized to operate the connected load for 30 minutes.	
Communications, Other Networks, Supervisory Control and Data Acquisition, Instrumentation	Appendix C, 90% Basis of Design Report (CH2M HILL, 2014)	

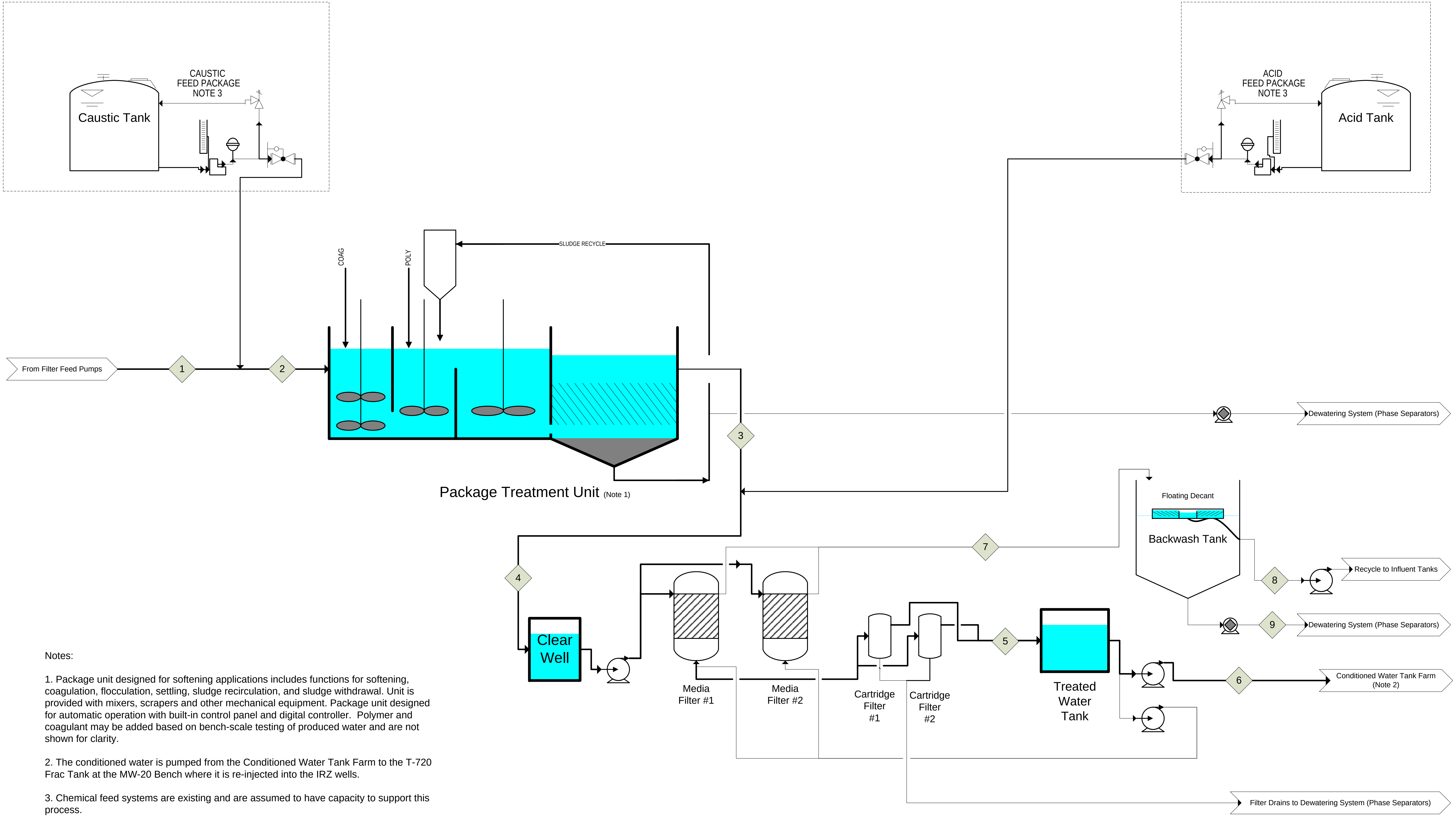
TABLE 2
Conceptual Design Criteria for Contingent Dissolved Metals Removal System
Contingent Dissolved Metals Removal System Conceptual Design Basis TM
PG&E Topock Compressor Station, Needles, California

Subject	Criteria	Comments/Reason
Environmental Requirements	Equipment and instrumentation will be suitable for the following conditions: • Non-air-conditioned Spaces: 0°C to 50°C and a relative humidity of 10 to 95 percent. • Outdoors: 0°C to 60°C and a relative humidity of 5 to 100 percent.	Environmental controls, such as heaters, fans, and air conditioning will be provided to maintain equipment within the operating conditions recommended by the manufacturer.
Standards/References	Appendix C, 90% Basis of Design Report (CH2M HILL, 2014)	

TABLE 3
Preliminary Major Equipment List
Contingent Dissolved Metals Removal System Conceptual Design Basis TM
PG&E Topock Compressor Station, Needles, California

Quantity	Name	Description
2	Single or Multimedia Filter Vessels	2 foot diameter carbon steel vessels with internal epoxy lining skid-mounted on a structural steel frame (maximum of 6 gpm/sq. ft. feed hydraulic loading rate and 15 to 30 gpm/sq. ft. backwash hydraulic loading rates)
1	Package treatment unit designed for chemical softening	Carbon steel epoxy coated internals. Functions include softening, coagulation, flocculation, settling, sludge recirculation, and sludge withdrawal. Complete with mixers, scrapers and other mechanical equipment (sludge pump). Automatic operation with built in control panel and digital controller allowing communication/control to Remedy SCADA.
1	Chemical Feed System	No new equipment needed; use planned acid and caustic feed systems
2	Media Filter Feed Pumps	Duplex centrifugal pumps
1	Duplex cartridge filters with replaceable elements	Package unit with differential pressure indication and alarm, automated valves (pneumatic type), and electric actuated purge valves
2	Backwash Recycle Pumps	Duplex centrifugal pumps
1	Treated Water Tank	Flat bottom 1,000 gallon fiberglass reinforced plastic tank
1	Backwash Tank	Cone bottom 1,000 gallon fiberglass reinforced plastic tank provided with tank support
1	Backwash Solids Pump	Air operated diaphragm pump
1	Softener Clearwell	250 gallon HDPE tank, flat bottom
2	Backwash Pumps	Duplex centrifugal pumps
2	Treated Water Pumps	Duplex centrifugal pumps
1	Polymer System (contingency)	Pre-engineered skid with chemical metering pumps for polymer

Figures



Notes:

1. Package unit designed for softening applications includes functions for softening, coagulation, flocculation, settling, sludge recirculation, and sludge withdrawal. Unit is provided with mixers, scrapers and other mechanical equipment. Package unit designed for automatic operation with built-in control panel and digital controller. Polymer and coagulant may be added based on bench-scale testing of produced water and are not shown for clarity.

2. The conditioned water is pumped from the Conditioned Water Tank Farm to the T-720 Frac Tank at the MW-20 Bench where it is re-injected into the IRZ wells.

3. Chemical feed systems are existing and are assumed to have capacity to support this process.

CH2MHILL

FIGURE 1a

Process Flow Diagram

Contingent Dissolved Metals Removal System Conceptual Design Basis Memorandum

PG&E Topock Compressor Station, Needles, California

Stream #:	1	2	3	4	5	6	7	8	9
Parameter	From Filter Feed Pumps	To the Package Treatment Unit	Downstream of Package Treatment Unit	To Clear Well	To Treated Water Tank	To Conditioned Water Tank Farm	To Backwash Tank	Recycle to Influent Tank Farm	To the Liquid Phase Separators
Maximum Flowrate (gpm)	35	35	35	35	35	35	94	12	--
Nominal Flowrate (gpm)	20	20	20	20	20	20	94	12	--
Iron (mg/L)	2.56	2.56	2.56	2.56	0.15	0.15	0.15	0.15	--
Iron (lbs/yr)	100	100	100	100	5.8	5.8	5.8	5.8	--
Manganese (mg/L)	1.74	1.74	1.74	1.74	0.02	0.02	0.02	0.02	--
Manganese (lbs/yr)	67.8	67.8	67.8	67.8	0.8	0.8	0.8	0.8	--
Calcium (mg/L)	304	304	200	200	200	200	200	200	104
Calcium (lbs/yr)	11840	11840	7790	7790	7790	7790	7790	7790	4,051
Magnesium (mg/L)	99	99	99	99	99	99	99	99	--
Magnesium (lbs/yr)	3856	3856	3856	3856	3856	3856	3856	3856	--
pH	7.40	9.70	9.70	7.5	7.5	7.5	7.5	7.5	--
Caustic (mg/L)	--	93	93	--	--	--	--	--	--
Caustic (gal/year)	--	340	340	--	--	--	--	--	--
Hydrochloric Acid (mg/L)	--	--	3.6	3.6	--	--	--	--	--
Hydrochloric Acid (gal/year)	--	--	15	15	--	--	--	--	--
Sludge (mg/L)	--	--	--	--	--	--	260	--	260
Sludge (tons/yr)	--	--	--	--	--	--	168	--	168

Assumptions

Annual water flow 4.67 million gallons

Media filter backwash daily frequency at a rate of 94 gpm or 30 gpm/sf

Number of media filter vessels in service - 2

No magnesium is assumed to precipitate due to pH conditions. Iron and manganeses quantities are neglected in sludge mass due to small contribution

Sludge concentration is 3% solids

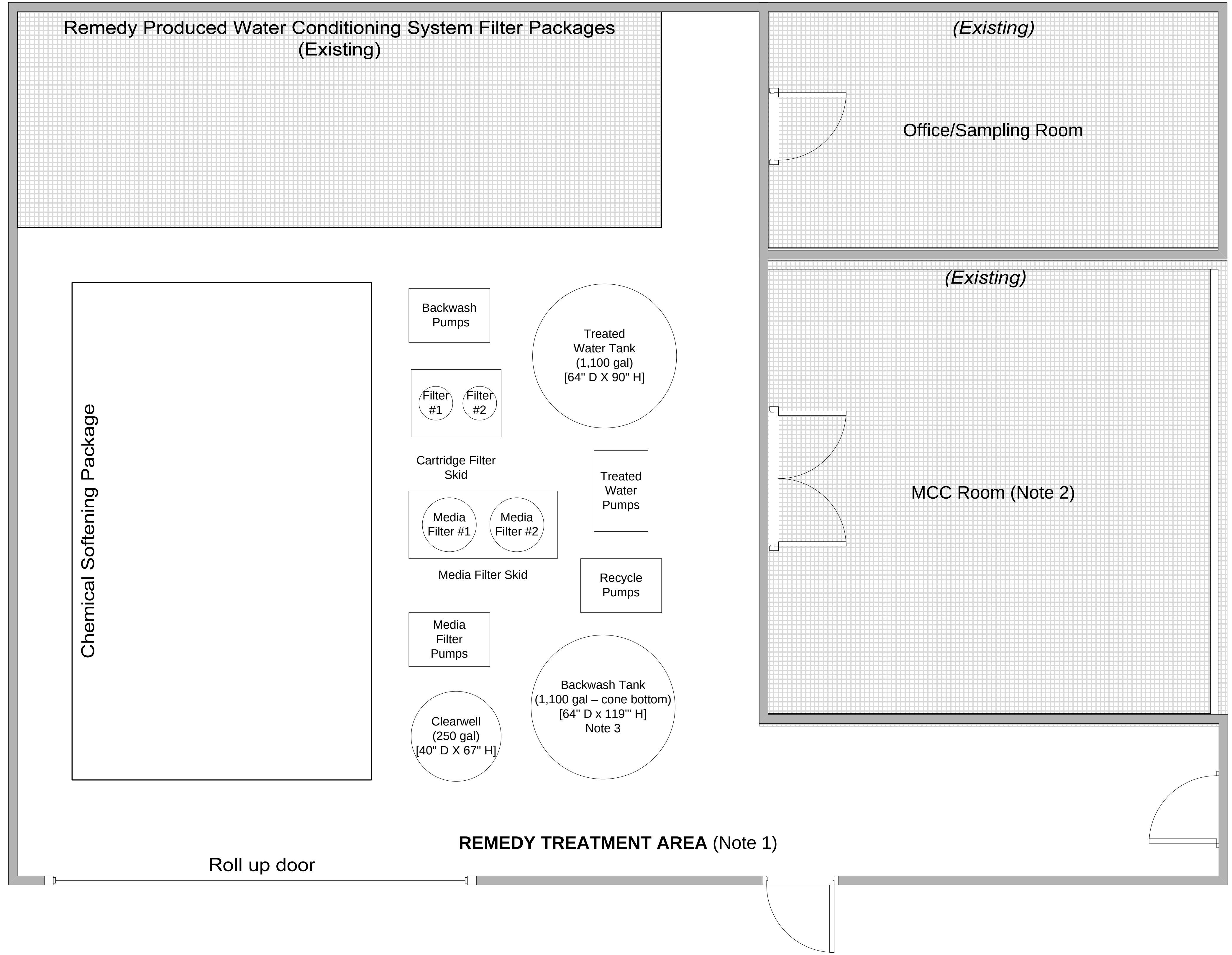
CH2MHILL

FIGURE 1b

Mass Balance

Contingent Dissolved Metals Removal System Conceptual Design Basis Memorandum

PG&E Topock Compressor Station, Needles, California



Notes:
1. Total 2nd floor space approximately 32" x 28 based on building column spacing.
2. Shower/eyewash located outside of MCC, near wall between MCC and Office/Sampling Room (not shown for clarity).
3. Solids pump is located beneath the Backwash Tank.

CH2MHILL

Scale: 1/4" = 1'-0"

0 ft. 3 ft. 5 ft. 10 ft.

FIGURE 2
General Arrangement
Contingent Dissolved Metals Removal System Conceptual Design Basis Memorandum
PG&E Topock Compressor Station, Needles, California

Appendix B
Addendum to Freshwater Pre-injection Treatment System Conceptual Design Basis

Addendum to Freshwater Pre-injection Treatment System Conceptual Design Basis PG&E Topock Compressor Station, Needles, California

PREPARED FOR: Pacific Gas and Electric Company

PREPARED BY: CH2M HILL

DATE: August 28, 2014

1.0 Introduction

Since the submittal of the 60% design of the Pacific Gas and Electric Company (PG&E) Topock Compressor Station (TCS) (CH2M HILL 2013), the State Water Resources Control Board (State Board) has issued a decision letter on November 20, 2013, and the California Department of Toxic Substances Control (DTSC) has provided direction in its comment on the 60% design (#145 DTSC-50) that will include an arsenic pre-treatment contingency as part of the 90% design. In compliance with this DTSC directive, this technical memorandum (TM) presents the design basis for a potential future pre-treatment option for freshwater.

This option assumes that the primary source is groundwater from well HNWR-1A and the secondary source is groundwater from wells HNWR-1 or Site B. All three freshwater supply wells are located in Arizona. This assumption will be revisited after completion of the alternative freshwater source evaluation—the field work is currently under way. The potential future treatment system, referred to herein as the freshwater pre-injection treatment system (FWPTS), will be located in the vicinity of the planned remedy-produced water-conditioning plant. All components of the FWPTS are located on previously disturbed areas within the PG&E-owned parcel.

The treatment goals of the FWPTS are arsenic removal to concentrations less than the federal and California maximum contaminant level (MCL) of 10 micrograms per liter (µg/L) (California Department of Public Health, 2013). This TM discusses the evaluation of available treatment technologies for arsenic; the selection of technologies for bench-scale testing; the results from bench-scale testing at CH2M HILL's Applied Science Laboratory (ASL) in Corvallis, Oregon; and the design basis/design criteria for the FWPTS. This document also includes a process flow diagram, a preliminary equipment layout, and a preliminary list of key equipment.

The design information presented herein has been developed based on Topock-specific information (that is, bench-scale testing results of HNWR-1 water) and experience in designing and operating arsenic groundwater treatment systems on non-Topock projects. Because of its location, the potential future FWPTS will be designed to achieve a safe, harmonious, and sustainable operation within TCS. Engineering design details of the FWPTS are included in the 90% design.

2.0 Freshwater Water Quality, Treatment Goals, and Design Flow Rates

For the purpose of this conceptual design, it is assumed that the water quality from the future supply well (HNWR-1A) in Arizona is similar to that of the HNWR-1 well. PG&E has collected and analyzed six samples from HNWR-1 starting in November 2010. Analytical results from November 2010 through February 2014 indicate that the naturally-occurring arsenic concentrations in HNWR-1 water were 14-16 µg/L, greater than the federal and California MCL of 10 µg/L arsenic. Tables 1A and 1B summarize available analytical results for HNWR-1 (all tables and figures are presented at the end of this TM). As previously mentioned, the treatment goals for the FWPTS are to remove arsenic to concentrations less than 10 µg/L.

The total freshwater supply flow rates are based on the sum of the modeled freshwater flows into the Freshwater and Inner Recirculation Loop injection wells. The FWPTS will be designed to treat freshwater for remedy injection only. Exhibit 1 shows the FWPTS design flow rates.

EXHIBIT 1
Design Flow Rates
Addendum to Freshwater Pre-injection Treatment System Design Basis Memorandum
PG&E Topock Compressor Station, Needles, California

Element	Unit	Minimum Flow	Nominal Flow	Maximum Flow
Freshwater Pre-Injection Treatment System (FWPTS)	gpm	150	450	900

3.0 Evaluation and Selection of Treatment Technologies

For this conceptual design basis, PG&E has identified and evaluated proven treatment technologies for arsenic that are United States Environmental Protection Agency (USEPA) Best Available Technologies (USEPA 2001) and have been successfully used by municipalities and industry. Unproven technologies or technologies that have not been used in full-scale applications were not considered.

The initial list included nine technologies: anion exchange, activated alumina (AA) adsorbents, reverse osmosis (RO), electrodialysis reversal (EDR), lime softening, distillation, iron-based adsorbents, titanium-based adsorbents, and coagulation/filtration (see Exhibit 2). These technologies were evaluated and screened in a two-step process: (1) the initial screening was based on the experience of the engineering team with the individual technology, and (2) the second-level screening was based on a set of criteria - namely treatment effectiveness, reliability and flexibility[1], operational complexity, waste generation, footprint, and cost effectiveness. After completion of the technology screening and evaluation process, the AA technology with disposable and regenerable (AA) adsorptive media, coagulation filtration, and iron-based adsorbent granular ferric hydroxide (GFH) were selected for bench-scale testing. For more details of this screening and a description of the evaluation processes, see Attachment A.

EXHIBIT 2
Technologies Considered for Arsenic Removal
Addendum to Freshwater Pre-injection Treatment System Design Basis Memorandum
PG&E Topock Compressor Station, Needles, California

Technology	Evaluation Status
Anion exchange	Screened out, significant waste generation.
AA	Selected for bench-testing
Titanium-based adsorbents	Screened out, similar as other adsorbents considered, with less experience.
Reverse osmosis (RO)	Screened out, significant waste generation.
Electrodialysis reversal (EDR)	Screened out, significant waste generation.
Lime softening	Screened out, significant waste generation.
Distillation	Screened out, significant energy use and capital cost.
Coagulation filtration	Selected for bench-testing
Iron-based adsorbents	Selected for bench-testing

[1] Flexibility is defined as the ability of a system to respond to potential internal or external changes affecting its performance, in a timely and cost-effective manner. Also includes aspects such as handling changes in influent water quality and flowrates.

4.0 Summary of Bench-scale Testing Results

The objectives of bench-scale testing were to: (1) verify the effectiveness of each adsorptive media in removing arsenic from HNWR-1 water to the treatment goals, (2) understand the time to break through (critical for equipment sizing and waste management) for AA and GFH, (3) understand effectiveness of coagulation with a jar test, and (4) understand waste generation amounts. This section summarizes the testing and results to date as it relates to arsenic treatment.

To accomplish the first two objectives, CH2M HILL's ASL employs a testing procedure for evaluating adsorptive media effectiveness in removing arsenic in a small-diameter laboratory column analogous to the rapid small-scale column test method developed for assessing granular-activated carbon in a continuous flow system. This method significantly reduces the amount of time and water required for testing compared to pilot-scale and full-scale systems (USEPA 1996). A jar test was performed to evaluate the effectiveness of ferric chloride as coagulant.

A groundwater sample was continuously pumped, sampled, and collected in three 55-gallon drums from HNWR-1 well in early January 2013 and was shipped to ASL for bench-scale testing. The groundwater sample was processed continuously through the column, and the treated water was sampled and analyzed for arsenic until breakthrough (defined as at least 70 percent of the average influent concentration). After the first breakthrough, the media was regenerated, and the test was repeated. Two treatment cycles (termed Service Cycle 1 and Service Cycle 2) were conducted for regenerable AA (due to fluoride breakthrough caused by the greater affinity of fluoride versus arsenic to AA). Because of time constraints, not all media samples were able to be tested until arsenic breakthrough. In total, 133 liters of HNWR-1 well water were processed using disposable AA and 204 liters using GFH. These samples were tested for as long as time permitted in the laboratory. The rapid small-scale column test results provide information on adsorption capacity (extent of adsorption) and the rate of adsorption (adsorption kinetics), which are the two dominant factors affecting breakthrough in the media columns.

The rapid small-scale column test for arsenic removal was performed using the following media

- Regenerable AA (BASF AA-400G)
- Disposable AA (BASF AA-FS50)
- Alum-impregnated AA (AIAA)
- GFH

Prior to passing the water over the media, the groundwater was pretreated as follows: the pH was adjusted to 6.5 with hydrochloric acid and the water was injected with chlorine to maintain a residual concentration of 1 mg/L for 60 seconds (this is to oxidize any arsenite present in the water to arsenate), and was followed by inline filtration.

Column Testing Treatment Effectiveness and Time to Breakthrough

Figure 1 shows concentrations of arsenic in treated water versus the number of bed-volumes of groundwater passed through (one bed-volume is equivalent to the amount of adsorptive media in the column). During the first service cycle, the regenerable AA performs well, but in the second service cycle the effluent concentration begins to increase more rapidly indicating after the initial service cycle the media loses capacity to adsorb arsenic. Due to this fact and the difficulty in regenerating AA media which requires using strong chemicals like caustic and sulfuric acid increasing safety concerns, cost, and associated wastewater management[2], this method is eliminated from further analysis. The AIAA performed somewhat better than the regenerable AA, but not as well as the disposable AA media. The poorer performance and the additional effort to impregnate the alum onto the AA, eliminates this media from further evaluation. The disposable media performed well to more than 44,000 bed volumes, although the arsenic effluent concentration appears to have increased more than the effluent from the GFH media column.

To ascertain the relative performance of the two media, another figure was prepared (Figure 2), which shows the measured effluent concentration as a function of the amount of arsenic adsorbed on the treatment media. The amount of arsenic absorbed was calculated by multiplying the measured concentration in effluent samples by the volume of water passing through during the sampling interval and dividing by the mass of media in the column.

[2] The estimated wastewater volume ranged from 3.3 to 11 million gallons per year (CH2M HILL 2013).

The effluent concentration in the disposable AA, begins to rise rapidly when the adsorption reaches 0.4 µg/mg media where as in the GFH varies between 0.15 and 0.35 µg/mg media until the test was stopped. These results more clearly indicate GFH will perform better.

Jar Testing Results

Jar testing was performed to test arsenic removal by coagulation with ferric chloride. Water samples were pre-oxidized with free chlorine dosed to provide approximately 1 mg/L free chlorine residual for 60 seconds prior to ferric chloride addition and mixing. Ferric chloride was added to reach doses 5, 10, 15, and 20 mg/L. The mixers were run at 70 revolutions per minute (rpm) for 30 seconds followed by 25 rpm for 20 minutes. The samples were then filtered through a 0.45 micron filter and the filtered water tested for arsenic and pH.

Figure 3 shows the arsenic concentration versus ferric chloride dose applied during testing. Jar testing demonstrated that arsenic could effectively be removed to <10 µg/L with ferric chloride dosed to 5 mg/L.

Process Selection

As shown above, the GFH was effective at removing arsenic to below the treatment goals (the federal and California MCL of 10 µg/L). The effluent remained less than 1 µg/L of arsenic for over 70,000 bed-volumes. The GFH media performed better than the disposable AA offering longer running periods between media change-outs. Coagulation and filtration although effective creates a solid waste stream 5 times greater than GFH that must be transported and disposed of off-site and is more difficult to operate. Based on these reasons, GFH was selected for the FWPTS design.

Section 5 discusses the treatment and backwash process in more details and provides a summary of the sustainability factors.

5.0 Freshwater Treatment Process and System Description

As previously mentioned, GFH was selected as the treatment technology to be carried forward into the design of the FWPTS. GFH is a granular, ferric-based, non-regenerative media that adsorbs arsenic and other heavy metal ions from solution. The USEPA has identified GFH as an effective media to remove arsenic (USEPA 2003). This section describes the design philosophy, the treatment process, and the system configuration envisioned at this stage. This section also discusses the uncertainties with the ongoing design and the work that is currently underway or being planned to address these uncertainties.

5.1 Treatment System Description

Groundwater will be pumped and conveyed from the future water supply well in Arizona to the remedy freshwater storage tank. Water will be pumped from this tank and will be injected with hypochlorite for arsenic oxidation and with acid to reduce pH to 6.5; both hypochlorite and lower pH improve arsenic removal in the media vessels. After chemical injection, water will be passed through cartridge filters to remove solids that would otherwise clog the media, reducing performance and runtime. With the solids removed, the water will be divided into two or three streams (nominal or maximum flow) and each will be processed through a single treatment media vessel (configured in parallel) in a downward flow direction. Automatic valves will divert the flow to the proper vessels and will control the flow rate into each in service vessel. During nominal flow, the third and treatment media vessel will be in standby mode. During maximum flow, three treatment media vessels will be operating.

PG&E evaluated dechlorination alternatives to remove residual chlorine from the treated freshwater. The reason for this step is to prevent the dechlorination chemicals in the freshwater plume from adversely effecting microorganisms in the remediation zones. Dechlorination is often accomplished by addition of commonly used chemicals such as ascorbic acid, calcium thiosulfate, and hydrogen peroxide. The evaluation included cost-effectiveness and safety issues related with handling and storage, and the results showed calcium thiosulfate was the best. The equipment needed include chemical storage tanks or totes, metering pumps, and an inline static mixer. Due to climate condition at Topock, the equipment would be housed in an air-conditioned storage building.

5.2 Media Backwash & Replacement Process

The amount of wastewater generated is primarily a function of backwash frequency. Backwashing prevents over compaction of the media bed enabling good flow conditions. The media bed should be backwashed once a month for proper media maintenance. Backwashing occurs in an upflow mode, the reverse of normal forward down-flow operation. Once the backwash process is complete, normal forward down-flow operation may resume. Each media vessel backwash process is expected take ten minutes.

At some point during treatment operations, the media will lose its adsorptive capacity and will need to be replaced. Based on bench scale testing, this point is anticipated to be after more than 70,000 bed-volumes or about 8 months at maximum flow rates. The actual replacement frequency will be determined during full-scale operation. For the purpose of the conceptual design, it is assumed that the media will be replaced once a year. Spent media will be removed from each vessel and sent to a landfill. Prior experience operating GFH treatment process shows the spent media is not hazardous (Ela 2006). Waste characterization testing will be performed in accordance with state and federal requirements and facility waste acceptance procedures. Virgin media will be placed in the media vessel and normal forward down-flow operation may resume.

Wastewater & Solid Waste Generation

The volume of wastewater needing to be managed is estimated based on the following assumptions:

- Backwash rate is 15 gpm/sq. ft. and vessel cross section area is 50 sq. ft.
- Backwashing time is 10 minutes resulting in 7,550 gallons per backwash
- Four vessels backwashed monthly at 900 gpm and two vessels backwashed monthly at 450 gpm
- 95 percent of the backwash water is recycled to the beginning of the process

At 450 gpm – 7,550 gallons/backwash x 2 vessels per month x 12 months per year x 5% = 9,000 gallons per year

For 900 gpm – 7,550 gallons/backwash x 4 vessels per month x 12 months per year x 5% = 18,000 gallons per year

The remaining (5 percent of the) backwash water can be discharged to the TCS evaporation ponds or disposed offsite at permitted facilities. There is no need to treat or neutralize the pH of the discharged backwash water as it will be within acceptable ranges. Treated water is used for backwashing and no arsenic desorbs from the media during the backwashing process. Discharged backwash water will have more solids compared to the treated water but it will be able to be pumped to the TCS evaporation ponds or disposed offsite without treatment.

Periodic disposal of the spent GFH media would be required also as a solid waste stream. Based on the bench testing, this would be no more frequently than every 8 months, but is expected to be less frequent. For the purposes of this conceptual design, it is assumed that the media will require annual replacement. The mass of solid waste to be managed

- The media has a specific gravity of 1.1 with water density of 62.4 pounds per cubic foot
- Each vessel has 200 cubic feet of media
- Four vessels need replacement at a rate 900 gpm and 2 vessels at a rate of 450 gpm

At 450 gpm – 200 cubic feet/vessel x 2 vessels per year x 1.1 x 62.4 pounds per cubic foot / 2,000 tons/pound = 13.7 tons per year

At 900 gpm – 200 cubic feet/vessel x 4 vessels per year x 1.1 x 62.4 pounds per cubic foot / 2,000 tons/pound = 27.5 tons per year

5.3 Chemical and Media Use

Chemicals will be used in the treatment system. Chlorine in the form of calcium hypochlorite tablets is used to oxidize arsenite to arsenate. Arsenate is more readily removed by the treatment process. Acid is used in pretreatment to improve adsorption by lowering the pH to about 6.5. The estimated chemical use is shown in Exhibit 3.

EXHIBIT 3
Annual Chemical Usage Rates
Addendum to Freshwater Pre-injection Treatment System Design Basis Memorandum
PG&E Topock Compressor Station, Needles, California

Flow Case	Flowrate, gpm	Hypochlorite, pounds/year	93% Sulfuric Acid, gallons/year	Calcium Thiosulfate
Nominal	450	3,500	5,150	2,550
Maximum	900	7,000	10,300	1,275

5.4 Sustainability Summary

For each of the treatment plant operating scenarios (450 and 900 gpm), sustainability parameters such as waste generation, chemical usage, energy use, and greenhouse gas emissions were estimated for the FWPTS as shown on Exhibit 4.

EXHIBIT 4
Sustainability Summary [a]
Addendum to Freshwater Pre-injection Treatment System Design Basis Memorandum
PG&E Topock Compressor Station, Needles, California

Operations									Construction	
Treatment Case	Chemical Truck Trips	Solid Waste Truck Trips	Electricity, kw-hr/yr	Wastewater Generation, MG/yr	Solid Waste Generated, tons/ year [b]	Chemical Use, gal/yr	Total Miles/ year	Emissions, CO2 eq, Tons/year [c]	CO2 eq, Tons [d]	Footprint, sf [e]
450 gpm	20	2	280,000	Minimal	17	21,300	7,000	180	210	2,400
900 gpm	39	~3	320,000	Minimal	33	42,500	13,000	200	250	3,900

Notes:
Units: kw-hr/year = kilowatt-hours per year; MG/yr = million gallons per year; gal = gallons; sf = square feet; gpm=gal per minute; CO2 eq – carbon dioxide equivalent
[a] Previously submitted on March 29, 2013. Additional effects for using a dechlorination agent if required will be added to this table in the 90% design submittal.
[b] Solid waste includes spent filter cartridges (500 to 1,000 per year)
[c] Operational emissions include vehicle emission and electricity generation
[d] Construction includes site work, material delivery, and workers travel
[e] Footprint based on foundations for building, process tanks, and chemical storage

5.5 Controls Philosophy

The system will be automated to reduce the need for continuous operator oversight. Electronic notifications will be sent automatically to on-site operators that notify them of system alarms, shutdown, or other issues. System automation will be controlled using a programmable logic controller that will communicate with the groundwater remedy supervisory control and data acquisition system. Pneumatic valves will be automated to control flow. Online pH, turbidity, and conductivity sensors will be incorporated to enable remote process monitoring and control. Arsenic cannot be monitored using an online analyzer. Grab samples will be collected periodically and analyzed using a bench top colorimetric instrument in the sample room (located in the Remedy Produced Water Conditioning Building) to monitor arsenic levels.

5.6 Other Related Systems and Infrastructure

Electricity will be provided from the Compressor Station. The new FWPTS location will have a heating, ventilation, and air conditioning (HVAC) system for only critical equipment such as electrical and controls equipment.

5.7 Design Philosophy/Uncertainties in Design

As previously mentioned, the FWPTS will be designed to achieve a safe, efficient, and sustainable operation within the compressor station over the anticipated decades-long life of the remedy. Most of the uncertainty in the design is related to the bed life and adsorptive capacity of the media. Based on bench testing, it is anticipated that the media will not need to be replaced before 70,000 bed volumes are processed– or every 8 months. The actual adsorptive capacity will need to be determined during full-scale operation and the result will greatly influence the amount of wastewater and solid waste generated by the process.

6.0 Design Information

Process calculations used to develop the design criteria were prepared using the conservative assumption that the treatment vessels each needed to be backwashed once a month and media replaced annually. Conceptual design information is presented in Tables 2, 3, and 4 and on Figures 4, 5, and 6.

7.0 References

California Department of Public Health. 2013. "Comparison of MCLs and PHGs for Regulated Contaminants in Drinking Water" Web page. Online: http://www.cdph.ca.gov/certlic/drinkingwater/Pages/MCLsandPHGs.aspx. Accessed March 22.

CH2M HILL. 2009. *Groundwater Background Study, Steps 3 and 4: Revised Final Report of Results, PG&E Topock Compressor Station, Needles, California*. November 6.

_________. 2013. *Basis of Design Report/Intermediate (60%) Design Submittal for the Final Groundwater Remedy, PG&E Topock Compressor Station, Needles, California*. April 5.

_________. 2014. *Basis of Design Report/Pre-Final (90%) Design Submittal for the Final Groundwater Remedy, PG&E Topock Compressor Station, Needles, California*. In preparation for submittal on September 8.

Ela, Wendell P., and A. E. Saez. *Innovative Technologies for Arsenic Residuals Stabilization*. Publication. AWWA Research Foundation, 2006. Web.

United States Environmental Protection Agency (USEPA). 1996. *ICR Manual for Bench- and Pilot-Scale Treatment Studies.* EPA 814/B-96-003. April.

__________. 2001. National Primary Drinking Water Regulations; Arsenic and Clarifications to Compliance and New Source Contaminants Monitoring; Final Rule Federal Register / Vol. 66, No. 14 / Monday, January 22, 2001 / Rules and Regulations [[Page 6976]] 40 CFR Parts 9, 141 and 142

__________. 2003. *Design Manual: Removal of Arsenic from Drinking Water by Adsorptive Media,* EPA/600/R-03/019. March.

Tables

TABLE 1A

HNWR-1 Analytical Results (November 2010 through January 2013)

Groundwater Remedy Operation and Maintenance Manual

Volume 3: Contingency Plan

PG&E Topock Compressor Station, Needles, California

Location:		HNWR-01	HNWR-01	HNWR-01	HNWR-01	HNWR-01	HNWR-01
Sample Date:		**11/10/2010**	**2/23/2012**	**3/14/2012**	**4/4/2012**	**6/27/2012**	**1/22/2013**
Parameter	**Units**						
Field							
Dissolved oxygen	mg/L	**5.33**	**3.52**	**3.29**	**3.72**	---	---
Oxidation reduction potential	mV	**159**	**172**	**200**	**112**	**33.5**	---
pH	pH units	**7.84**	**7.68**	**7.61**	**8.07**	**7.51**	---
Salinity	%	**0.42**	**0.0662**	**0.0537**	**0.0509**	**0.439**	---
Specific conductance	µS/cm	**870**	**1,024**	**830**	**787**	**6,791**	---
Temperature	°C	**35.9**	**38.3**	**38.1**	**38.0**	**37.9**	---
Turbidity	NTU	**5.10**	**5.10**	**2.50**	---	**8.00**	---
Anions							
Bromide	mg/L	---	---	---	---	---	---
Chloride	mg/L	---	**130**	**130**	**130**	**130**	---
Fluoride	mg/L	**3.80**	---	---	---	**4.00**	**3.90**
Nitrate (as nitrogen)	mg/L	**2.50**	**2.60**	**2.50**	**2.50**	**2.60**	---
Nitrite as Nitrogen	mg/L	---	---	---	---	---	---
Sulfate	mg/L	**47.0**	**45.0**	**44.0**	**45.0**	**44.0**	---
General Chemistry							
Alkalinity, bicarb as CaCO3	mg/L	---	**110**	**110**	**110**	**100**	---
Alkalinity, carb as CaCO3	mg/L	---	ND (5.0)	ND (5.0)	ND (5.0)	ND (5.0)	---
Alkalinity, hydroxide	mg/L	---	ND (5.0)	ND (5.0)	ND (5.0)	ND (5.0)	---
Alkalinity, total as CaCO3	mg/L	**100**	**110**	**110**	**110**	**100**	---
Ammonia as nitrogen	mg/L	ND (0.1)	**0.13**	**0.12**	**0.15**	ND (0.1)	---
Cyanide	mg/L	---	---	ND (0.01)	ND (0.01)	ND (0.01)	---
Deuterium	0/00	**-75.3**	**-73.8**	---	---	**-77.1**	---
Oxygen 18	0/00	**-10.3**	**-10.2**	---	---	**-10.2**	---
pH	pH units	---	---	---	---	---	---
Soluble silica	mg/L	**28.6**	---	---	---	**25.9**	---
Specific conductance	µS/cm	**740**	---	---	---	---	---
Total dissolved solids	mg/L	**490 J**	**480**	**510**	**430**	**440**	---
Total Kjeldahl Nitrogen	mg/L	ND (0.4)	---	---	---	---	---
Total organic carbon	mg/L	ND (1.0)	ND (1.0)	ND (1.0)	ND (1.0)	ND (1.0)	---
Total suspended solids	mg/L	---	---	ND (10)	---	ND (10)	---
Herbicides							
2,4,5-T	µg/L	---	---	ND (2.7)	ND (0.26)	---	---
2,4,5-TP (Silvex)	µg/L	---	---	ND (2.7)	ND (0.26)	---	---
2,4-D	µg/L	---	---	ND (2.7)	ND (0.26)	---	---
2,4-DB	µg/L	---	---	ND (2.7)	ND (0.26)	---	---
4-Nitrophenol	µg/L	---	---	ND (2.7)	---	---	---

TABLE 1A

HNWR-1 Analytical Results (November 2010 through January 2013)

Groundwater Remedy Operation and Maintenance Manual

Volume 3: Contingency Plan

PG&E Topock Compressor Station, Needles, California

Location:		HNWR-01	HNWR-01	HNWR-01	HNWR-01	HNWR-01	HNWR-01
Sample Date:		**11/10/2010**	**2/23/2012**	**3/14/2012**	**4/4/2012**	**6/27/2012**	**1/22/2013**
Parameter	**Units**						
Herbicides							
Dalapon	µg/L	---	---	ND (4.4)	ND (0.42)	---	---
Dicamba	µg/L	---	---	ND (2.7)	ND (0.26)	---	---
Dichlorprop	µg/L	---	---	ND (2.7)	ND (0.26)	---	---
Dinoseb	µg/L	---	---	ND (2.7)	ND (0.26)	---	---
MCPA	µg/L	---	---	ND (2.7)	ND (0.26)	---	---
MCPP	µg/L	---	---	ND (2.7)	ND (0.26)	---	---
Pentachlorophenol	µg/L	---	---	ND (2.7)	ND (0.26)	---	---
Metals							
Aluminum, dissolved	µg/L	ND (50)	---	ND (50)	ND (50)	ND (50)	---
Antimony, dissolved	µg/L	ND (10)	ND (10)	ND (10)	ND (0.5)	ND (0.5)	---
Arsenic	µg/L	---	---	---	---	---	**16.0**
Arsenic, dissolved	µg/L	**15.0**	**15.0**	**16.0**	**15.0**	**16.0**	**16.0**
Barium, dissolved	µg/L	**130**	**110**	**110**	**110**	**110**	---
Beryllium, dissolved	µg/L	ND (1.0)	ND (1.0)	ND (1.0)	ND (1.0)	ND (1.0)	---
Boron, dissolved	µg/L	**380**	---	---	---	---	---
Cadmium, dissolved	µg/L	ND (3.0)	ND (3.0)	ND (3.0)	ND (3.0)	ND (3.0)	---
Calcium, dissolved	µg/L	**23,000**	**19,000 J**	**19,000**	**20,000**	---	---
Chromium, Hexavalent	µg/L	**17.5**	**15.0**	**18.0**	**14.0**	**15.0**	---
Chromium, total dissolved	µg/L	**19.2**	**16.0**	**18.0**	**17.0**	**18.0**	---
Cobalt, dissolved	µg/L	ND (3.0)	ND (3.0)	ND (3.0)	ND (3.0)	ND (3.0)	---
Copper, dissolved	µg/L	ND (5.0)	ND (5.0)	ND (5.0)	ND (5.0)	ND (5.0)	---
Iron, dissolved	µg/L	ND (20)	**37.0**	ND (20)	**25.0**	**38.0**	---
Lead, dissolved	µg/L	ND (10)	ND (10)	ND (10)	ND (10)	ND (10)	---
Magnesium, dissolved	µg/L	**4,000**	**3,100**	**3,200 J**	**3,100 J**	---	---
Manganese, dissolved	µg/L	ND (10)	**1.90**	**0.64**	**1.70**	**1.70**	---
Mercury, dissolved	µg/L	ND (0.2)	ND (0.2)	ND (0.2)	ND (0.2)	ND (0.2)	---
Molybdenum, dissolved	µg/L	**11.0**	**9.40**	**10.0**	**9.00**	**9.10**	---
Nickel, dissolved	µg/L	ND (5.0)	ND (5.0)	ND (5.0)	ND (5.0)	ND (5.0)	---
Potassium, dissolved	µg/L	**5,100**	**4,400**	**4,000**	**3,700**	---	---
Selenium, dissolved	µg/L	**0.73**	**0.87**	**0.75**	**0.75**	**0.71**	---
Silver, dissolved	µg/L	ND (3.0)	ND (3.0)	ND (3.0)	ND (3.0)	ND (3.0) J	---
Sodium, dissolved	µg/L	**130,000**	**130,000**	**130,000**	**130,000**	---	---
Soluble silica	mg/L	---	---	---	---	---	---
Thallium, dissolved	µg/L	ND (0.5)	ND (0.5)	ND (0.5)	ND (0.5)	ND (0.5)	---
Vanadium, dissolved	µg/L	**20.0**	**21.0**	**22.0 J**	**20.0**	**20.0**	---
Zinc, dissolved	µg/L	ND (10)	ND (10)	**16.0**	ND (10)	ND (10)	---

TABLE 1A
HNWR-1 Analytical Results (November 2010 through January 2013)
Groundwater Remedy Operation and Maintenance Manual
Volume 3: Contingency Plan
PG&E Topock Compressor Station, Needles, California

Location:		HNWR-01	HNWR-01	HNWR-01	HNWR-01	HNWR-01	HNWR-01
Sample Date:		11/10/2010	2/23/2012	3/14/2012	4/4/2012	6/27/2012	1/22/2013
Parameter	**Units**						
Perchlorate							
Perchlorate	µg/L	---	---	ND (2.0)	ND (2.0)	---	---
Pesticides							
4,4-DDD	µg/L	---	---	ND (0.053)	ND (0.052)	---	---
4,4-DDE	µg/L	---	---	ND (0.053)	ND (0.052)	---	---
4,4-DDT	µg/L	---	---	ND (0.053)	ND (0.052)	---	---
Aldrin	µg/L	---	---	ND (0.027)	ND (0.026)	---	---
alpha-BHC	µg/L	---	---	ND (0.027)	ND (0.026)	---	---
alpha-Chlordane	µg/L	---	---	ND (0.027)	ND (0.026)	---	---
beta-BHC	µg/L	---	---	ND (0.027)	ND (0.026)	---	---
delta-BHC	µg/L	---	---	ND (0.027)	ND (0.026)	---	---
Dieldrin	µg/L	---	---	ND (0.053)	ND (0.052)	---	---
Endo sulfan I	µg/L	---	---	ND (0.027)	ND (0.026)	---	---
Endo sulfan II	µg/L	---	---	ND (0.053)	ND (0.052)	---	---
Endosulfan sulfate	µg/L	---	---	ND (0.053)	ND (0.052)	---	---
Endrin	µg/L	---	---	ND (0.053)	ND (0.052)	---	---
Endrin aldehyde	µg/L	---	---	ND (0.053)	ND (0.052)	---	---
gamma-BHC	µg/L	---	---	ND (0.027)	ND (0.026)	---	---
gamma-Chlordane	µg/L	---	---	ND (0.027)	ND (0.026)	---	---
Heptachlor	µg/L	---	---	ND (0.027)	ND (0.026)	---	---
Heptachlor Epoxide	µg/L	---	---	ND (0.027)	ND (0.026)	---	---
Methoxy chlor	µg/L	---	---	ND (0.27)	ND (0.26)	---	---
Toxaphene	µg/L	---	---	ND (2.7) J	ND (2.6) J	---	---
Polyaromatic Hydrocarbons							
1-Methyl naphthalene	µg/L	---	---	ND (0.22)	ND (0.2)	---	---
2-Methyl naphthalene	µg/L	---	---	ND (0.22)	ND (0.2)	---	---
Acenaphthene	µg/L	---	---	ND (0.22)	ND (0.2)	---	---
Acenaphthylene	µg/L	---	---	ND (0.22)	ND (0.2)	---	---
Anthracene	µg/L	---	---	ND (0.22)	ND (0.2)	---	---
B(a)P Equivalent	µg/L	---	---	ND (0.19)	ND (0.18)	---	---
Benzo (a) anthracene	µg/L	---	---	ND (0.22)	ND (0.2)	---	---
Benzo (a) pyrene	µg/L	---	---	ND (0.22)	ND (0.2)	---	---
Benzo (b) fluoranthene	µg/L	---	---	ND (0.22)	ND (0.2)	---	---
Benzo (ghi) perylene	µg/L	---	---	ND (0.22)	ND (0.2)	---	---
Benzo (k) fluoranthene	µg/L	---	---	ND (0.22)	ND (0.2)	---	---
Chrysene	µg/L	---	---	ND (0.22)	ND (0.2)	---	---
Dibenzo (a,h) anthracene	µg/L	---	---	ND (0.22)	ND (0.2)	---	---

Location:		HNWR-01	HNWR-01	HNWR-01	HNWR-01	HNWR-01	HNWR-01
Sample Date:		**11/10/2010**	**2/23/2012**	**3/14/2012**	**4/4/2012**	**6/27/2012**	**1/22/2013**
Parameter	**Units**						
Polyaromatic Hydrocarbons							
Fluoranthene	µg/L	---	---	ND (0.22)	ND (0.2)	---	---
Fluorene	µg/L	---	---	ND (0.22)	ND (0.2)	---	---
Indeno (1,2,3-cd) pyrene	µg/L	---	---	ND (0.22)	ND (0.2)	---	---
Naphthalene	µg/L	---	---	ND (0.22)	ND (0.2)	---	---
PAH High molecular weight	µg/L	---	---	ND (0.0)	ND (0.0)	---	---
PAH Low molecular weight	µg/L	---	---	ND (0.0)	ND (0.0)	---	---
Phenanthrene	µg/L	---	---	ND (0.22)	ND (0.2)	---	---
Pyrene	µg/L	---	---	ND (0.22)	ND (0.2)	---	---
Polychlorinated Biphenyls							
Aroclor 1016	µg/L	---	---	ND (0.53)	ND (0.52)	---	---
Aroclor 1221	µg/L	---	---	ND (1.1)	ND (1.0)	---	---
Aroclor 1232	µg/L	---	---	ND (0.53)	ND (0.52)	---	---
Aroclor 1242	µg/L	---	---	ND (0.53)	ND (0.52)	---	---
Aroclor 1248	µg/L	---	---	ND (0.53)	ND (0.52)	---	---
Aroclor 1254	µg/L	---	---	ND (0.53)	ND (0.52)	---	---
Aroclor 1260	µg/L	---	---	ND (0.53)	ND (0.52)	---	---
Radiochemistry							
Gross Alpha	pCi/L	---	---	---	---	---	---
Gross Beta	pCi/L	---	---	---	---	---	---
Total Petroleum Hydrocarbons							
Orthophosphate, dissolved	mg/L	---	---	---	---	---	---
TPH as diesel	µg/L	---	---	**190**	ND (51) J	---	---
TPH as gasoline	µg/L	---	---	ND (100)	ND (100)	---	---
TPH as motor oil	µg/L	---	---	ND (53)	ND (51)	---	---
Volatile Organic Compounds							
1,1,1,2-Tetrachloroethane	µg/L	---	---	ND (1.0)	ND (1.0)	---	---
1,1,1-Trichloroethane	µg/L	---	---	ND (1.0)	ND (1.0)	---	---
1,1,2,2-Tetrachloroethane	µg/L	---	---	ND (1.0)	ND (1.0)	---	---
1,1,2-Trichloroethane	µg/L	---	---	ND (1.0)	ND (1.0)	---	---
1,1,2-Trichlorotrifluoroethane (Freon 113)	µg/L	---	---	ND (1.0)	ND (1.0)	---	---
1,1-Dichloroethane	µg/L	---	---	ND (1.0)	ND (1.0)	---	---
1,1-Dichloroethene	µg/L	---	---	ND (1.0)	ND (1.0)	---	---
1,1-Dichloropropene	µg/L	---	---	ND (1.0)	ND (1.0)	---	---
1,2,3-Trichlorobenzene	µg/L	---	---	ND (1.0)	ND (1.0)	---	---
1,2,3-Trichloropropane	µg/L	---	---	ND (1.0)	ND (1.0)	---	---
1,2,4-Trichlorobenzene	µg/L	---	---	ND (1.0)	ND (1.0)	---	---

TABLE 1A

HNWR-1 Analytical Results (November 2010 through January 2013)

Groundwater Remedy Operation and Maintenance Manual

Volume 3: Contingency Plan

PG&E Topock Compressor Station, Needles, California

Location:		HNWR-01	HNWR-01	HNWR-01	HNWR-01	HNWR-01	HNWR-01
Sample Date:		11/10/2010	2/23/2012	3/14/2012	4/4/2012	6/27/2012	1/22/2013
Parameter	**Units**						
Volatile Organic Compounds							
1,2,4-Trimethylbenzene	µg/L	---	---	ND (1.0)	ND (1.0) J	---	---
1,2-Dibromo-3-chloropropane	µg/L	---	---	ND (2.0)	ND (2.0)	---	---
1,2-Dibromoethane	µg/L	---	---	ND (1.0)	ND (1.0)	---	---
1,2-Dichlorobenzene	µg/L	---	---	ND (1.0)	ND (1.0)	---	---
1,2-Dichloroethane	µg/L	---	---	ND (1.0)	ND (1.0)	---	---
1,2-Dichloropropane	µg/L	---	---	ND (1.0)	ND (1.0)	---	---
1,3,5-Trimethylbenzene	µg/L	---	---	ND (1.0)	ND (1.0) J	---	---
1,3-Dichlorobenzene	µg/L	---	---	ND (1.0)	ND (1.0)	---	---
1,3-Dichloropropane	µg/L	---	---	ND (1.0)	ND (1.0)	---	---
1,4-Dichlorobenzene	µg/L	---	---	ND (1.0)	ND (1.0)	---	---
2,2-Dichloropropane	µg/L	---	---	ND (1.0)	ND (1.0)	---	---
2-Chlorotoluene	µg/L	---	---	ND (1.0)	ND (1.0)	---	---
4-Isopropyltoluene	µg/L	---	---	ND (1.0)	ND (1.0)	---	---
Acetone	µg/L	---	---	ND (10)	ND (10)	---	---
Acrolein	µg/L	---	---	ND (20)	ND (20)	---	---
Acrylonitrile	µg/L	---	---	ND (20)	ND (20)	---	---
Benzene	µg/L	---	---	ND (1.0)	ND (1.0)	---	---
Bromobenzene	µg/L	---	---	ND (1.0)	ND (1.0)	---	---
Bromochloromethane	µg/L	---	---	ND (1.0)	ND (1.0)	---	---
Bromodichloromethane	µg/L	---	---	ND (1.0)	ND (1.0)	---	---
Bromoform	µg/L	---	---	ND (1.0)	ND (1.0)	---	---
Bromomethane	µg/L	---	---	ND (1.0)	ND (1.0)	---	---
Carbon disulfide	µg/L	---	---	ND (1.0)	ND (1.0)	---	---
Carbon tetrachloride	µg/L	---	---	ND (1.0)	ND (1.0)	---	---
Chloro methane	µg/L	---	---	ND (1.0)	ND (1.0)	---	---
Chlorobenzene	µg/L	---	---	ND (1.0)	ND (1.0)	---	---
Chloroethane	µg/L	---	---	ND (1.0)	ND (1.0)	---	---
Chloroform	µg/L	---	---	ND (1.0)	ND (1.0)	---	---
cis-1,2-Dichloroethene	µg/L	---	---	ND (1.0)	ND (1.0)	---	---
cis-1,3-Dichloropropene	µg/L	---	---	ND (1.0)	ND (1.0)	---	---
Dibromochloromethane	µg/L	---	---	ND (1.0)	ND (1.0)	---	---
Dibromomethane	µg/L	---	---	ND (1.0)	ND (1.0)	---	---
Dichlorodifluoromethane	µg/L	---	---	ND (1.0)	ND (1.0)	---	---
Ethyl- benzene	µg/L	---	---	ND (1.0)	ND (1.0)	---	---
Hexachlorobutadiene	µg/L	---	---	ND (1.0)	ND (1.0)	---	---
Isopropylbenzene	µg/L	---	---	ND (1.0)	ND (1.0)	---	---
Methyl ethyl ketone	µg/L	---	---	ND (10)	ND (10)	---	---

TABLE 1A
HNWR-1 Analytical Results (November 2010 through January 2013)
Groundwater Remedy Operation and Maintenance Manual
Volume 3: Contingency Plan
PG&E Topock Compressor Station, Needles, California

Location:		HNWR-01	HNWR-01	HNWR-01	HNWR-01	HNWR-01	HNWR-01
Sample Date:		**11/10/2010**	**2/23/2012**	**3/14/2012**	**4/4/2012**	**6/27/2012**	**1/22/2013**
Parameter	**Units**						
Volatile Organic Compounds							
Methyl isobutyl ketone	µg/L	---	---	ND (10)	ND (10)	---	---
Methyl tert-butyl ether (MTBE)	µg/L	---	---	ND (1.0)	ND (1.0) J	---	---
Methylene chloride	µg/L	---	---	ND (5.0)	ND (5.0)	---	---
N-Butylbenzene	µg/L	---	---	ND (1.0)	ND (1.0)	---	---
N-Propylbenzene	µg/L	---	---	ND (1.0)	ND (1.0)	---	---
p-Chlorotoluene	µg/L	---	---	ND (1.0)	ND (1.0)	---	---
sec-Butylbenzene	µg/L	---	---	ND (1.0)	ND (1.0)	---	---
Styrene	µg/L	---	---	ND (1.0)	ND (1.0) J	---	---
tert-Butylbenzene	µg/L	---	---	ND (1.0)	ND (1.0)	---	---
Tetrachloroethene	µg/L	---	---	ND (1.0)	ND (1.0)	---	---
Toluene	µg/L	---	---	ND (2.5)	ND (2.5)	---	---
trans-1,2-Dichloroethene	µg/L	---	---	ND (1.0)	ND (1.0)	---	---
trans-1,3-Dichloropropene	µg/L	---	---	ND (1.0)	ND (1.0)	---	---
Trichloroethene	µg/L	---	---	ND (1.0)	ND (1.0)	---	---
Trichlorofluoromethane (Freon 11)	µg/L	---	---	ND (1.0)	ND (1.0)	---	---
Vinyl chloride	µg/L	---	---	ND (1.0)	ND (1.0)	---	---
Xylene, m,p-	µg/L	---	---	ND (1.0)	ND (1.0)	---	---
Xylene, o-	µg/L	---	---	ND (1.0)	ND (1.0)	---	---
Xylenes, total	µg/L	---	---	ND (2.0)	ND (2.0)	---	---

Notes:

---	not collected or not available.
%	percent
0/00	differences from global standards in ppt.
°C	degrees Celcius.
J	analyte was present, but reported value was estimated.
mg/L	milligrams per liter.
mV	millivolts.
ND	parameter not detected at the listed reporting limit.
NTU	nephelometric turbidity units.
µg/L	micrograms per liter.
µS/cm	microSiemens per centimeter.

TABLE 1B

HNWR-1 Analytical Results (October 2013 through February 2014)

Groundwater Remedy Operation and Maintenance Manual

Volume 3: Contingency Plan

PG&E Topock Compressor Station, Needles, California

Location:		**HNWR-01**	**HNWR-01**	**HNWR-01**	**HNWR-01**	**HNWR-01**	**HNWR-01**	**HNWR-01**
Sample Date:		**10/22/2013**	**2/11/2014**	**2/12/2014**	**2/12/2014**	**2/12/2014**	**2/13/2014**	**2/14/2014**
Time (hours):		**--**	**1**	**6**	**12**	**24**	**48**	**72**
Parameter	**Units**							
Anions								
Bromide	mg/L	ND (0.5)	ND (0.5)	---	---	---	---	ND (0.5)
Chloride	mg/L	140	140	---	---	---	---	140
Fluoride	mg/L	3.90	4.00	4.00	4.00	4.00	3.80	3.90
Nitrate (as nitrogen)	mg/L	2.50	2.60	2.70	2.70	2.70	2.50	2.50
Nitrite as Nitrogen	mg/L	ND (2.5)	ND (1.0)	---	---	---	---	ND (1.0)
Sulfate	mg/L	45.0	45.0	---	---	---	---	51.0
General Chemistry								
Deuterium	0/00	---	-73.6	-73.4	-73.4	-73.4	-74.3	-72.5
Oxygen 18	0/00	---	-10.1	-10.4	-10.4	-10.4	-10.5	-10.4
pH	pH units	---	7.90 J	---	---	---	---	7.70 J
Total organic carbon	mg/L	---	ND (1.0)	---	---	---	---	ND (1.0)
Herbicides								
2,4,5-T	µg/L	---	ND (0.012)	---	---	---	---	ND (0.012)
2,4,5-TP (Silvex)	µg/L	---	ND (0.016)	---	---	---	---	ND (0.016)
2,4-D	µg/L	---	ND (0.065)	---	---	---	---	ND (0.065)
2,4-DB	µg/L	---	ND (0.32)	---	---	---	---	ND (0.32)
Dalapon	µg/L	---	ND (2.4) J	---	---	---	---	ND (2.4) J
Dicamba	µg/L	---	ND (0.037)	---	---	---	---	ND (0.037)
Dichlorprop	µg/L	---	ND (0.012)	---	---	---	---	ND (0.012)
Dinoseb	µg/L	---	ND (0.04)	---	---	---	---	ND (0.04)
MCPA	µg/L	---	ND (0.29) J	---	---	---	---	ND (0.29) J
MCPP	µg/L	---	ND (0.3) J	---	---	---	---	ND (0.3) J
Metals								
Antimony, dissolved	µg/L	ND (0.5)	ND (0.5)	ND (0.5)	ND (0.5)	ND (0.5)	ND (0.5)	ND (0.5)
Arsenic, dissolved	µg/L	14.0	16.0	16.0	16.0	16.0	15.0	14.0
Barium, dissolved	µg/L	110	120	120	120	120	130	120
Beryllium, dissolved	µg/L	ND (1.0)	ND (0.5)	ND (0.5)	ND (0.5)	ND (0.5)	ND (0.5)	ND (0.5)
Cadmium, dissolved	µg/L	ND (3.0)	ND (0.5)	ND (0.5)	ND (0.5)	ND (0.5)	ND (0.5)	ND (0.5)
Calcium, dissolved	µg/L	---	19,000	---	---	---	---	23,000
Chromium, Hexavalent	µg/L	20.0	20.0	20.0	20.0	20.0	19.0	19.0
Chromium, total dissolved	µg/L	17.0	18.0	19.0	19.0	19.0	17.0	16.0
Cobalt, dissolved	µg/L	ND (3.0)	ND (0.5)	ND (0.5)	ND (0.5)	ND (0.5)	ND (0.5)	ND (0.5)
Copper, dissolved	µg/L	ND (5.0)	ND (1.0)	ND (1.0)	ND (1.0)	ND (1.0)	ND (1.0)	ND (1.0)
Iron, dissolved	µg/L	---	ND (20)	---	---	---	---	ND (20)
Lead, dissolved	µg/L	ND (10)	ND (1.0)	ND (1.0)	ND (1.0)	ND (1.0)	ND (1.0)	ND (1.0)
Magnesium, dissolved	µg/L	---	3,200	---	---	---	---	4,200

TABLE 1B
HNWR-1 Analytical Results (October 2013 through February 2014)
Groundwater Remedy Operation and Maintenance Manual
Volume 3: Contingency Plan
PG&E Topock Compressor Station, Needles, California

	Location:	HNWR-01	HNWR-01	HNWR-01	HNWR-01	HNWR-01	HNWR-01	HNWR-01
	Sample Date:	10/22/2013	2/11/2014	2/12/2014	2/12/2014	2/12/2014	2/13/2014	2/14/2014
	Time (hours):	--	1	6	12	24	48	72
Parameter	**Units**							
Metals								
Manganese, dissolved	µg/L	---	ND (0.5)	---	---	---	---	ND (0.5)
Mercury, dissolved	µg/L	ND (0.2)	ND (0.2)	ND (0.2)	ND (0.2)	ND (0.2)	ND (0.2)	ND (0.2)
Molybdenum, dissolved	µg/L	**9.10**	**9.00**	**9.40**	**9.40**	**9.40**	**9.20**	8.90
Nickel, dissolved	µg/L	ND (5.0)	ND (1.0)	ND (1.0)	ND (1.0)	ND (1.0)	ND (1.0)	ND (1.0)
Potassium, dissolved	µg/L	---	**4,100**	---	---	---	---	4,600
Selenium, dissolved	µg/L	**0.68**	**0.79**	**0.77**	**0.77**	**0.77**	**0.76**	0.75
Silver, dissolved	µg/L	ND (3.0)	ND (0.5)	ND (0.5)	ND (0.5)	ND (0.5)	ND (0.5)	ND (0.5)
Sodium, dissolved	µg/L	---	**130,000**	---	---	---	---	140,000
Soluble silica	mg/L	**27.0**	**24.0**	**25.0 J**	**25.0 J**	**25.0 J**	**25.0**	27.0
Thallium, dissolved	µg/L	ND (0.5)	ND (0.5)	ND (0.5)	ND (0.5)	ND (0.5)	ND (0.5)	ND (0.5)
Vanadium, dissolved	µg/L	**20.0**	**18.0**	**19.0**	**19.0**	**19.0**	**17.0**	16.0
Zinc, dissolved	µg/L	**12.0**	ND (10)	ND (10)	ND (10)	ND (10)	ND (10)	ND (10)
Perchlorate								
Perchlorate	µg/L	---	ND (2.0)	---	---	---	---	ND (2.0)
Pesticides								
4,4-DDD	µg/L	---	ND (0.05)	---	---	---	---	ND (0.052)
4,4-DDE	µg/L	---	ND (0.05)	---	---	---	---	ND (0.052)
4,4-DDT	µg/L	---	ND (0.05)	---	---	---	---	ND (0.052)
Aldrin	µg/L	---	ND (0.025)	---	---	---	---	ND (0.026)
alpha-BHC	µg/L	---	ND (0.025)	---	---	---	---	ND (0.026)
alpha-Chlordane	µg/L	---	ND (0.025)	---	---	---	---	ND (0.026)
beta-BHC	µg/L	---	ND (0.025)	---	---	---	---	ND (0.026)
delta-BHC	µg/L	---	ND (0.025)	---	---	---	---	ND (0.026)
Dieldrin	µg/L	---	ND (0.05)	---	---	---	---	ND (0.052)
Endo sulfan I	µg/L	---	ND (0.025)	---	---	---	---	ND (0.026)
Endo sulfan II	µg/L	---	ND (0.05)	---	---	---	---	ND (0.052)
Endosulfan sulfate	µg/L	---	ND (0.05)	---	---	---	---	ND (0.052)
Endrin	µg/L	---	ND (0.05)	---	---	---	---	ND (0.052)
Endrin aldehyde	µg/L	---	ND (0.05)	---	---	---	---	ND (0.052)
gamma-BHC	µg/L	---	ND (0.025)	---	---	---	---	ND (0.026)
gamma-Chlordane	µg/L	---	ND (0.025)	---	---	---	---	ND (0.026)
Heptachlor	µg/L	---	ND (0.025)	---	---	---	---	ND (0.026)
Heptachlor Epoxide	µg/L	---	ND (0.025)	---	---	---	---	ND (0.026)
Methoxy chlor	µg/L	---	ND (0.25)	---	---	---	---	ND (0.26)
Toxaphene	µg/L	---	ND (2.5)	---	---	---	---	ND (2.6)

TABLE 1B
HNWR-1 Analytical Results (October 2013 through February 2014)
Groundwater Remedy Operation and Maintenance Manual
Volume 3: Contingency Plan
PG&E Topock Compressor Station, Needles, California

Location:		HNWR-01	HNWR-01	HNWR-01	HNWR-01	HNWR-01	HNWR-01	HNWR-01
Sample Date:		10/22/2013	2/11/2014	2/12/2014	2/12/2014	2/12/2014	2/13/2014	2/14/2014
Time (hours):		--	1	6	12	24	48	72
Parameter	**Units**							
Polyaromatic Hydrocarbons								
1-Methyl naphthalene	µg/L	---	ND (0.2)	---	---	---	---	ND (0.21)
2-Methyl naphthalene	µg/L	---	ND (0.2)	---	---	---	---	ND (0.21)
Acenaphthene	µg/L	---	ND (0.2)	---	---	---	---	ND (0.21)
Acenaphthylene	µg/L	---	ND (0.2)	---	---	---	---	ND (0.21)
Anthracene	µg/L	---	ND (0.2)	---	---	---	---	ND (0.21)
Benzo (a) anthracene	µg/L	---	ND (0.2)	---	---	---	---	ND (0.21)
Benzo (a) pyrene	µg/L	---	ND (0.2)	---	---	---	---	ND (0.21)
Benzo (b) fluoranthene	µg/L	---	ND (0.2)	---	---	---	---	ND (0.21)
Benzo (ghi) perylene	µg/L	---	ND (0.2)	---	---	---	---	ND (0.21)
Benzo (k) fluoranthene	µg/L	---	ND (0.2)	---	---	---	---	ND (0.21)
Chrysene	µg/L	---	ND (0.2)	---	---	---	---	ND (0.21)
Dibenzo (a,h) anthracene	µg/L	---	ND (0.2)	---	---	---	---	ND (0.21)
Fluoranthene	µg/L	---	ND (0.2)	---	---	---	---	ND (0.21)
Fluorene	µg/L	---	ND (0.2)	---	---	---	---	ND (0.21)
Indeno (1,2,3-cd) pyrene	µg/L	---	ND (0.2)	---	---	---	---	ND (0.21)
Naphthalene	µg/L	---	ND (0.2)	---	---	---	---	ND (0.21)
Phenanthrene	µg/L	---	ND (0.2)	---	---	---	---	ND (0.21)
Pyrene	µg/L	---	ND (0.2)	---	---	---	---	ND (0.21)
Polychlorinated Biphenyls								
Aroclor 1016	µg/L	---	ND (0.5)	---	---	---	---	ND (0.52)
Aroclor 1221	µg/L	---	ND (1.0)	---	---	---	---	ND (1.0)
Aroclor 1232	µg/L	---	ND (0.5)	---	---	---	---	ND (0.52)
Aroclor 1242	µg/L	---	ND (0.5)	---	---	---	---	ND (0.52)
Aroclor 1248	µg/L	---	ND (0.5)	---	---	---	---	ND (0.52)
Aroclor 1254	µg/L	---	ND (0.5)	---	---	---	---	ND (0.52)
Aroclor 1260	µg/L	---	ND (0.5)	---	---	---	---	ND (0.52)
Radiochemistry								
Gross Alpha	pCi/L	---	**7.42**	---	---	---	---	6.34 J
Gross Beta	pCi/L	---	ND (4.0)	---	---	---	---	ND (4.0)
Total Petroleum Hydrocarbons								
Orthophosphate, dissolved	mg/L	---	ND (0.02)	---	---	---	---	ND (0.02)
TPH as diesel	µg/L	---	ND (50)	---	---	---	---	ND (50)
TPH as gasoline	µg/L	---	ND (100)	---	---	---	---	ND (100)
TPH as motor oil	µg/L	---	ND (50)	---	---	---	---	ND (50)

Notes:

---	not collected or not available.
0/00	differences from global standards in ppt.
J	analyte was present, but reported value was estimated.
mg/L	milligrams per liter.
ND	parameter not detected at the listed reporting limit.
NTU	nephelometric turbidity units.
pCi/L	picocurries per liter.
µg/L	micrograms per liter.

TABLE 2
Design Criteria for Arsenic Treatment System
Addendum to Freshwater Pre-injection Treatment System Design Basis Memorandum
PG&E Topock Compressor Station, Needles, California

Subject	Criteria	Comments/Reason
OPERATIONAL CRITERIA		
Maximum Groundwater Injection Flow Capacity	900 gpm	
Minimum Groundwater Injection Flow Capacity	150 gpm	
Average Groundwater Injection Flow Capacity	450 gpm	
SITE CIVIL		
Location	Designated freshwater treatment at PG&E Topock Compressor Station near Needles, California. Next to the Remedy Produced Water Conditioning Building, within the footprint of the planned Decontamination Pad	
Building Finish Floor Elevation	Finished first floor, Elevation 626 feet (NGVD88).	
Grading	Longitudinal Slopes: Minimum 1% away from structures (2% desirable).	
Vehicle Access	WB 50 (turning radius for semi-truck and trailer with 50-foot wheel base). HS 20 (wheel loading on access roadways and parking areas). 50-foot minimum turning radius. Designated site accommodates truck circulation. Roads will be constructed at new facility for maintenance activities.	Required for delivery of chemicals, pumps, motors, and fire vehicles.
Site Constraints	Proposed facility located within the boundary of the compressor station. Access to all critical compressor station facilities must be maintained.	No modifications to the perimeter site fence or entrance gate will be made.
Parking	No parking will be required for new facility.	
Pedestrian Traffic	Limited to paved roadways, sidewalks are not located between existing facilities.	
PROCESS EQUIPMENT, MOTORS, VALVES, AND ANCILLARIES		
Treatment Process	Pre-oxidation, influent pH adjustment, followed by ligand exchange with granular ferric hydroxide for arsenic removal. Periodic backwash of media with treated water and annual media replacement. Treated water will be dechlorinated to limit adverse effects on microorganisms and remedy performance (see Dechlorination System below).	Design criteria listed below is what is expected from planned pre-purchase bid, but not a guarantee of what equipment will be selected.

TABLE 2
Design Criteria for Arsenic Treatment System
Addendum to Freshwater Pre-injection Treatment System Design Basis Memorandum
PG&E Topock Compressor Station, Needles, California

Subject	Criteria	Comments/Reason
Granular Ferric Hydroxide (GFH) Treatment		
Treatment Objective	Arsenic removal	
Number of Vessels	Three when operating a maximum flow: Three online. Two online when operating at nominal flow;	Three vessels were included in the 90% design instead of four following a value engineering evaluation. Three vessels on-line will meet treatment requirements and have a very small effect on performance because the total downtime during backwashing (i.e., vessel is off-line) is 30 minutes per month (<0.1% of time).
Residence Time	5 minutes empty bed contact time	USEPA guidance.
Vessel Height	10.5 feet overall	
Vessel Diameter	8 feet	4 to 8 gpm/ft^2 hydraulic loading.
Materials of Construction	Low-carbon steel with epoxy lining that is NSF 61 listed.	
Media	Granular ferric hydroxide	Siemens, Severn Trent, or equal
Performance Limits		
Effluent Arsenic Concentration	< 10 µg/L	
Wastewater Volume	9,000 – 18,000 gal/year	
Chlorine Feed System		
Chemical Feed System	One calcium hypochlorite tablet feeder system—HDXLPE (with oxidation resistant liner) mix tank, feed pump, tablet hopper, controller and panel with disconnect. Sized for 0.2 to 2 lbs/hour of chlorine. Three days' minimum tablet capacity.	Feed system located in a containment area.
Safety Equipment	One eyewash and shower unit	Located in chemical storage area.
Coatings/Finishes	Chemical resistant coatings in chemical areas	
Controls	Chemical feed pump speed control	
Sulfuric Acid Feed System		
Chemical Feed System	One 1,000-gallon carbon steel with baked phenolic lining. Desiccant drier installed on vent. Sulfuric acid tank with tank pad. One chemical feed skid with two controllable chemical feed pumps (up to 2 gal/hour)	Tank will be located in a containment area. Monthly fill frequency is the design basis. Solution concentration will be 93%.
Safety Equipment	One eyewash and shower unit	Located in chemical storage area.
Coatings/Finishes	Chemical resistant coatings in chemical areas	
Controls	Chemical feed pump speed control	
Backwash Tank and Treated Water Tank		
Material	Fiberglass Reinforced Plastic (FRP)	
Number	Two	

TABLE 2
Design Criteria for Arsenic Treatment System
Addendum to Freshwater Pre-injection Treatment System Design Basis Memorandum
PG&E Topock Compressor Station, Needles, California

Subject	Criteria	Comments/Reason
Capacity	10,000-gallons tanks	Backwash is anticipated to be just over 7,000 gallons per vessel – 10 minutes of backwashing at 15 gpm/ft^2. Backwash tank will have floating decanter and cone bottom to aid in solids recovery and improve backwash recycle rate. Treated water tank will be flat-bottomed. Both tanks will be equipped with ladders and top access platforms with safety cages and railings.
Dechlorination System		Chemical selected for use in dechlorination is calcium thiosulfate.
Chemical Feed System	Drums or chemical tote compatible with calcium thiosulfate. One chemical feed skid with two controllable chemical feed pumps	Container will be located in a containment area. Monthly fill frequency is the design basis, It is assumed there is sufficient space for this equipment.
Safety Equipment	One eyewash and shower unit	Located in chemical storage area.
Coatings/Finishes	Chemical resistant coatings in chemical areas	
Controls	Chemical feed pump speed control Inline static mixer	
Flow Meters		
Type	Magnetic	
Number	Seven	
Flow Control Strategy	FWPTS will receive raw water from the primary source well (HNWR-1A) into a new freshwater storage tank (10,000 gallons). The secondary sources (HNWR-1 and Site B) may be connected to the pipeline in the future. PG&E is considering augmenting the supply with a gravity flow line from the existing TCS storage tanks only when required.) A booster pump with variable frequency drive will vary the flow through the treatment plant to maintain set point water levels in the treated water tank and prevent pump operating when the remedy freshwater storage tank water levels are below the setpoint. Media vessel inlet control valves equalize flows through each vessel based on flowmeters located downstream of each media vessel.	
Pressure Transmitters	Furnished before/after media vessels.	
Static Mixer		
Number	Two (at the inlet and outlet)	
Diameter	10-inch	
Type	Wafer style with integral injection ports	

TABLE 2
Design Criteria for Arsenic Treatment System
Addendum to Freshwater Pre-injection Treatment System Design Basis Memorandum
PG&E Topock Compressor Station, Needles, California

Subject	Criteria	Comments/Reason
Piping Materials		
Process	HDPE SDR 11 or CPVC Schedule 80, per ASTM D1784, ASTM D1785, and NSF/ANSI 14 and NSF 61 listed	
Treatment Media Vessel Manifold	HDPE SDR 11 or CPVC Schedule 80, per ASTM D178, ASTM D1785, NSF/ANSI 14 and NSF-61 listed	
Potable Water	Buried: Copper, Type K, per ASTM B88 Exposed: Copper, Type L, per ASTM B88 or CPVC Sch. 80	
Process Piping Installation	Major process piping headers will be installed in pipe trenches inside the treatment building and buried outside the building. Media vessel piping will be aboveground. Actuated valves will be installed above grade whenever possible.	
Remedy freshwater storage tank Interface	Inlet from Remedy freshwater storage tank	
YARD PIPING		
Design Criteria	Appendix C, Basis of Design Report (CH2M HILL 2014)	
CORROSION CONTROL		
Design Criteria	Appendix C, Basis of Design Report (CH2M HIL, 2014)	
ARCHITECTURAL/STRUCTURAL		
Building Code	Appendix C, Basis of Design Report (CH2M HILL 2014)	
Building Design Concept	Single building adjacent to Remedy Produced Water Conditioning System	
Building Construction Materials	Appendix C, Basis of Design Report (CH2M HILL 2014)	
Loads	Appendix C, Basis of Design Report (CH2M HILL 2014)	
HVAC		
Codes/Standards	Appendix C, Basis of Design Report (CH2M HILL 2014)	
Design Conditions		
Site Elevation	See Section C.2 Civil, Appendix C, Basis of Design Report (CH2M HILL 2014)	
Cooling Load Basis	Building envelope heat gain and internal heat gains from equipment.	
System Type		
Process Building	A free standing electrical and controls equipment panel will be installed. The panel will have dedicated cooling system.	
PLUMBING		
Lavatory/Toilet Room	No facilities provided.	
Potable Water	Emergency shower/eye wash stations.	Per 2010 California Plumbing Code, and ANSI Z358.1.

TABLE 2
Design Criteria for Arsenic Treatment System
Addendum to Freshwater Pre-injection Treatment System Design Basis Memorandum
PG&E Topock Compressor Station, Needles, California

Subject	Criteria	Comments/Reason
Non-potable Water	The non-potable water supply will have a reduced pressure backflow preventer. Non-potable water will be supplied for wash down water. Wash down hose valves, hoses and hose racks will be furnished in the area as required.	Per 2010 California Plumbing Code.
	ELECTRICAL	
Electrical Load	The electrical load will consist of process pumps, motor operated valves, filter system, control panel and instrumentation, building HVAC, convenience receptacles and interior and exterior lighting. Power distribution will be sized in accordance with NFPA 70 (National Electric Code) to operate process and facility loads. Short-circuit current interrupting capacity of power distribution equipment will be coordinated with existing power distribution system.	.
Service Voltage	480V, 3-phase, 3-wire power will be supplied from XFMR 099	
Utilization Voltage	Appendix C, Basis of Design Report (CH2M HILL 2014)	
Redundancy Requirements	Power distribution system redundancy will be limited to equipment supporting the operation of back-up process and facility equipment (i.e. motor control combination starters, and breakers,). Power distribution system for FWPTS will incorporate spare breakers and fuses. Supporting quick replacement of failed components. Backup power when needed by portable diesel generator located near Remedy Produced Conditioning Building.	.
Manufacturers of Electrical Equipment, Grounding, Lightning Protection, Illumination, Emergency Lights, Stand-by/Backup Power, Raceways, and Duct Banks	Appendix C, Basis of Design Report (CH2M HILL 2014)	
	SECURITY	
Security	None	All security covered through TCS main facility
	CONTROL AND TELEMETRY	
Control and Telemetry Design Criteria	The treatment vessels will be a packaged system with the equipment manufacturer providing a fully configured programmable logic controller based system control panel with panel-mounted operator interface terminal. The control panel will be specified with an uninterruptible power supply to provide true online conditioned power sized to operate the connected load for 30 minutes.	

TABLE 2
Design Criteria for Arsenic Treatment System
Addendum to Freshwater Pre-injection Treatment System Design Basis Memorandum
PG&E Topock Compressor Station, Needles, California

Subject	Criteria	Comments/Reason
Communications, Other Networks, Supervisory Control and Data Acquisition, Instrumentation	Appendix C, Basis of Design Report (CH2M HILL 2014)	
Environmental Requirements	Equipment and instrumentation will be suitable for the following conditions: Air-conditioned Spaces: 10°C to 35°C and a relative humidity of 10 to 80 percent. Non-air-conditioned Spaces: 0°C to 50°C and a relative humidity of 10 to 95 percent. Outdoors: 0°C to 60°C and a relative humidity of 5 to 100 percent.	Environmental controls, such as heaters, fans, and air conditioning will be provided to maintain equipment within the operating conditions recommended by the manufacturer.
Standards/References	Appendix C, Basis of Design Report (CH2M HILL 2014)	

TABLE 3
Major Equipment List
Addendum to Freshwater Pre-injection Treatment System Design Basis Memorandum
PG&E Topock Compressor Station, Needles, California

Quantity	Name	Description
3	Treatment Media Vessels	8-feet-diameter low-carbon steel with epoxy lining (4 - 8 gpm/ft^2 hydraulic loading rate)
1	Hypochlorite Feeder	Calcium hypochlorite tablet feeder: HDXLPE (with oxidation-resistant liner) mix tank, feed pump, tablet hopper, controller, and panel with disconnect
1	Sulfuric Acid Tank	1,000-gallon, (93% sulfuric acid), desiccant drier installed on vent. Baked phenolic lining on steel.
1	Acid Feed System	Pre-engineered skid with two chemical metering pumps for 93% sulfuric acid (0.5 to 2 gph)
1	Dechlorination System	Pre-engineered chemical feed skid to pump calcium thiosulfate, storage tote(s) or tanks, and static mixer. Air-conditioned chemical storage shed will be provided to maintain chemical quality.
2	Pre-and post-treatment Wafer-Style Static Mixers	With integral injection ports
2	Booster Pumps	Centrifugal pump with variable frequency drive
2	Filters skids with replaceable elements	Package unit with differential pressure indication and alarm and flow control valves to divert water to the online filter. Cartridge type
2	Backwash Recycle Pumps	Multistage centrifugal pump
2	Backwash Pumps	Centrifugal pump 755 gpm (15 gpm/ft^2 hydraulic loading rate)

TABLE 4
Mass Balance Table
Addendum to Freshwater Pre-injection Treatment System Design Basis Memorandum
PG&E Topock Compressor Station, Needles, California

Stream # (see Figure 4)	1	2	3	4	5	6	7
Waste Stream	Downstream of the Booster Pumps	To the Media Filters	To the Treated Water Tank	To the Injection Wells	Backwash	Recycle	Liquid Phase Separators in Remedy Produced Water Conditioning Building
Maximum Flow (gpm)	900	900	900	900			
Maximum Flow (ac-ft/Year)	1,452	1,452	1,452	1,452			
Arsenic (mg/L)	0.015	0.015	0.001	0.001	0.001		
Arsenic (lbs/yr)	59.1	59.1					
pH	8.0	6.5	6.5	6.5	6.5		
Chlorine (mg/L)	0	1.15	1.15	1.15	1.15		
Calcium Hypochlorite (lb/year)		6,969					
Sulfuric Acid (mg/L)		40					
Acid (gal/year)		10,297					
Dechlorination Agent (mg/L)					74		
Dechlorination Agent (gal/yr)					2,550		
Wastewater Volume (MG/yr)					0.36	0.344	0.018
Wastewater Volume (ac-ft/yr)					1.11	1.055	0.056
Nominal Flow (gpm)	450	450	450	450			
Nominal Flow (ac-ft/Year)	726	726	726	726			
Arsenic (mg/L)	0.015	0.015	0.001	0.001	0.001		
Arsenic (lbs/yr)	29.5	29.5					
pH	8.0	6.5	6.5	6.5	6.5		
Chlorine (mg/L)	0	1.15	1.15	1.15	1.15		
Calcium Hypochlorite (lb/year)		3,485					
Sulfuric Acid (mg/L)		40					
Acid (gal/year)		5,148					
Dechlorination Agent (mg/L)					74		
Dechlorination Agent (gal/yr)					1275		
Wastewater Volume (MG/yr)					0.18	0.172	0.009
Waste Volume (ac-ft/yr)					0.56	0.528	0.028

CH2MHILL

REUSE OF DOCUMENTS

GROUNDWATER REMEDY PROJECT
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CA

PROCESS

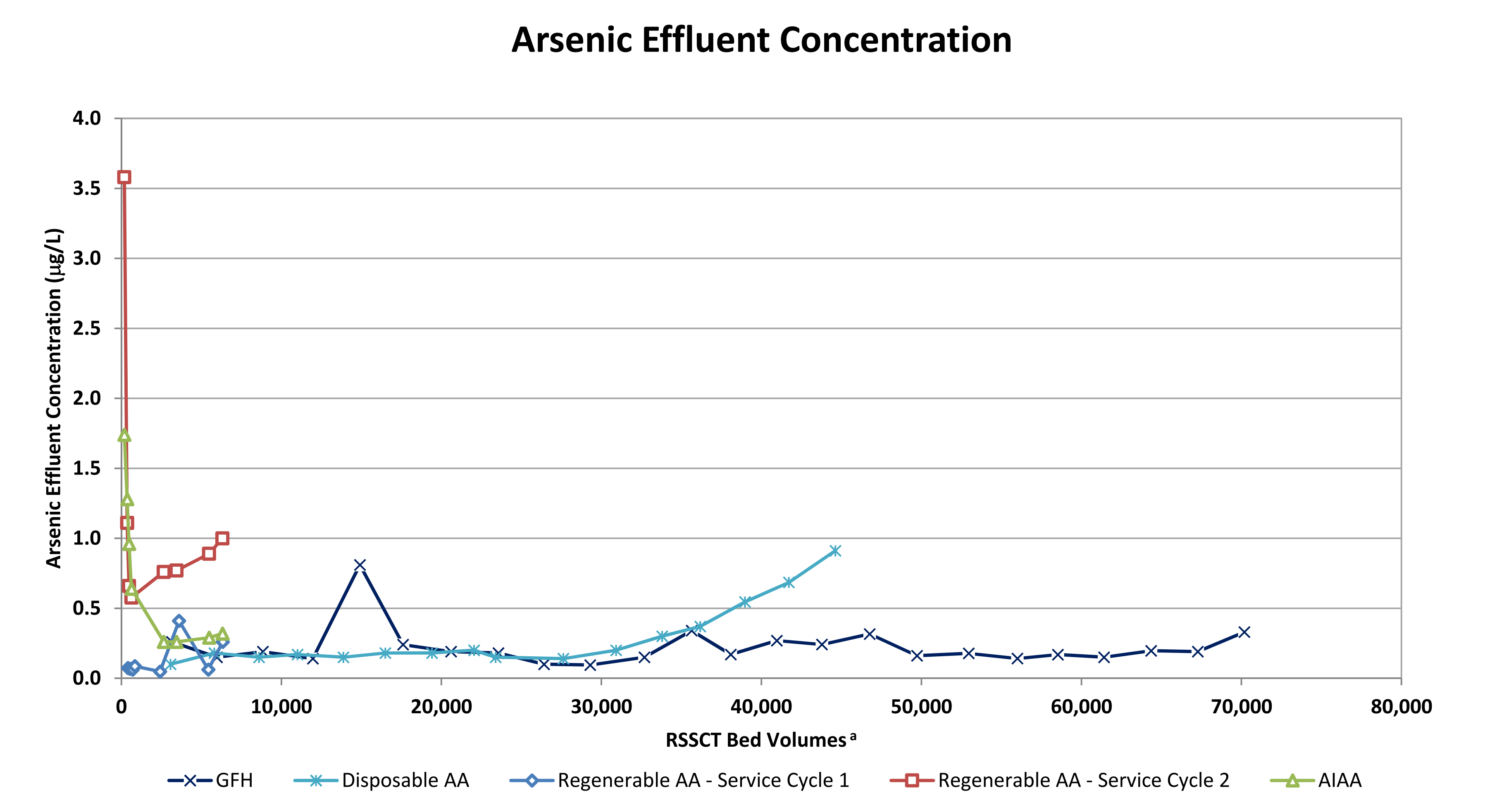
FRESHWATER PRE-INJECTION TREATMENT SYSTEM – MASS BALANCE

SHEET
DWG NO.
DATE 8/21/2014 01:35
REV 1

PRINTED AUGUST 9, 2014 06:39

Figures

FIGURE 1
Arsenic Effluent Concentration versus Bed Volumes
Addendum to Freshwater Pre-injection Treatment System Design Basis Memorandum
PG&E Topock Compressor Station, Needles, California



Notes:
a. One bed-volume is equivalent to the amount of adsorptive media in the column. At maximum flow, this equates to about 289 bed volumes per day.

FIGURE 2

Arsenic Effluent and Adsorption Rate

Addendum to Freshwater Pre-injection Treatment System Design Basis Memorandum

PG&E Topock Compressor Station, Needles, California

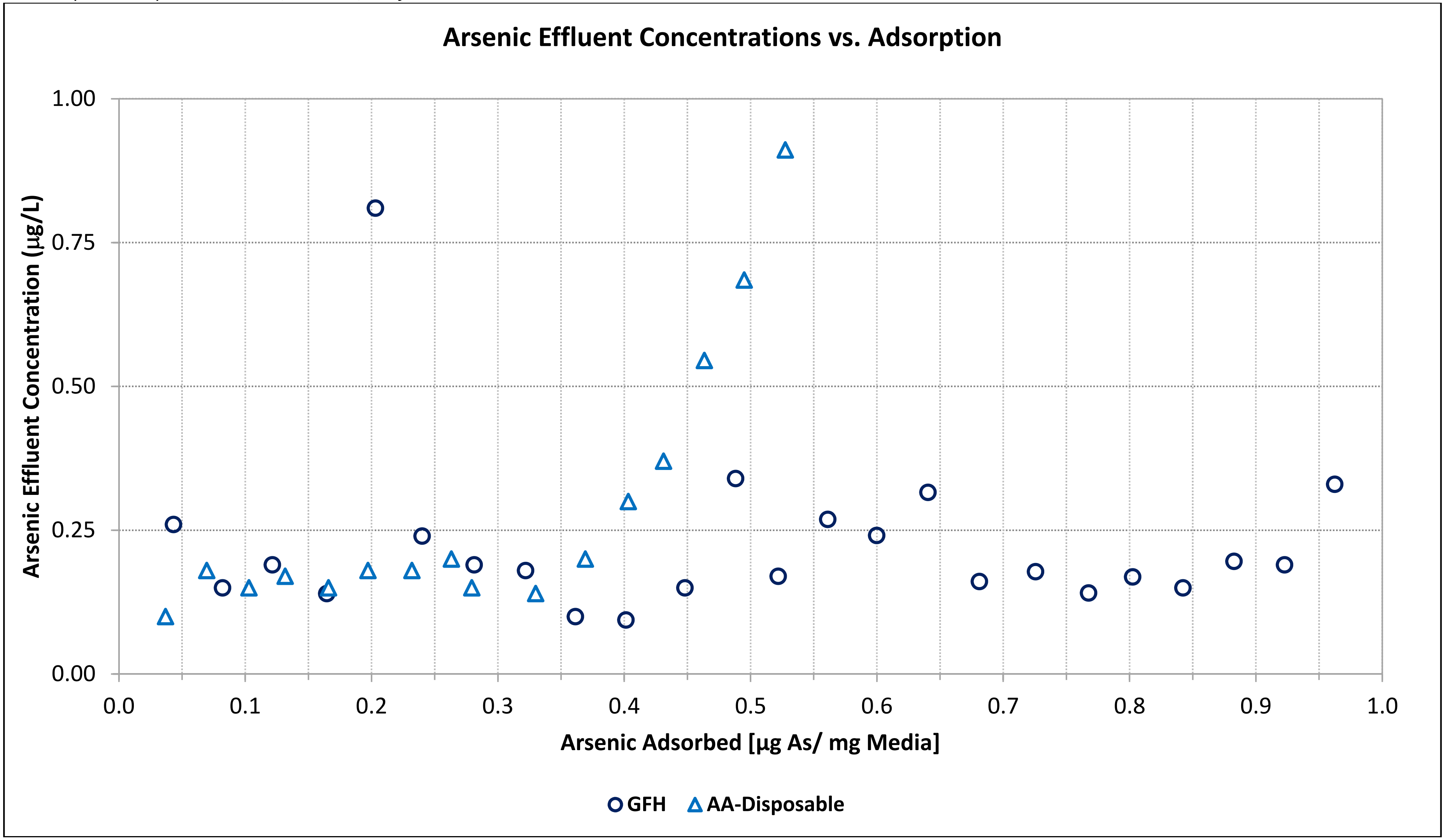


FIGURE 3
Jar Test Results
Addendum to Freshwater Pre-injection Treatment System Design Basis Memorandum
PG&E Topock Compressor Station, Needles, California

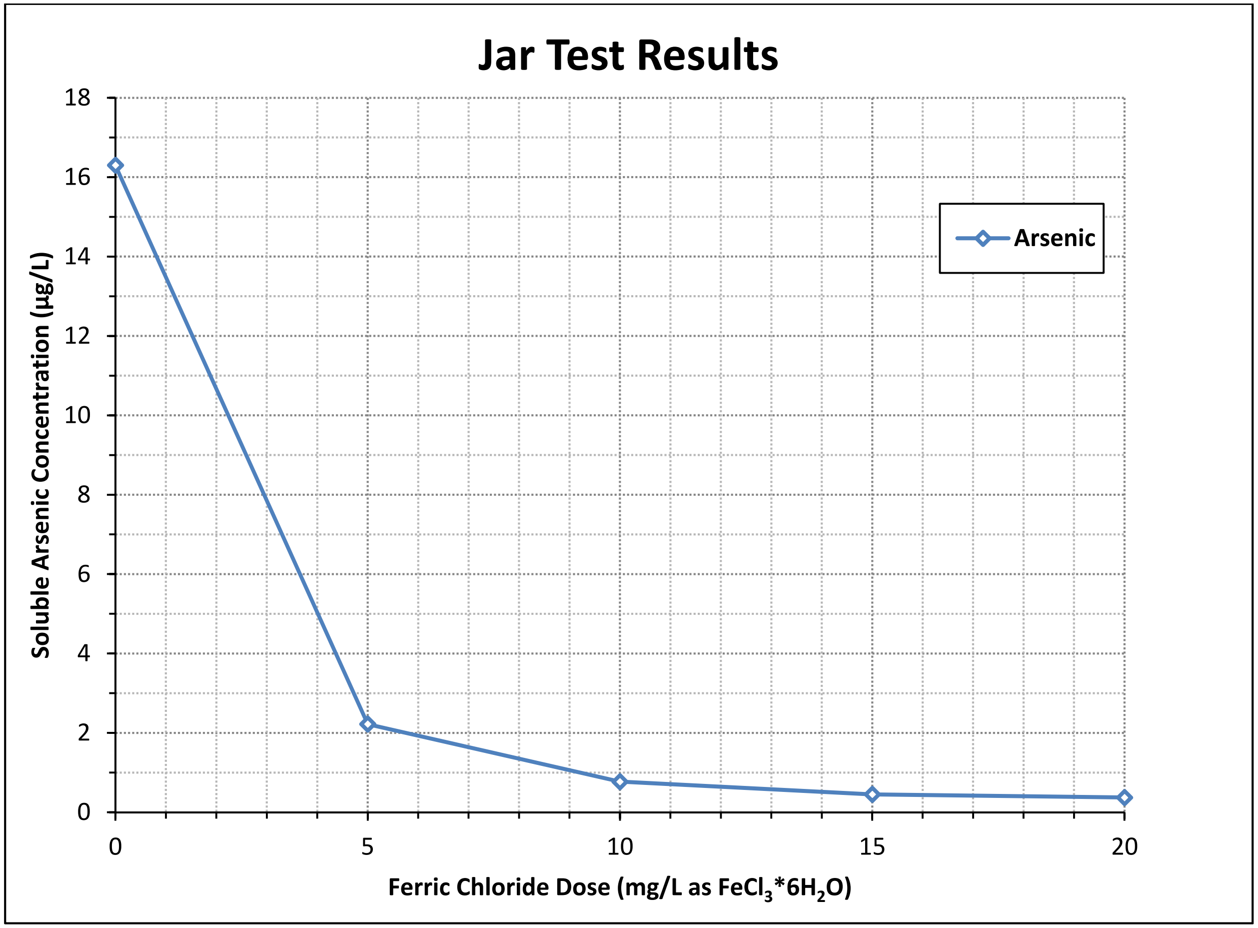
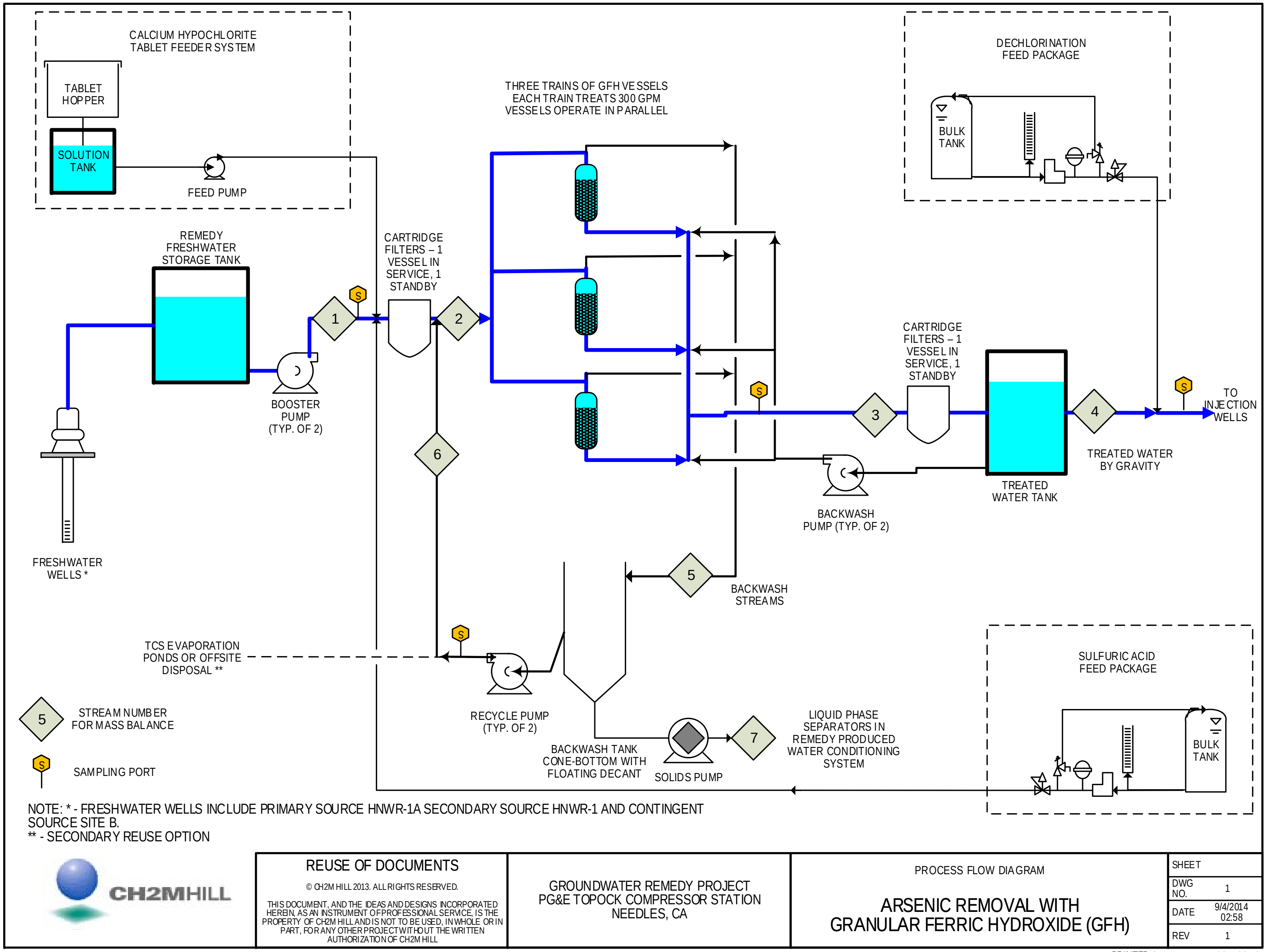


FIGURE 4

Process Flow Diagram

Addendum to Freshwater Pre-injection Treatment System Design Basis Memorandum

PG&E Topock Compressor Station, Needles, California



PRINTED SEPTEMBER 4, 2014 02:49

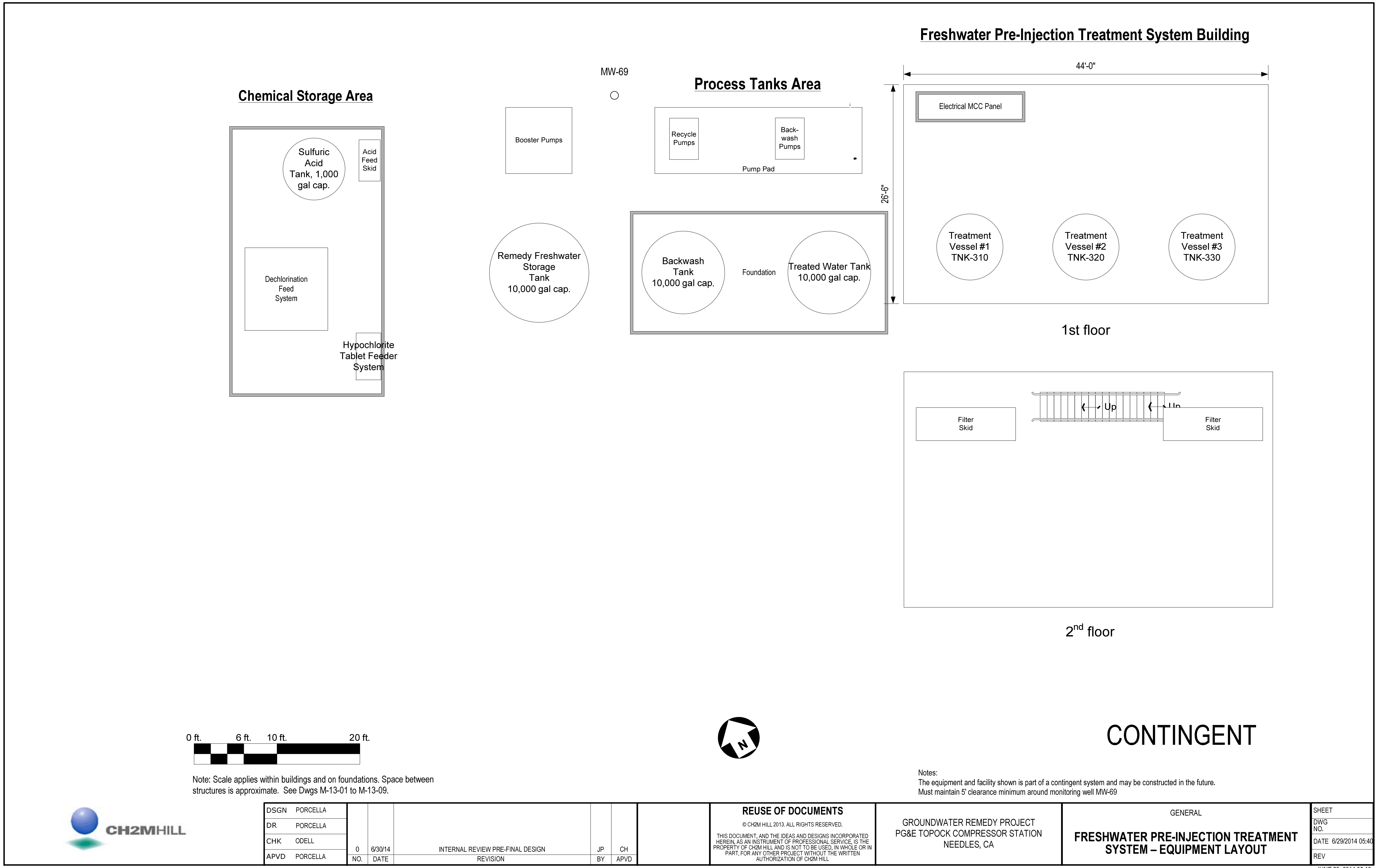
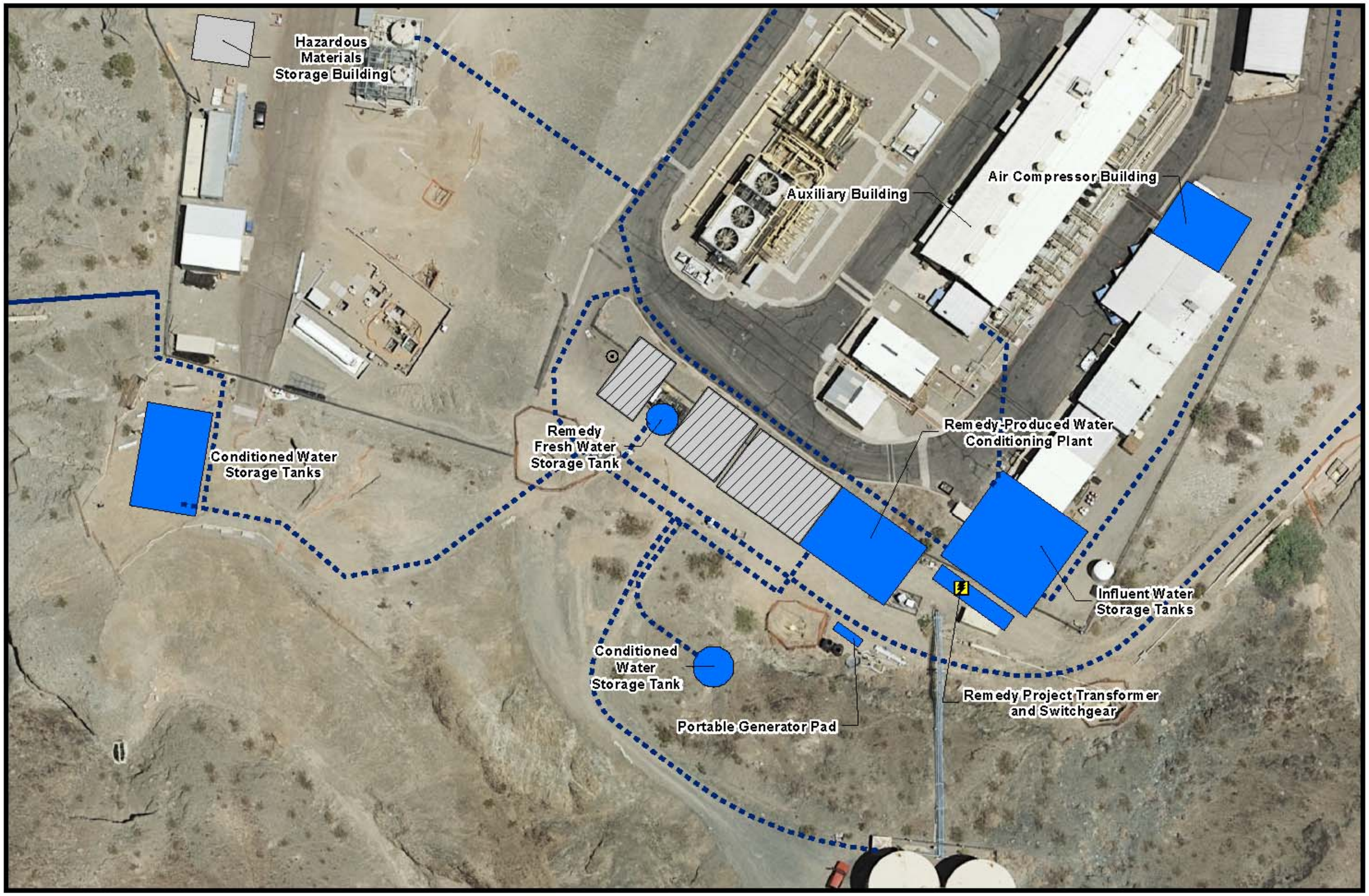


FIGURE 5
Equipment Layout
Addendum to Freshwater Pre-injection Treatment System Design Basis Memorandum
PG&E Topock Compressor Station, Needles, California



LEGEND

Electrical Transformer

Aboveground Pipe

Underground Pipe/Conduit

Proposed Remedy Structure

Contingent Freshwater Pre-injection Treatment System

Note:
All remedy structure locations are approximate.

FIGURE 6
LAYOUT OF CONTINGENT FRESHWATER PRE-INJECTION TREATMENT SYSTEM
ADDENDUM TO THE FRESHWATER PRE-INJECTION TREATMENT SYSTEM DESIGN BASIS MEMORANDUM
PG&E TOPOCK COMPRESSOR STATION,
NEEDLES, CALIFORNIA

FIGURE 6
Site Layout
Addendum to Freshwater Pre-injection Treatment System Design Basis Memorandum
PG&E Topock Compressor Station, Needles, California

Attachment A
Arsenic and Fluoride Treatment Technology Screening

ATTACHMENT A

Arsenic and Fluoride Treatment Technology Screening

As part of the pre-conceptual design work, several treatment technologies were identified and screened to help select an effective and efficient treatment process for two removal processes -- arsenic/fluoride removal and arsenic only removal. After technology identification, the list was screened qualitatively with a more detailed screening was completed on a short list of five technologies. Bench-scale testing was then performed to select the technology to carry forward into design.

A.1 Initial Screening

The United States Environmental Protection Agency, water and wastewater utilities, industrial concerns, research universities and centers, and industry groups have published numerous case studies and reports on testing and performance of these technologies in treating arsenic and fluoride in water (American Water Works Association, 1999; Odell, 2010). The initial list of technologies evaluated for the Topock freshwater pre-injection treatment system was developed from those technologies that have been successfully used by municipalities and industry. Unproven technologies or technologies that have not been used in full-scale applications were not considered in the screening. The initial list included anion exchange, activated alumina (AA), reverse osmosis (RO), electrodialysis reversal (EDR), lime softening, distillation, iron-based adsorbents, titanium-based adsorbents, and coagulation/filtration. The status of selection is summarized in Table A-1.

TABLE A-1
Technologies Considered for Arsenic and Fluoride Removal
Addendum to Freshwater Pre-injection Treatment System Design Basis Memorandum
PG&E Topock Compressor Station, Needles, California

Technology	Status
Anion exchange	Screened out, significant waste generation.
Activated Alumina (AA)	Selected for bench-testing. Primary treatment option is regenerable AA if arsenic and fluoride treatment required.
Titanium-based adsorbents	Screened out, similar as other adsorbents considered, with less experience.
Reverse Osmosis (RO)	Screened out, significant waste generation.
Electrodialysis Reversal (EDR)	Screened out, significant waste generation.
Lime Softening	Screened out, significant waste generation.
Distillation	Screened out, significant energy use and capital cost.
Coagulation Filtration	Screened out, this process does not treat fluoride. If arsenic-only treatment is required, this technology would be screened out due to more residuals are generated, additional chemicals are used, and the process is more complex than iron-based adsorbents. However, it will be retained for bench-scale testing for data collection due to the quick and simple test.
Iron-based Adsorbents	Screened out, this process does not treat fluoride. If arsenic-only treatment required, this process may be used.

A brief process description is provided below.

Anion Exchange. Anions such as fluoride, nitrate, arsenate, selenate, and chromate can be removed from water by using ion exchange with resin. This physical-chemical process involves an easily displaceable ion on the solid phase, exchanging with an unwanted ion in the water that adsorbs to the solid phase. To accomplish the exchange reaction, a packed bed of ion-exchange resin beads is used. Source water is continually passed through the bed in a downflow or upflow mode until the adsorbent is exhausted, as evidenced by the appearance (breakthrough) of the unwanted contaminant at an unacceptable concentration in the effluent.

The most useful ion-exchange reactions are reversible. In the simplest cases, the exhausted bed is regenerated using an excess of the displaceable ion in the form of salt brine. Ideally, no permanent media structural change occurs during the exhaustion/regeneration cycle. This is a proven technology, is widely used, and is easy to automate, but it generates considerable wastewater.

Activated Alumina*.* AA is a semi-crystalline porous inorganic adsorbent, is a proven technology for fluoride removal, and effectively removes arsenic. The removal mechanism, which is one of exchange of contaminant anions for surface hydroxides on the alumina, is generally called adsorption, although ligand exchange is a more appropriate term for the highly specific surface reactions involved. Packed beds of AA are used in water treatment plants in a similar manner to anion exchange. Regeneration is accomplished using a basic solution like sodium hydroxide (caustic). The adsorbent media can be purchased in a disposable form as well. In this case, the spent media is disposed in an offsite facility. This is a proven technology, is widely used, is easy to automate, but it generates considerable wastewater.

Titanium-based adsorbents*.* These are porous adsorbents made with titanium that work similarly to AA in that surface hydroxides exchange with fluoride in the water stream. Similarly, caustic is used to regenerate the adsorbent in the packed beds. This is a newer process with fewer systems in service.

Reverse Osmosis. RO is a membrane water treatment system in which water is pressurized to more than 100 pounds per square inch and is directed through small pores in a synthetic membrane. Treated water is produced through the other side of the small pores while larger particulates are retained on the inlet side of the membrane. RO is effective in removing uranium, radium, arsenic, fluoride, nitrates, microbial contaminants, and many chemicals. Because of the high pressure required for the process, RO systems typically are energy-intensive and have high initial costs. Furthermore, these systems can require more operator attention and can require membrane integrity testing. RO systems also risk fouling and scaling from hard water, colloids, and bacteria. The fouling and scaling increase the pressure drop and result in a shorter lifetime for the membrane or frequent chemical cleaning. In addition, this process generates considerable volumes of wastewater.

Electrodialysis Reversal. EDR is a membrane water treatment process that relies on polarizing electrodes to remove contaminants. The ions in the water are attracted to the membrane by a cathode or anode. Once attracted to the membrane, the ion is transported electrically through the membrane. EDR systems reverse the polarity of the electrodes every 15 to 20 minutes. This process releases accumulated ions and has the following advantages:

- Breaks up scale and reduces the potential for scaling.
- Reduces microbiological growth on the membrane.
- Reduces membrane cleaning frequency.

EDR systems operate at higher pressures than most water treatment systems but not as high as RO systems. They are maintenance intensive and generate considerable volumes of wastewater.

Lime Softening. Hardness in water is characterized by elevated levels of magnesium and calcium. Lime softening removes the hardness by mixing lime (slaked or hydrated) during the treatment process. The lime addition increases the pH of the water and causes the magnesium and calcium to precipitate out. Flocculation and sedimentation units are employed to provide a sufficient time and space to accumulate solids. Magnesium requires a higher pH than calcium to cause precipitation and results in water with a pH as high as 11. Carbon dioxide is used commonly to reduce the pH back to desired levels. This process, although used often, requires careful chemical dosing and process monitoring, requires large amounts of chemicals, and generates large amounts of waste sludge.

Distillation. To distill water, water is heated until boiling and vaporized. The resulting steam is collected and condensed in a clean storage tank. Distillation is effective in removing metals, hardness, and particulates because they do not vaporize with the water. The boiling process also kills bacteria and some viruses. Distillation is ineffective in removing contaminants with a lower boiling point than water, such as benzene. These contaminants must be removed before condensation or recontamination will occur. This process is straightforward to operate but uses high amounts of energy and requires costly metal alloys for construction.

Coagulation Filtration. Coagulation is a process in which smaller particles in suspension attach to one another through electrostatic forces. As the particles attach to one another, larger particles start to form. Aluminum and ferric salts are the most commonly used compounds to enhance coagulation because aluminum or iron hydroxide is formed. Once finished with the coagulation process, the water is filtered through a media filter or microfilter to remove the aggregated particles. Coagulation filtration has been found very effective in removing arsenic from water. While often some form of pretreatment is needed (usually chlorine oxidation), coagulation filtration systems can achieve over a 90 percent reduction in arsenic. However, this process does not treat fluoride. The process is relatively easy to operate.

Iron-based Adsorbents. Contaminated water is passed through a pressure vessel that contains iron based adsorbents that remove arsenic. Granular ferric hydroxide is a common example that is in an amorphous crystalline form. Iron-based adsorbents have been shown effective in removing arsenic (not fluoride) at pH levels normally found in drinking water; however, best performance happens at lower pH levels. Lower pH levels may result in the need for more operator attention and the possibility of handling hazardous chemicals. Once the media has been lost its adsorbent capacity, the spent media is replaced.

A.1.1 Initial Screening Results

As a result of the screening, four technologies were retained for further evaluation:

- AA adsorption – disposal media and regenerable media
- Iron-based adsorbents
- Coagulation/filtration

The following technologies were rejected based on the reasons listed below.

- **Anion exchange, EDR, and RO:** processes generate large residual wastewater streams that must be disposed of.
- **Lime softening:** generates large volume of waste sludge that is difficult and costly to dispose of.
- **Titanium-based adsorbents:** effective at very low pH or with expensive rare earth metals and has the fewest number of operating systems.
- **Distillation:** high cost for energy use.

A.2 Second-level Screening

The two remaining technologies were screened at a second level with AA divided into regenerable and disposable forms. The screening criteria were as follows:

1. Treatment Effectiveness
   - Ability to achieve treatment goals
2. Reliability and Flexibility
   - Ability to allow variation in influent water
   - Expandability

3. Operational Complexity
    - Ease of operation
    - Safety
4. Waste Generation
    - Quantity and quality
5. Footprint
6. Cost Effectiveness

As a result of the screening, anion exchange was not carried forward and was dropped from further consideration because of its lower effectiveness, greater operational complexity, the wastewater volumes generated, and its higher operating cost. The four processes— regenerable AA and disposable AA, iron-based adsorbents, and coagulation/filtration —were advanced to bench-scale testing.

A.3 Bench-scale Testing

As described in the body of the Design Basis Technical Memorandum, bench-scale testing was performed after the technology screening. Testing showed that regenerable AA and iron-based adsorbent were the technologies that best met design needs if both arsenic and fluoride removal, or arsenic removal alone is required Disposable AA was eliminated from further evaluation.

A.4 References

American Water Works Association. 1999. *Water Quality and Treatment - A Handbook of Community Water Supplies*, 5th Edition. Ed. by R.D. Letterman.

Odell, Lee H. 2010. *Treatment Technologies for Groundwater*. American Water Works Association.