Phelps Dodge Sierrita Inc.
6200 W. Duval Mine Road • P. O. Box 527 • Green Valley, AZ 85622-0527
(520) 648-8500

December 22, 2006

CERTIFIED MAIL #7002 1000 0005 6776 4500
RETURN RECEIPT REQUESTED

Mr. Robert Casey
Arizona Department of Environmental Quality
Water Quality Enforcement Unit
1110 West Washington Street
Phoenix, Arizona 85007-2935

Re: Identification of Potential Interim Actions
Phelps Dodge Sierrita, Inc. – Mitigation Order on Consent, Docket No. P-50-06

Dear Mr. Casey:

Phelps Dodge Sierrita, Inc. submits three copies of the attached Interim Action Identification Technical Memorandum. This document was prepared by Hydro Geo Chem, Inc. and Brown and Caldwell as described in Section 4.0 of the Work Plan.

Please do not hesitate to contact Mr. Stuart Brown at (503) 675-5252 or myself at (520) 648-8857 if you have any question regarding this submittal.

Very Truly Yours,

Ned Hall

E. L. (Ned) Hall
Chief Environmental Engineer

Attachment

cc: John Brack, Phelps Dodge Sierrita, Inc.
Chad Fretz, Phelps Dodge Sierrita, Inc.
Ray Lazuk, Phelps Dodge Corporation
Stuart Brown, Bridgewater Group, Inc.

INTERIM ACTION IDENTIFICATION
TECHNICAL MEMORANDUM FOR
MITIGATION ORDER ON CONSENT DOCKET NO. P-50-06
PIMA COUNTY, ARIZONA

Prepared for:

PHELPS DODGE SIERRITA, INC.
6200 West Duval Mine Road
Green Valley, Arizona 85614

Prepared by:

HYDRO GEO CHEM, INC.
51 West Wetmore Road, Suite 101
Tucson, Arizona 85705
(520) 293-1500

December 22, 2006

TABLE OF CONTENTS

TABLE

FIGURE

APPENDIX

1. INTRODUCTION

This technical memorandum identifies potential interim actions to mitigate sulfate in drinking water supplies in the vicinity of the Phelps Dodge Sierrita, Inc. Tailing Impoundment (PDSTI) and describes the process for interim action implementation. The identification of potential interim actions and this memorandum are requirements of the Work Plan for sulfate mitigation (Hydro Geo Chem, Inc. (HGC), 2006a) submitted to and approved by Arizona Department of Environmental Quality pursuant to Mitigation Order on Consent Docket No. P-50-06 (MO). HGC prepared this memorandum under contract to Phelps Dodge Sierrita, Inc. (PDSI).

The MO identifies a mitigation level of 250 milligram per liter (mg/L) sulfate for drinking water supplies. Because the Mitigation Plan will be completed in June 2008, PDSI would implement interim actions before development of the Mitigation Plan if:

(1) the sulfate concentration at the point of use in a drinking water supply exceeds 250 mg/L, or

(2) if data demonstrate that the sulfate concentration at the point of use in a drinking water supply would exceed 250 mg/L before the Mitigation Plan is completed and selected mitigation measures are implemented.

The objective of an interim action is to provide a drinking water supply that meets the 250 mg/L mitigation level. The intent of this technical memorandum is to define a methodology for identifying drinking water supplies that contain or may potentially contain sulfate in excess of 250 mg/L, to identify triggering events for interim actions, and to describe potentially applicable interim actions and how they will be selected and implemented, if needed. This technical memorandum discusses the following aspects of the interim action process:

- Water supply monitoring to determine the sulfate concentration (Section 2)
- Triggers for implementation of interim actions (Section 3)
- Potentially applicable interim actions (Section 4)
- Site-specific factors to be considered in selecting an interim action (Section 5)

PDSI will apply the interim action process to drinking water supply wells and drinking water supplies identified through the well inventory required by the MO (HGC, 2006b), if the source of the sulfate is the PDSTI. The well inventory identified ten (10) drinking water supply wells within one mile downgradient and cross-gradient of the outer edge of the sulfate plume. Figure 1 shows the area of the well inventory and the drinking water supply wells. Table 1 lists the drinking water supply wells. As discussed in the Work Plan, the well inventory area may be adjusted in the future based on new information on the geographic extent of the sulfate plume.

2. WATER SUPPLY MONITORING TO DETERMINE SULFATE CONCENTRATIONS

Section III.D of the MO requires a Mitigation Plan that bases the need for mitigation of a drinking water supply on an "average" sulfate concentration greater than 250 mg/L if the source of the sulfate is the PDSTI. Additionally, the MO indicates that the Mitigation Plan needs verification sampling and analysis to determine the average sulfate concentration, and a process to confirm the source of the sulfate concentrations. These concepts will be used for the interim action process to address any water supplies found to be impacted by sulfate from the PDSTI before development and implementation of the Mitigation Plan.

2.1 Determination of Sulfate Concentrations

Two sulfate concentrations will be used for interim action decisions: the discrete sulfate concentration and the average sulfate concentration. The discrete sulfate concentration of a drinking water supply will be the concentration determined by the analysis of the most recent single sample at a particular location. The average sulfate concentration of a drinking water supply will be the arithmetic mean concentration calculated for the sulfate concentrations of the three most recent discrete samples of the water supply at a particular location. The average sulfate concentration will be a running average recalculated after each subsequent discrete sampling event for follow-up monitoring as described in Section 2.2.

2.2 Sampling Frequency to Determine Sulfate Concentrations

Drinking water supply wells identified by the well inventory are listed in Table 1. The drinking water supply wells consist of a private well operated by a home owner for drinking water use and drinking water supply wells operated by public water providers. A drinking water supply may be either a well that discharges directly into a distribution system or discharges along with other wells into a storage reservoir connected to a distribution system. Water quality samples collected from drinking water supply wells or distribution system storage reservoirs will be used to determine the point of use average sulfate concentration of the drinking water supply at a particular location.

PDSI will sample and analyze drinking water supplies for sulfate concentration free of charge or will work with water providers to collect and share water quality data sufficient to determine the sulfate concentration of the water supply. Drinking water supplies will be characterized by both their discrete and average sulfate concentrations.

Once the initial discrete sulfate concentration for each well is determined, additional sampling for follow-up monitoring will be conducted quarterly if the discrete sulfate concentration is less than 135 mg/L or monthly if the discrete sulfate concentration is between 135 mg/L and 250 mg/L. If the initial discrete sulfate concentration is greater than 250 mg/L, interim action implementation will be triggered. The frequency of follow-up monitoring will be quarterly once the interim action is implemented. The average sulfate concentration will be recalculated after each follow-up monitoring event based on the three most recent discrete samples.

The sampling frequency for water supplies with a discrete sulfate concentration between 135 mg/L and 250 mg/L would be increased to monthly to monitor for any trend in concentration. The sampling frequency for follow-up monitoring is based on the most rapid rate of sulfate increase observed in water supply and monitoring wells. The most rapid rate of increase in sulfate was approximately 38 mg/L per month observed at ESP-1 from November 2005 through July 2006. Rates of increase observed at wells CW-7, CW-8, ESP4, and MH-12 were significantly lower, ranging from approximately 2 to 10 mg/L per month. If the sulfate concentration in a water supply rose by 38 mg/L per month it would take three months to increase from 135 mg/L to 250 mg/L. If sulfate concentrations rose at the slower rate of 10 mg/L per month, it would take more then 11 months for sulfate concentrations to increase from 135 mg/L to 250 mg/L. Thus, the frequency of follow-up monitoring, which is based on a site-specific worst case scenario for the rate of increase of sulfate, would be able to detect an upward trend in the concentration of a water supply in either event.

As described in Section 3, interim action selection and planning will be triggered for a water supply with a discrete sulfate concentration between 135 to 250 mg/L, and interim action implementation will be triggered if the discrete sulfate concentration is 250 mg/L or greater. Potential interim actions are discussed in Section 4.

3. INTERIM ACTION TRIGGERS

Interim action triggers will be based on both the discrete and average sulfate concentrations of the water supply as determined by chemical analysis of water supply samples (Section 2). Types of potential interim actions are generally described in Section 4 and evaluated in detail in Appendix A. Discrete sulfate concentrations that trigger interim actions are as follows:

- If during initial sampling the discrete sulfate concentration of a drinking water supply is found to exceed 250 mg/L, interim action selection and implementation will begin immediately. Upon receipt of the initial results, PDSI may resample the drinking water supply to confirm that the sulfate exceeds 250 mg/L. Interim actions could be implemented in two phases: a first phase action that could be put in place in a matter of days or weeks to provide drinking water with sulfate less than 250 mg/L (e.g., bottled water) and, if needed, a second phase action that might be implemented over a matter of months until the Mitigation Plan is completed and implemented.

- If during the initial sampling the discrete sulfate concentration of a water supply is between 135 mg/L and 250 mg/L, or over time the discrete sulfate concentration increases above 135 mg/L, an interim action will be selected for the water supply based on site-specific conditions, and a plan will be developed to implement the interim action, if possible, before the discrete sulfate concentration at the point of use exceeds 250 mg/L. The decision on if and when to implement the interim action will be based on the rate of increase in sulfate concentrations estimated from monthly follow-up monitoring results. PDSI may resample the drinking water supply to confirm follow-up monitoring results.

- Water supplies with discrete sulfate concentrations less than 135 mg/L will receive water sampling quarterly as follow-up monitoring to track the discrete and average sulfate concentrations.

Any interim action implemented would continue until follow-up monitoring determines that the average sulfate concentration of the drinking water supply is less than the sulfate mitigation level of 250 mg/L based on at least three quarters of follow-up monitoring or until the Mitigation Plan is developed. Follow-up monitoring for ongoing determination of the discrete and average sulfate concentrations of a water supply would be conducted until superseded by the monitoring recommendations of the Mitigation Plan.

Initiating interim actions based on discrete rather than average sulfate concentration means that interim actions would be developed as early as possible in the sampling of a water supply should it exceed the interim action triggers. Basing interim action termination on the average sulfate concentration means the water supply will need to demonstrate sulfate concentrations less than the 250 mg/L mitigation limit for a sustained period of time before the interim action is discontinued.

4. POTENTIALLY APPLICABLE INTERIM ACTIONS

Potentially applicable interim actions were evaluated for the three types of water supply wells that might be in the well inventory area: (1) private domestic wells that serve one or several households, (2) public drinking water supply wells that feed a distribution system without blending, and (3) public drinking water supply wells that feed the distribution system after blending. The potential interim actions include different means of providing alternate water supply, water treatment to remove sulfate, and blending to meet the sulfate mitigation level. An evaluation of potential interim actions to mitigate sulfate in drinking water supplies, including their effectiveness, implementability, and cost, is reported in Appendix A.

As described in Appendix A, potential interim actions include actions that can be implemented relatively quickly to provide a drinking water supply meeting the interim action level for sulfate and actions that have lead times of several months. Examples of actions that could be implemented in a matter of days to weeks include bottled water, point of use treatment, recommissioning wells that are inactive, and blending. Actions that may take months to implement include wellhead treatment and well replacement.

A prescribed interim action cannot be identified in advance due to the multiplicity of alternatives. The specific choice of an alternative for an interim action will be determined upon an evaluation of site-specific conditions. Appendix A describes the full range of potential interim actions that will be considered for implementation at a minimum; however, other actions may be developed and evaluated based on site-specific conditions that cannot be anticipated in advance.

5. SITE-SPECIFIC FACTORS TO BE CONSIDERED IN SELECTING INTERIM ACTIONS

The most appropriate interim action for a water supply will be based on site-specific conditions including factors such as the type of water supply, the number of service connections, distance from potential sources of alternative water, and location with respect to existing infrastructure. If an interim action trigger is exceeded, a team from PDSI will evaluate the water supply to assess the various site-specific engineering factors that influence the selection and cost of an interim action. Appendix A describes the site-specific engineering factors that may be evaluated. The PDSI team will recommend an interim action based on the site-specific evaluation, including discussion with the water supply owner.

A site-specific factor to be considered is the origin of sulfate impacting a water supply. If the sulfate impacting a drinking water supply is not from the PDSTI, then PDSI is not responsible for its mitigation. Hydrogeologic flow path analysis and hydrochemical analysis of water quality may be used on a case by case basis to show whether the sulfate in wells peripheral to the sulfate plume is likely derived from the PDSTI. As discussed in the Work Plan (HGC, 2006a) there are areas of potentially elevated sulfate in groundwater due to ambient or background conditions unrelated to the PDSTI; such as in the vicinity of the Santa Cruz River and the Twin Buttes Mine. In some instances, therefore, the source of sulfate in a water supply may be uncertain. A site-specific hydrogeologic and water quality analysis will be conducted for any water supply found to be impacted by sulfate in a location where the PDSTI may not be the likely source. The purpose of the hydrogeologic and water quality analysis will be to assess whether sulfate in a water supply is due to the PDSTI.

6. REFERENCES

Hydro Geo Chem, Inc. (HGC). 2006a. Work Plan to Characterize and Mitigate Sulfate with Respect to Drinking Water Supplies in the Vicinity of the Phelps Dodge Sierrita Tailing Impoundment, Pima County Arizona. August 11, 2006. Revised October 31, 2006.

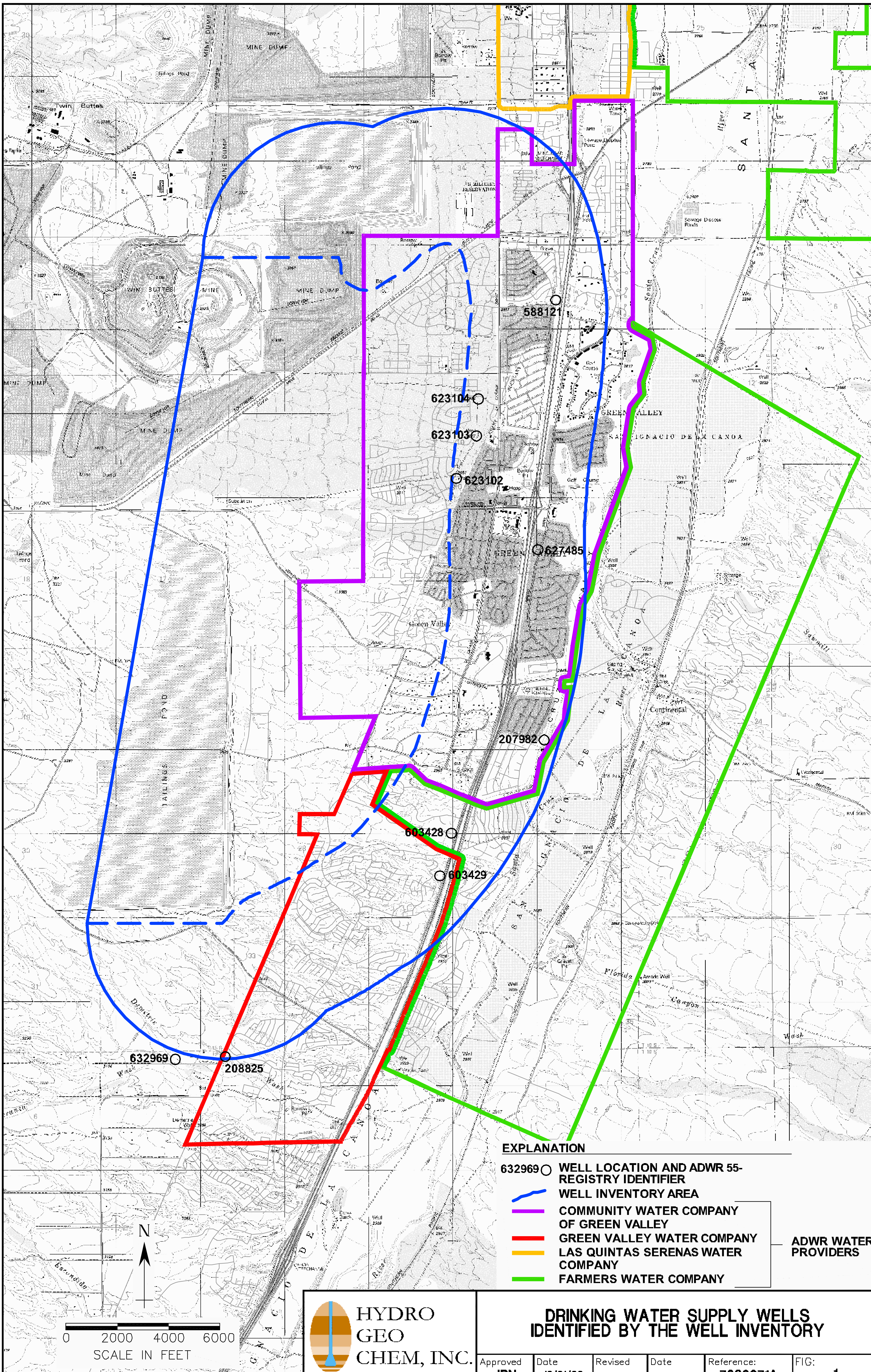
HGC. 2006b. Well Inventory Report Task 1 of Aquifer Characterization Plan for Mitigation Order on Consent No. P-50-06. December 20, 2006.

TABLE

TABLE 1
Drinking Water Supply Wells Identified by the Well Inventory

Owner/Operator	ADWR 55-Registry No.	Well Name
Community Water Company (CWC)	207982	CW-10
	588121	CW-9
	627485	CW-6
Gatterer, A.H. (Private Domestic)	632969	Gatterer
Green Valley Domestic Water Improvement District (GVDWID)	208825	SI
	603428	GV-1
	603429	GV-2
Phelps Dodge Sierrita, Inc.	623102	ESP-1
	623103	ESP-2
	623104	ESP-3

FIGURE



HYDRO GEO CHEM, INC.

DRINKING WATER SUPPLY WELLS IDENTIFIED BY THE WELL INVENTORY

Approved	Date	Revised	Date	Reference:	FIG:
JRN	12/21/06			7830071A	1

APPENDIX A

EVALUATION OF POTENTIAL INTERIM ACTIONS TO MITIGATE SULFATE IN DRINKING WATER SUPPLIES IN THE VICINITY OF THE PHELPS DODGE SIERRITA TAILINGS IMPOUNDMENT

201 North Civic Drive, Suite 115
Walnut Creek, California 94596-3864

Tel: (925) 937-9010
Fax: (925) 937-9026

BROWN AND CALDWELL

December 21, 2006

Mr. John Brack
General Manager
Phelps Dodge Sierrita, Inc.
6200 West Duval Mine Road
Green Valley, Arizona 85614 1011.131099-002/3

Subject: Evaluation of Potential Interim Actions to Mitigate Sulfate in Drinking Water Supplies in the Vicinity of the Phelps Dodge Sierrita Tailings Impoundment

Dear Mr. Brack:

As requested, Brown and Caldwell has evaluated potential interim actions that could be used to mitigate sulfate in drinking water supplies in the vicinity of the Phelps Dodge Sierrita Tailings Impoundment (PDSTI) before the Mitigation Plan is completed in accordance with Mitigation Order on Consent, Docket No. P-50-06 (MO). This technical memorandum presents our evaluation.

BACKGROUND

Groundwater in the vicinity of the PDSTI has been found to contain concentrations of sulfate that exceed 250 milligrams per liter (mg/L), the Secondary Maximum Contaminant Level (SMCL) for sulfate. Public water supply systems and private wells use groundwater as a source of drinking water supply downgradient of the PDSTI. The MO between Phelps Dodge Sierrita, Inc. (PDSI) and the Arizona Department of Environmental Quality (ADEQ) requires a Mitigation Plan to identify and evaluate alternatives to provide drinking water with an average sulfate concentration less than 250 mg/L.

PDSI submitted a "Work Plan to Characterize and Mitigate Sulfate with Respect to Drinking Water Supplies in the Vicinity of the Phelps Dodge Sierrita Tailings Impoundment, Pima County, Arizona" on August 11, 2006. This Work Plan stated that PDSI will conduct a Feasibility Study to identify and evaluate mitigation alternatives that can be incorporated into the Mitigation Plan. PDSI incorporated a task to identify potential interim actions that could be implemented while the Mitigation Plan was being developed should: (1) the average sulfate concentration at a point of use in a drinking water supply exceed 250 mg/L; or (2) if data demonstrate that the average sulfate concentration at a point of use in a drinking water supply will exceed 250 mg/L before the Mitigation Plan is completed. This task was voluntarily added by PDSI; it was not identified as a required work element in the ADEQ MO. This document presents Brown and Caldwell's identification and evaluation of potential interim actions.

POTENTIAL TYPES OF DRINKING WATER SUPPLIES

Brown and Caldwell evaluated potential interim actions for three types of drinking water supplies identified through a preliminary well inventory for the study area:[1]

1. Private wells
2. Public drinking water supply wells feeding a distribution system directly, i.e., without being blended with water from other sources
3. Public drinking water supply wells blended with water from other sources and then fed to a distribution system.

We made the distinction between the second and third types of drinking water supplies, because the third has additional response actions.

GENERAL RESPONSE ACTIONS EVALUATED

Brown and Caldwell evaluated the following mitigation strategies or general response actions, which are consistent with the mitigation actions allowed under Arizona Revised Statute Section 49-286:

- Providing an alternative water supply
- Economically and technically practicable treatment before ingesting the water
- Mixing or blending if economically practicable.

The first two general response actions – providing an alternative water supply and treatment – have a range of process options and technologies. Table 1 lists these process options and technologies and their applicability to each of the three potential types of drinking water supplies. These process options and technologies are evaluated in depth in the next sections.

[1] In accordance with the work plan, PDSI is conducting a parallel task to identify all wells within one mile downgradient and cross-gradient of the sulfate plume, as defined by a sulfate concentration in groundwater of 250 mg/L.

OPTIONS FOR MITIGATING EFFECTS TO PRIVATE WELLS

Table 1 provides the initial screening of the mitigation options for private wells.

Ion exchange (IX) was eliminated in the initial screening, because home units would not achieve the total dissolved solids (TDS) SMCL of 500 mg/L. Furthermore, IX would replace sulfate with chloride, potentially increasing the chloride concentration above its SMCL of 250 mg/L. Industrial IX systems that remove sulfate, TDS and chloride would not be feasible for treating water from private wells because of the hazardous chemicals and special training required.

Well-head membrane treatment was also eliminated. The only difference between it and full-house reverse osmosis, which passed the initial screening, is that a well-head system would provide low-sulfate water for irrigation, which is not necessary. In addition, well-head treatment using a home system would waste a tremendous amount of water. A more efficient commercial system would be too complicated for a private well owner to operate and maintain.

Table 2 summarizes the effectiveness, implementability and cost of options passing the initial screening for mitigating the effects to private wells. The options fall under two strategies: providing an alternative water supply and treating the water to remove sulfate.

Alternative Water Supply

Four process options were evaluated for providing an alternative water supply.

Modify Well to Eliminate Pumping from Sulfate-Containing Strata. The predominant aquifer materials intersected by wells in Green Valley are sand and gravel. Existing private wells are typically between 500 feet (ft) and 1,000 ft deep. Typical groundwater depth in the area is 300 ft to 500 ft below ground surface.

If groundwater in a particular portion of the aquifer contained less than 250 mg/L sulfate, the well could potentially be modified to pump only from the strata containing less sulfate by sealing the well screen from the sulfate-containing strata. If the entire screened zone produced water containing more than 250 mg/L sulfate, the well could potentially be deepened to find water with less sulfate.

The ability to utilize well modifications would be based on the distribution of sulfate within the screened interval of the well and site-specific well construction details. The vertical distribution of sulfate would need to be delineated by depth-specific sampling. If sulfate entered the well through a discrete interval, flow from the interval might be minimized or excluded by changing pump elevation, placing a swedge over the interval or packing off the interval. Based on Brown and Caldwell's past experience and discussions with drilling companies, attempts to block a section of screened zone are difficult to accomplish, present a risk of damage to the well, and may not result in meeting the numeric objective for the well depending on the relative effectiveness of the seal and the future vertical distribution of sulfate. For these reasons, election of well modification would have to be evaluated on a case-by-case basis.

Replace Well. Instead of modifying a well, it could be replaced with one screened over a different depth interval or intervals and/or constructed at a different location. The well would have to be designed, permitted, drilled and developed. This process would take 6 months to 12 months. Brown and Caldwell estimates the cost of a new private well at $120,000, as shown in Table 3.

Installing a new private well at the same depth but at a new location on the same property might not be effective, because it might not be possible to install the well beyond the boundary of the plume. Moreover, the user of this well water is currently connected by pipe to the well at the present location. This piping might have to be extended to the new well location. There would be a trade-off between locating the new well far enough to move away from sulfate-containing groundwater and keeping it close to minimize the piping needed. Installing a new well at the same location but screening it over a different depth interval or intervals might be more feasible.

Connect to Alternative Water Supply. The use of water from an affected well for drinking could be discontinued, and the water user could be connected to an alternative water supply such as a public drinking water distribution system or another well. The well could be also used for other purposes (e.g., irrigation) after providing the user with an alternative drinking water supply. If the distance were relatively short (500 ft or less), connection to the distribution system might not be difficult. Connection would require installation of a dedicated, underground pipe; a water meter and a cut-off valve. Depending on permits involved and availability of installers, this option could take 1 month to 4 months.

The ease and cost of installation depends on the terrain through which a pipe would be laid. Brown and Caldwell estimates a minimum cost of $2,500, assuming a pipe length of approximately 200 ft. However, if asphalt or concrete had to be cut and replaced for the piping, the cost would be significantly higher. This cost does not include the monthly water service fee.

Provide Bottled Water. Household water providers are available in the area that could deliver bottled water to homes. Delivery could be implemented quickly, but it would only be feasible to provide enough water for drinking and, possibly, for cooking. Other household water demands, such as bathing and irrigation, would have to continue to be met by well water. The implementation time for this option is very short (a few days).

Using data provided by DS Waters of America, the parent of Sparkletts, we estimated that bottled water for drinking purposes only would cost approximately $35 per home per month, including the dispenser rental cost. This cost is based on three, 5-gallon bottles per month. These bottles are heavy (over 40 pounds each), so 3-gallon bottles would be needed by some homeowners. The monthly charge for five, 3-gallon bottles plus a dispenser is approximately $41 per home per month. If bottled water were provided for both drinking and cooking, we estimate the volume of water required would triple, raising the average cost to approximately $110 per home per month. Thus, the cost of providing bottled water to a private well owner for 2 years would be approximately $1,000 to $3,000. These costs are detailed in Appendix A.

Treatment for Sulfate Removal

Two options were evaluated to treat water from a private well and reduce its sulfate concentration. These options involve reverse osmosis (RO), a membrane process that separates dissolved solids from water. RO produces two streams: a permeate, which has very low levels of sulfate and other dissolved solids, that could be used for drinking water; and a concentrate that contains most of the dissolved solids and would need to be disposed as a waste. RO systems are rated on their recovery, which is the percentage of water that becomes permeate. Large, high pressure systems have a recovery of 80 percent or higher. Often, pretreatment is needed to achieve this high recovery. Small systems, which have no pretreatment and operate at low pressure, have a recovery of 50 to 60 percent.

Point-of-Use Reverse Osmosis. A point-of-use system is one that is installed directly adjacent to a water outlet. Well water containing more than 250 mg/L sulfate could be treated with a point-of-use RO system installed in the user's kitchen. It would provide low-sulfate water for drinking and cooking but not for other uses such as bathing or irrigation. The typical permeate production for these units is 10 gallons per day.

The water wastage of point-of-use RO systems is high, because the recovery is only 50 to 60 percent. Thus, for every gallon of permeate produced, 1.6 gallons to 2 gallons must be pumped. The remaining 0.6 gallons to 1 gallon is discharged to the drain. Since the volume of wastage (approximately 10 gallons per day) is relatively small, we have assumed that the well has enough pumping capacity to overcome the wastage. The additional pumping energy cost would be negligible.

Implementation of this option would be fairly rapid: one or two weeks. The capital cost would be approximately $500 to $800 installed per home.[2] Annual operating and maintenance (O&M) costs would be up to $1,000 per home for RO supplies (cartridge

---

[2] All costs shown in this report are for a single unit without redundancy.

replacement). Thus, the cost of a point-of-use RO system over 2 years would be approximately $3,000 per home. Details of this estimate are shown in Appendix A.

Full-House RO. Unlike a point-of-use RO system, which could only treat enough water for drinking and cooking, a full house RO system could produce enough water to meet all household demands. These units are much larger, with a capacity of 500 gallons per day. All water used in the house would be low in sulfate. Typically, outside uses such as irrigation would continue to receive untreated water.

As with point-of-use RO units, full-house RO systems have a very low recovery (typically 50 percent, so one gallon of water is wasted for each gallon of permeate produced). The high wastage rate could put an increased demand on the house's septic system and it would increase power requirements for the well. It would only be feasible if the well had significant excess capacity, since half the water pumped from the well would be wasted.

Implementation of this option would take about 1 month. The cost would be approximately $12,000 installed per home. Annual maintenance costs would be about $1,000 per home for RO supplies. The cost of providing full-house RO water over a period of 2 years would be approximately $14,000 per home. This estimate does not include the additional costs for the increased pumping energy and, potentially, for the additional strain on the septic system.

OPTIONS FOR MITIGATING EFFECTS TO DRINKING WATER SUPPLY WELLS FEEDING A DISTRIBUTION SYSTEM WITHOUT BLENDING

Table 1 provides the initial screening for mitigation options in this section. As with private wells, IX was eliminated in the initial screening. IX systems that removed only sulfate might produce water that did not meet the SMCLs for TDS and chloride. Industrial demineralization systems would be effective and could be implemented at a well head, but, because of the high sulfate and TDS concentrations, they would not be cost-competitive when compared with RO. Also, large volumes of regenerant wastes requiring disposal would be produced.

Table 4 summarizes the effectiveness, implementability and cost of options that passed the initial screening for mitigating the effects to drinking water supply wells feeding a water distribution system without blending. As with private wells, the options fall under two strategies: providing an alternative water supply and treating the water to remove sulfate.

Another option, not shown in Table 4, would be to convey the well water to a storage tank or reservoir where it could be blended with water containing lower sulfate concentrations from other wells. This option would have to be evaluated on a case-by-case basis. Its feasibility depends on the presence and proximity of other wells producing water with less sulfate, and the distance and accessibility to an existing storage tank or potential to construct a new storage tank.

Alternative Water Supply

Three options were evaluated for providing an alternative water supply.

Modify Well to Eliminate Pumping from Sulfate-Containing Strata. Existing water supply wells around Green Valley are between 800 ft and 1,300 ft deep. Typical groundwater depth in the area is 300 ft to 500 ft below ground surface.

As previously discussed, the feasibility of well modification would have to be evaluated on a case-by-case basis.

Replace Well. The well could be replaced with one screened at over a different depth interval or intervals or at a different location. Replacement would take 12 months to 18 months. Brown and Caldwell estimates the cost of a new, 1,300-ft deep water supply well at $2.8 million. This cost would increase to $4.0 million if the new well required arsenic treatment (Table 5).

Recommission the Esperanza Wells. There are four existing Esperanza wells, of which three are currently used by Community Water Company (CWC) for domestic water supply. Their capacities are as follows:

- Esperanza No. 1 – 850 gpm
- Esperanza No. 2 – 800 gpm
- Esperanza No. 3 – 1,025 gpm.

PDSI owns these wells but is providing their water to CWC until June 2007. A new well, CWC No. 10 (2,400 gpm), went online in December 2006, and CWC No. 11 (2,500 gpm) will go online in the first half of 2007. We expect that the Esperanza wells will be available for other potential water supply applications once these two wells are in service.

However, in the event that a CWC well subsequently becomes affected by sulfate, after CWC No. 11 is online, the Esperanza wells could be recommissioned as an interim action. The Esperanza wells could be operated as they are currently, pumping water to a common reservoir (the “Sand Tank”) for blending and then to a CWC reservoir before entering the distribution system. Esperanza No. 1 is currently producing water with greater than 250 mg/L sulfate, but the other two wells have significantly lower sulfate concentrations (in the range of 30 mg/L to 60 mg/L). The blended water from the sand tank has had sulfate concentrations consistently well below the 250 mg/L SMCL. Therefore, this option would be effective.

This option could be implemented immediately with virtually no cost besides O&M on the pumps. There would be no additional costs for planning, design or construction.

Provide Bottled Water. If the affected well had to be kept in service to meet demands for landscaping and firefighting or to maintain the system pressure, bottled water could be provided to the homes receiving this water. It would only be feasible to provide enough water for drinking and, possibly, also for cooking. Because of the potentially large number of homes affected, the implementation time would be longer than for a single private well. Brown and Caldwell estimates an implementation time of 2 weeks to 4 weeks.

As discussed above, the cost for bottled water would be the same as discussed above, approximately $35 to $41 per home per month, including the dispenser rental cost, if water were provided for drinking only. If bottled water were provided for both drinking and cooking, we estimate the average cost at approximately $110 per home, per month. These costs are detailed in Appendix A. The cost for 2 years would be approximately $1,000 to $3,000 per home. The cost would be higher for institutions such as schools and hospitals that use more water.

Treatment for Sulfate Removal

Three options involving water treatment were evaluated for water from wells feeding a domestic water system. Some involve systems in individual homes, while others involve well-head treatment.

Point-of-Use RO. This option was previously described. It would provide water for drinking and cooking only. The implementation time would be lengthy (several months) to install thousands of individual units. The cost would be approximately $3,000 per home over 2 years.

Full-House RO. This option was also previously described. It would provide enough water to meet all household demands. However, due to the low recovery (approximately 50 percent), the pumping rate of the well would have to be increased substantially. Alternatively, increased supply would need to be obtained from another unaffected source. This option would greatly increase the amount of domestic wastewater to be treated.

The implementation time would be several months. The cost would be approximately $14,000 per home over 2 years.

Well-head Membrane Treatment. Rather than installing individual RO systems in homes, a single membrane system could be installed adjacent to the affected well. Brown and Caldwell evaluated three types of commercially available membrane systems:

- RO, which removes all ions and silica
- Nanofiltration (NF), which generally removes sulfate and other large ions but lets chloride and other monovalent ions pass
- Electrodialysis Reversal (EDR), which removes all ions but not silica so, it can have a higher recovery than RO.

GE, a leading supplier of membrane systems for water, provided information on the application of these technologies to Green Valley groundwater. Table 6 shows GE's projected recovery for each system in each of three water types. Water quality data used in this analysis were developed by PDSI from wells affected by the plume. GE predicted that RO and NF would have similar recovery percentages, because they would be limited by concentration of gypsum (calcium sulfate). The concentrations of calcium and sulfate ions would increase on the concentrate side of an RO or NF membrane. Gypsum would precipitate when the concentrations exceeded saturation. Precipitation could be reduced using specialty chemicals (antiscalents), but eventually precipitates would form and scale the membrane. To prevent scaling, the system would have to be operated below the effective gypsum precipitation point. EDR would have a higher recovery because of its inherent ability to resist fouling by passing silica.

Designing, manufacturing and installing a well-head RO or NF system would take at least 12 months. The time estimate would be double for EDR. Consequently, EDR was discarded as a feasible option for interim action, and RO and NF were retained. The selection of RO versus NF would be made at the stage of actual design. At the current level of analysis, the differences are negligible, since they use similar process components. NF might perform somewhat better since it passes the monovalent ions, such as chloride and sodium, so its operating pressure would be lower. RO would retain virtually all ions, including chloride and sodium, so the RO system pump would have to work against a higher osmotic pressure. This pressure is a function of difference between ionic concentrations across the membrane (i.e., between the permeate and concentrate). At a higher osmotic pressure, a higher pressure would be required to generate permeate across the membrane, so power costs would be higher. However, NF-treated water might have excessive TDS, and NF membranes cost more than RO membranes, so it is difficult at this stage of analysis to determine the relative economics.

Maximizing the recovery is critical in a system of this size. GE predicted that RO would have a recovery of 58 percent to 81 percent (Table 6). Thus, a 1,000-gallon per minute (gpm) well-head RO system will produce 190 gpm to 420 gpm concentrate (270,000 gallons per day to 600,000 gallons per day). For the same well, an EDR system would generate 110 gpm to 250 gpm concentrate (160,000 gallons per day to 360,000 gallons per day).

Capital costs are in the $2 million to $3.5 million range, depending on water quality (Table 7). Appendix B contains the development of these costs. Operating costs are approximately $0.4 to $0.6 per 1,000 gallons treated (Table 8), not including concentrate and cleaning waste disposal. A 1,000-gpm system would cost approximately $22,000 per month to operate. Over 2 years, the cost to purchase, install and operate a 1,000-gpm RO system treating water containing 570 mg/L sulfate would be approximately $2.3 million. An NF system would have approximately the same cost, while an EDR system would cost $3.1 million. These estimates do not include costs for disposal of concentrate and cleaning wastes. Costs would be higher if the water to be treated were more highly concentrated.

A system could be operational in about 3 months if rental RO systems were used. Rental units are available from several vendors. GE provided cost information to Brown and Caldwell. The initial cost to provide a system to treat 1,000 gpm would be approximately $290,000 (Table 9). The operating cost would be about $130,000 per month. The total cost would be about $3.4 million over 2 years, not including costs for disposal of concentrate and cleaning wastes, which are discussed in a later section.

OPTIONS FOR MITIGATING EFFECTS TO DRINKING WATER SUPPLY WELLS FEEDING A DISTRIBUTION SYSTEM AFTER BLENDING

The third type of drinking water supply considered was a drinking water supply well feeding a distribution system after blending. Water from the well is mixed with water from other sources before it enters the distribution system for use.

Each option considered for a well feeding a distribution system directly – well modification or replacement, recommissioning the Esperanza wells, bottled water, and membrane treatment systems – is equally applicable for this type of drinking water supply. Table 1 shows the initial screening, and Table 10 shows further analysis of retained options.

Another option, effective due to pre-distribution blending, is the management of the production wells to keep the blended sulfate concentration below 250 mg/L. This option would require monitoring of pumping rates and sulfate concentrations in each well discharging to a tank or reservoir feeding the distribution system. A mass balance would show whether the blended water contains less than 250 mg/L sulfate.

Blending is explained using the following example. Three sources of water with assumed flows of Q_1, Q_2, and Q_3 and sulfate concentrations C_1, C_2, and C_3, respectively, are available for mixing in a reservoir:

Q_1 = 1,000 gpm, C_1 = 100 mg/L of sulfate
Q_2 = 800 gpm, C_2 = 400 mg/L of sulfate
Q_3 = 500 gpm C_3 = 150 mg/L of sulfate.

The sulfate concentration in a blend of these three water sources can be computed with the following mass balance equation:

$$C_{blended} = \frac{Q_1C_1 + Q_2C_2 + Q_3C_3}{Q_1 + Q_2 + Q_3}$$

$$= \frac{(1{,}000 * 100) + (800 * 400) + (500 * 150)}{(1{,}000 + 800 + 500)}$$

=215 mg/L sulfate.

Ideally, a system would continuously measure the flow rate and sulfate concentration in each water source, perform the mass balance calculation, and adjust pumping rates as needed to maintain the desired concentration in the blended water. However, there is no online method for sulfate analysis, and field test kits use a method prone to interferences, so a laboratory instrument must be used. Therefore, for blending to be effective, the following conditions must be met:

- There should be sufficient water at low sulfate concentration feeding the reservoir such that the blended water sulfate concentration is less than 250 mg/L with the largest pump out of service.

- The system should be operated using a safety factor based on the rate at which sulfate concentration changes over time and the amount of time required to collect and analyze a sample.

MEMBRANE CONCENTRATE DISPOSAL

Any membrane system – RO, NF, or EDR – would produce a concentrate requiring disposal. Point-of-use and full-house RO systems could discharge their concentrates to the sewer or septic system, because the concentrates would be fairly dilute. At a recovery of 50 percent, the waste would have double the sulfate concentration as the untreated water.

In contrast, well-head systems would generate a much more highly concentrated waste. A 1,000-gpm system at 80 percent recovery would produce nearly 300,000 gallons per day of waste with five times the original sulfate concentration. Other constituents would be similarly concentrated. These characteristics of the concentrate and its volume pose special disposal challenges.

Brown and Caldwell evaluated eight options for concentrate disposal (Table 11). Cost estimates were prepared for options considered feasible.

Discharge to Sanitary Sewer

In many parts of the country, RO concentrate is discharged to the sanitary sewer, which conveys it to the local wastewater treatment and disposal facilities. If the local sewer authority were amenable, this option could be implemented in a few weeks, i.e., within the time it would take to mobilize rental RO equipment.

Green Valley discharges treated wastewater to percolation ponds. Sending 300,000 gallons per day of RO concentrate to the sewer would transport a large amount of sulfate to this site. It is possible that sulfate could migrate to groundwater at this location. This action could have negative impact on downgradient users of groundwater. Furthermore, if Green Valley wanted to reuse its wastewater for irrigation, the high TDS of the concentrate would render it unusable. Table 11 lists additional implementability factors that show that discharging a large amount of concentrate to the sanitary sewer is infeasible.

However, the impacts of discharging a small amount of concentrate to the sanitary sewer might be manageable. For example, rather than discharging the entire concentrate flow of a well-head RO system, some fraction could be sent to the sanitary sewer. Retaining this option provides flexibility to the operators of an RO system.

Truck to PDSI

Concentrate could be transported by truck to PDSI for reuse in mining operations. From trucks, it could be pumped into the pipe that conveys groundwater recovered by interceptor wells to the mine. The volume of water and mass of sulfate from the RO concentrate would be small when compared with the 5,500-gpm flow from the interceptor wells. This option would require a number of large storage tanks and a fleet of at least six trucks operating continuously to carry concentrate to the PDSTI. Trucking the water to PDSI would add traffic to local streets and consume fuel.

Assuming six water trucks and rental tanks were available, this option could be implemented in several weeks, i.e., within the time needed to mobilize a rental RO system. Trucking and tank rental costs are estimated at $190,000 per month, based on a concentrate production rate of 300,000 gallons per day (Appendix C). Over 2 years, this cost would total approximately $2.3 million. A permanent tank would cost $600,000 but would reduce the tank rental cost by $1.0 million over 2 years.

These costs are based on 1,000 gpm continuous pumping and an RO with 80-percent recovery, producing 300,000 gallons of concentrate per day. The wells and RO system might operated intermittently (i.e., less than 1,000 gpm on average), but the recovery percentage may be lower than 80 percent, so this estimate provides a safety margin for the capacity of the concentrate handling system.

Trucking could be used initially until a more permanent system for concentrate disposal (via a pipe) or for the RO system (a new well) is in place.

Convey to PDSI in Pipe

A dedicated pipe and pumping system could be installed to convey concentrate to the PDSTI. This pipe would have to be laid underground, because it would cross city streets. The following major pieces of equipment and facilities would be needed:

- Storage tank (assumed to be 300,000 gallons)
- Pump station (200 gpm average flow, 400 gpm peak flow)
- Buried pipe to the PDSI interceptor well collection pipe (assumed to be 8 inches in diameter, 2 miles long).

Using a dedicated pipe would eliminate the traffic issues caused by trucking, although there would be traffic impacts during construction. We estimate that the implementation time would be 1 year at a minimum for designing the pipe, securing the necessary permits and easements, and construction. The cost would be approximately $2 million (Appendix C). Power costs would be about $2,000 per month. Over 2 years, the total cost would be approximately $2.2 million.

Reduce Concentrate Volume

Costs for the previous options were based on 80 percent recovery from a 1,000-gpm well. This recovery rate may be optimistic. GE predicted it may be as low as 58 percent (Table 6), depending on the source water. Some waters contain high concentrations of scale-forming materials such as calcium and silica. Softening may be required to achieve a high recovery.

Softening would add a significant cost and require additional land and labor. Chemicals would be added to the water before RO. Precipitates would be removed by settling and filtration, which would produce a sludge that needed to be dewatered in a separate process and disposed as solid waste. Due to the increased complexity, labor, and operation and maintenance requirements, softening is not recommended for well-head treatment, and no cost estimate is provided.

Another option for reducing the concentrate volume is evaporation and crystallization. These are energy-intensive processes that have a high equipment cost. A brine evaporator would cost around $10 million installed. It would reduce the 200-gpm concentrate flow to about 40 gpm. This volume could be trucked or piped to the PDSTI. Alternatively, it could be sent to a crystallizer, which would produce dry salt cake. This crystallizer and its ancillary equipment would cost another $10 million. These systems would take 18 months to 2 years to design and install.

Deep Well Injection

Some RO installations inject their concentrate into the ground. This activity is regulated under the Underground Injection Control (UIC) Program, established under the Safe Drinking Water Act. Arizona has not received primary responsibility for UIC Program, so the U.S. Environmental Protection Agency (EPA) remains the responsible regulatory agency. A permit would be required from EPA, and well construction and monitoring data would have to be submitted to that agency.

A large amount of data would be required to procure an UIC permit. Studies would be required on the subsurface geologic formations and aquifers in the area. Interaction between the concentrate and water in the injection zone would have to be predicted. It is possible that the concentrate would have to be conditioned to have a similar density as the naturally saline water in the injection zone. Although such hydrogeologic conditions likely exists deep in the Tucson basin, the locations are at least 4 miles to 5 miles east of the well field currently being reviewed for this work. The completion of studies necessary for a UIC permit has not been successfully conducted in the Tucson Basin to-date.

Because of the long implementation time of this option (several years) and the uncertainty of obtaining an UIC permit, we believe this option is infeasible.

Discharge to Surface Water

Discharge to surface water would require an Arizona Pollutant Discharge Elimination System (AZPDES) permit. The lead time for obtaining an AZPDES permit would be approximately 12 months, unless ADEQ could expedite the permit review and comment period. To obtain the permit, the water quality of the projected discharge would have to meet Arizona numeric and narrative surface water quality standards. The ability of the discharge to meet surface water quality standards would be dependent on the chemistry of the water being treated and, therefore, would have to be evaluated on a case-by-case basis. In particular, the high sulfate and TDS concentrations of RO concentrate might cause the water to fail the Whole Effluent Toxicity test, thereby eliminating the possibility of obtaining an AZPDES permit.

Land Application

Concentrate could be applied to the land for evaporation and percolation. This action would require an Aquifer Protection Permit (APP). Given that the purpose of the RO system is to remove sulfate from groundwater, it is unlikely that an APP would be issued for land application of this concentrate in the affected area. It is possible that an APP permit could be obtained for land someplace else, but it would take several years to obtain this permit. In addition, the concentrate would have to be trucked or piped to this remote site, so this option would not be cost-competitive with trucking or piping the concentrate to the PDSTI. Therefore, this option is infeasible.

Concentrate Reuse

There are several possible uses of the concentrate:

- Dust control
- Fire suppression
- Toilet flushing

Brown and Caldwell has not identified sufficient demand in the area to use the 300,000 gallons per day or more of concentrate that would be generated. It is likely that the implementation time would be long. Costs might be high, since reuse would require large storage facilities and underground piping. Therefore, we believe this option is infeasible for interim actions.

MEMBRANE CLEANING WASTE DISPOSAL

Membrane systems require periodic cleaning to remove suspended solids and scale. Most units have a Clean-In-Place system that is automatically triggered based on elapsed time since the previous cleaning or pressure drop across a piece of equipment. The cleaning wastes may contain acids, detergents and/or suspended solids and TDS.

A 1,000-gpm system is expected to generate approximately 3,000 gallons of waste per cleaning. The frequency of cleaning depends on the source water composition, antiscalants used and the recovery at which the system is operated. Typically, cleaning frequencies are once every 1 month to 3 months.

Brown and Caldwell evaluated eight options for disposal of membrane cleaning wastes (Table 11). The only feasible option is trucking or piping it to PDSI. It should be combined with RO concentrate before trucking.

COST SUMMARY

Table 12 summarizes the costs over 2 years for feasible interim action options.

Please call me at (925) 210-2275 if you have questions on this technical memorandum.

Very truly yours,

BROWN AND CALDWELL

Matthew B. Gerhardt, Ph.D., P.E.
Project Manager

MBG:bfw

Enclosures (14)

cc: Dr. A. Drohobyczer, Brown and Caldwell

TABLES

Table 1. Summary of Options Evaluated to Mitigate Well Water Exceeding 250 mg/L Sulfate

General Response Action	Option	Applicability: Private Wells	Applicability: Drinking Water Supply Wells Feeding Distribution System Without Blending	Applicability: Drinking Water Supply Wells Feeding Distribution System After Blending
Alternative water supply	Modify well to eliminate pumping from sulfate-containing strata	✓	✓	✓
	Replace well	✓	✓	✓
	Connect to alternative water supply	✓	☒	☒
	Recommission the Esperanza wells	☒	✓	✓
	Provide bottled water	✓	✓	✓
Treatment	Point-of-use reverse osmosis	✓	✓	✓
	Full-house reverse osmosis	✓	✓	✓
	Ion exchange	☒	☒	☒
	Well-head membrane treatment	☒	✓	✓
Mix or blend	Manage pumping rates to achieve allowable sulfate concentration before distribution	☒	☒	✓

✓= Potentially applicable
☒= Not applicable

`

Table 2. Options for Mitigating Effects to Private Wells with Water Exceeding 250 mg/L Sulfate

General Response Action	Option	Evaluation: Effectiveness	Evaluation: Implementability	Evaluation: Cost for 2 years, dollars
Alternative water supply	Modify well to eliminate pumping from sulfate-containing strata	Unsuccessful in previous attempts	6 months to 12 months Difficult; may damage well User must be supplied with water during well modification period	Unknown
	Replace well	All water to home has low sulfate	6 months to 12 months User must be supplied with water during well replacement period	120,000
	Connect to alternative water supply	All water to homes has low sulfate	1 month to 4 months, if close proximity May require excavation in streets May require right-of-way permitting	2,500[a]
	Provide bottled water	Only for drinking and, possibly, cooking	A few days Bottles are heavy, so small bottles needed for some residents	1,000 to 3,000[b]
Treatment	Point-of-use reverse osmosis	Can only generate enough water for drinking and cooking	1 week to 2 weeks Low recovery Ongoing maintenance	3,000
	Full-house reverse osmosis	All water to homes has low sulfate	1 month Low recovery, so pumping increases Increased demand on septic system Energy needed for treatment and increased water pumping Ongoing maintenance	14,000

[a]Based on 200 ft of piping through unpaved terrain. Does not include monthly water service fee.

[b]Cost for bottled water depends on volume provided. Lower cost is for drinking water only. Higher cost includes additional water for cooking.

Table 3. New Private Well Capital Cost Estimate

UNIT PRICES AND QUANTITES

Item	Description	Quantity		Unit Price	Price
1	Mobilization and Demobilization (10% of total Items #2 through #8)	1.00	L.S.	6,675	6,675
2	Production Hole Drilling (10-inch borehole), complete in place	800.00	V.F.	25	20,000
3	Furnish and Install Stainless Steel Wirewrap Screen (5-inch), complete in place	150.00	V.F.	25	3,750
4	Furnish and Install Blank Steel Casing (5-inch), complete in place	800.00	V.F.	20	16,000
6	Furnish and Install Gravel Pack with Disinfection, complete in place	800.00	V.F.	30	24,000
7	Perform Mechanical Well Development, complete in place	20.00	HRS	150	3,000
8	Drilling Contingency (5% of items #1 through #7)	1.00	L.S.	3,671.25	3,671.25
	Subtotal for drilling				**$77,096.25**
1	PDP Unit, Yard Piping	1.00	LS	8,000	8,000
2	Motor, pump	1.00	LS	5,000	5,000
3	Electrical	1.00	LS	4,000	4,000
4	Well Building	0.00	LS	0	0
5	4-Inch Well Collector Main w/Valves & Fittings	20.00	LF	160	3,200
7	Trench Safety System	50.00	LF	1	50
8	Chainlink Fence	0.00	LF	25	0
10	Design Contingency (5% of items #2 through #10)	1.00	EA	1,012.50	1,012.50
	Subtotal for equipment				**$21,262.50**

Engineering and Construction Supervision, 20% of drilling and equipment	$19,671.75
Total	**$118,030.50**

Table 4. Options for Mitigating Effects to Drinking Water Supply Wells Feeding Distribution System Without Blending

General Response Action	Option	Evaluation: Effectiveness	Evaluation: Implementability	Evaluation: Cost for 2 years, dollars
Alternative water supply	Modify well to eliminate pumping from sulfate-containing strata	Unsuccessful in previous attempts Flow from the well will decrease, unless it is deepened	6 months to 12 months Another water source needed during well modification period	Unknown
	Replace well	All water to homes has low sulfate	12 months to 18 months Another water source needed during well modification period	2.8 million to 4 million[a]
	Recommission the Esperanza wells	All water to homes has low sulfate	Immediate	0[b]
	Provide bottled water	Only for drinking and, possibly, cooking May involve a large volume of water	2 weeks to 4 weeks Bottles are heavy, so small bottles needed for some residents	1,000 to 3,000[c] per home
Treatment	Point-of-use reverse osmosis	Can only generate enough water for drinking and cooking	Several months Low recovery Ongoing maintenance	3,000 per home
	Full-house reverse osmosis	All water to homes has low sulfate	Several months Low recovery, so pumping increases Increased demand on septic system Energy needed for treatment and increased water pumping Ongoing maintenance	14,000 per home
	Well-head membrane treatment (reverse osmosis [RO], nanofiltration [NF] or electodialysis reversal [EDR])	All water to homes is low sulfate	At least 12 months for RO or NF if system purchased; double for EDR 3 months if rental RO system used Generates concentrates and cleaning wastes requiring disposal Much less water wasted than individual RO in each home	2.3 million to 3.1 million[d] 3.4 million[d]

[a]Higher cost includes arsenic treatment, which might be needed for some wells.

[b]Not including pumping and other O&M costs, which would be about the same as for the wells taken out of service.

[c]Cost for bottled water depends on volume provided. Lower cost is for drinking water only. Higher cost includes additional water for cooking.

[d]Costs shown do not include disposal of concentrate and cleaning wastes.

Table 5. Replacement of Existing Supply Well Capital Cost Estimate

UNIT PRICES AND QUANTITIES

Item	Description	Quantity		Unit Price	Price
1	Top Hole Drilling (36-inch) complete in place	40	V.F.	230	9,200
2	Furnish and Install Steel Surface Casing (30-inch), complete in place	120	V.F.	213	25,560
3	Production Hole Drilling (24-inch), complete in place	1,300	V.F.	50	65,000
4	Geophysical Logging, complete in place	1	L.S.	5,000	5,000
5	Furnish and Install Stainless Steel Wirewrap Screen (16-inch), complete in place	150	V.F.	275	41,250
6	Furnish and Install Blank Steel Casing (16-inch), complete in place	1,300	V.F.	70	91,000
7	Furnish and Install Transducer Casing (2-inch), complete in place	1,300	V.F.	15	19,500
8	Furnish and Install Gravel Pack with Disinfection, complete in place	1,300	V.F.	40	52,000
9	Perform Mechanical Well Development, complete in place	40	HRS	350	14,000
10	Perform Downhole Video Survey, complete in place	1	L.S.	2,500	2,500
	Subtotal for drilling				**$325,010**
11	PDP Unit, VFD, Yard Piping	1	LS	70,000	70,000
12	Motor, pump, VFD	1	LS	110,000	110,000
13	Electrical	1	LS	80,000	80,000
14	Well Building	1	LS	53,000	53,000
15	10-Inch Well Collector Main w/Valves & Fittings	50	LF	160	8,000
16	8-Inch Blow-off LIne w/Fittings	50	LF	105	5,250
17	Trench Safety System	120	LF	1	120
18	Chainlink Fence	800	LF	25	20,000
19	Miscellaneous Materials (Well Shades)	1	EA	5,400	5,400
	Subtotal for well equipment				**$351,770**

Table 5. Replacement of Existing Supply Well Capital Cost Estimate, continued

UNIT PRICES AND QUANTITIES

Item	Description	Quantity		Unit Price	Price
20	Transmission line, 0.5 mile, 10 inch	2700	LF	110	297,000
21	Landscaping				20,000
22	Booster pumps, booster tank 20Kgal, and well site equipment				700,000
23	Arsenic treatment facility (optional)				800,000
24	Land purchase				50,000
25	Right of way				25,000
26	Zonal testing				120,000
27	Sampling				26,000
28	Miscellaneous				20,000
29	Hydrogeological Report	1	EA	15,000	15,000
	Subtotal for transmission line, booster pumps, arsenic treatment, miscellaneous				**$2,073,000**
				Subtotal	**$2,749,780**
				Contingency, 20%	**$549,956**
				Subtotal	**$3,299,736**
				Mobilization, 5%	**$164,987**
				Engineering, bidding and construction supervision, 15%	**$494,960**
				Total	**$3,959,683**

Table 6. Membrane System Recovery Percentages Predicted by GE

	Recovery, percent		
Membrane System	**Well Water 1**	**Well Water 2**	**Well Water 3**
Reverse Osmosis	81	74	58
Nanofiltration	81	74	58
Electrodialysis Reversal	89	82	75
Parameter	**Concentration in untreated water, milligrams per liter[a]**		
pH, standard units	7.8	7.7	7.7
Specific conductance, μmhos/cm	1,220	2,243	2,854
Alkalinity, as $CaCO_3$	108	100	100
Aluminum	<0.06	<0.06	<0.06
Barium	0.05	0.07	0.08
Boron	0.12	0.12	0.12
Calcium	196	330	513
Chloride	53	147	121
Fluoride	0.7	0.3	0.1
Iron	0.01	0.09	0.1
Magnesium	22	47	111
Manganese	0.05	0.015	0
Nitrate, as N		1.56	3.2
Phosphorus	Not available	Not available	Not available
Potassium	6	11	12
Silica	36	44	55
Sodium	69	121	98
Strontium	Not available	Not available	Not available
Sulfate	570	970	1,570
Temperature (mesured at the well), ºC	24 to 28	26.7	27.1
Total dissolved solids	1,030	1,810	2,670

[a]Unless otherwise indicated

Table 7. Reverse Osmosis and Electrodialysis Reversal Estimated Capital Costs

Basis: 1,000 gpm feed

	Estimated capital cost, millions		
Membrane System	**Well Water 1[a]**	**Well Water 2[a]**	**Well Water 3[a]**
Reverse Osmosis	1.9	2.0	2.3
Electrodialysis Reversal	2.7	3.4	3.2

[a]See Table 6 for well water characteristics

Table 8. Reverse Osmosis and Electrodialysis Reversal O&M Costs

Basis: 1,000 gpm feed

	Estimated O&M costs, dollars/1,000 gallons treated		
Membrane System	**Well Water 1[a]**	**Well Water 2[a]**	**Well Water 3[a]**
Reverse Osmosis	0.38	0.56	0.54
Electrodialysis Reversal	0.38	0.55	0.58

[a]See Table 6 for well water characteristics

Table 9. Estimated Costs for Rental Reverse Osmosis System

Type	Item	Quantity	Unit Cost	Total, dollars
Initial Costs	Replacement membranes			190,000
	Shipping			15,000
	Installation			20,000
	Electrical connection			35,000
	Start up and comissioning by GE			30,000
			Total	**$290,000**
Operating Costs (monthly)	RO, 500 gpm	2 x 30 days	$800/day	48,000
	Filter, 500 gpm	2 x 30 days	$480/day	28,800
	Booster pump, 1,000 gpm	30 days	$150/day	4,500
	Chemicals		$.50/1,000 gallons produced	17,000
	Labor	8 hrs x 30 days	$35/hr	8,400
	Power	30 days	$550/day	16,500
	Maintenance	30 days	$100/day	3,000
			Total	**$126,200**

Table 10. Options for Mitigating Effects to Drinking Water Supply Wells Feeding Distribution System After Blending

General Response Action	Option	Evaluation		
		Effectiveness	Implementability	Cost for 2 years, dollars
Alternative water supply	Modify well to eliminate pumping from sulfate-containing strata	Unsuccessful in previous attempts Flow from the well will decrease, unless it is deepened	6 months to 12 months Another water source needed during well modification period	Unknown
	Replace well	All water to homes has low sulfate	12 months to 18 months Another water source needed during well modification period	2.8 million to 4 million[a]
	Recommission the Esperanza wells	All water to homes has low sulfate	Immediate	0[b]
	Provide bottled water	Only for drinking and, possibly, cooking May involve a large volume of water	2 weeks to 4 weeks Bottles are heavy, so small bottles needed for some residents	1,000 to 3,000[c] per home
Treatment	Point-of-use reverse osmosis	Can only generate enough water for drinking and cooking	Several months Low recovery Ongoing maintenance	3,000 per home
	Full-house reverse osmosis	All water to homes has low sulfate	Several months Low recovery, so pumping increases Increased demand on septic system Energy needed for treatment and increased water pumping Ongoing maintenance	14,000 per home
	Well-head membrane treatment (reverse osmosis [RO], nanofiltration [NF] or electodialysis reversal [EDR])	All water to homes is low sulfate	At least 12 months for RO or NF if system purchased; double for EDR 3 months if rental RO system used Generates concentrates and cleaning wastes requiring disposal Much less water wasted than individual RO in each home	2.3 million to 3.1 million[d] 3.4 million[d]

Table 10. Options for Mitigating Effects to Drinking Water Supply Wells Feeding Distribution System After Blending, continued

General Response Action	Option	Evaluation		
		Effectiveness	Implementability	Cost for 2 years, dollars
Mix or blend	Manage pumping rates to achieve allowable sulfate concentration in tank or reservoir	All water to homes has low sulfate	Immediate implementation if tank or reservoir is online Time-consuming if additional piping needed to connect reservoir May preclude the need for treatment	Depends on system configuration

[a]Higher cost includes arsenic treatment, which might be needed for some wells.

[b]Not including pumping and other O&M costs, which would be about the same as for the wells taken out of service.

[c]Cost for bottled water depends on volume provided. Lower cost is for drinking water only. Higher cost includes additional water for cooking.

[d]Costs shown do not include disposal of concentrate and cleaning wastes.

Table 11. Options for Disposal of Membrane Concentrate and Cleaning Wastes

	Evaluation		
Option	Effectiveness	Implementability	Cost for 2 years, dollars
Discharge to sanitary sewer	Sulfate might migrate to groundwater at the wastewater treatment plant	Several weeks Little or no new piping needed No pumping needed Not likely to get a permit, because: - high TDS would eliminate possiblity of reusing treated effluent - might cause surcharge in sewers - might cause sewer corrosion due to sulfide generation - might cause odors problems in sewer and treatment plant - might cause treatment plant upsets - would consume capacity of treatment plant Discharge of a fraction of concentrate may be acceptable	Unknown
Truck to Phelps Dodge Sierrita Inc. for use in mine	Keeps sulfate out of groundwater	Several weeks Would require 4 or 6 dedicated water trucks operating non-stop Increased traffice and potential for accidents or spillage Energy-inefficient and labor-intensive means to convey water	$4.6 million
Convey by pipe to Phelps Dodge Sierrita Inc. for use in mine	Keeps sulfate out of groundwater	Minimum 1 year May require excavation in streets Maybe require right-of-way permitting Additional concentrate sources would require additional or larger pipes Chemicals might be needed to prevent scaling and corrosion	$2.2 million
Reduce concentrate volume	Keeps sulfate out of groundwater	18 months to 2 years Concentrate or salts must be hauled to disposal site	
Deep well injection	Moves sulfate to very deep groundwater	Several years Underground Injection Control permit required Geologic studies needed Life-time of well uncertain due to clogging potential Potentially high energy use	>$20 million

Table 11. Options for Membrane Concentrate Disposal, continued

Option	Evaluation		
	Effectiveness	Implementability	Cost for 2 years, dollars
Discharge to surface water	Eliminates need for treatment	No surface water present, so could not be implemented	Unknown
Land application	Eliminates need for treatment	Several years Dependant on suitable land availability Aquifer Protection Permit required; not expected to be obtainable Potentially long piping and pumping required Large land area requirements Extensive monitoring required	Unknown
Concentrate reuse Dust control Fire suppression Toilet flushing	Insufficient demand to use all concentrate	Variable time implementation for different options Permitting may be required Need method to convey concentrate to users	Unknown

Table 12. Summary of Costs for Options for Mitigating Well Water Exceeding 250 mg/L Sulfate

General Response Action	Option	Capital Cost Plus 2 Year O&M, dollars		
		Private Wells	Drinking Water Supply Wells Feeding Distribution System Without Blending	Drinking Water Supply Wells Feeding Distribution System After Blending
Alternative water supply	Modify well to eliminate pumping from sulfate-containing strata	Unknown	Unknown	Unknown
	Replace well	120,000	2.8 to 4 million[a]	2.8 to 4 million[a]
	Connect to alternative water supply	2,500[b]	N/A	N/A
	Recommission the Esperanza wells	N/A	0[c]	0[c]
	Provide bottled water	1,000 to 3,000 per home[d]		
Treatment	Point-of-use reverse osmosis	3,000 per home		
	Full-house reverse osmosis	14,000 per home		
	Install well-head reverse osmosis or nanofiltration system	N/A	2.3 million[e]	2.3 million[e]
	Install well-head electrodialysis reversal system	N/A	3.1 million[e]	3.1 million[e]
	Use rental RO system	N/A	3.4 million[e]	3.4 million[e]
	Truck concentrate and cleaning waste to PDSI, using rental storage tanks	N/A	4.6 million	4.6 million
	Truck concentrate and cleaning waste to PDSI, using purchased storage tanks	N/A	4.2 million	4.2 million
	Convey concentrate and cleaning waste in pipe to PDSI	N/A	2.2 million	2.2 million
Mix or blend	Manage pumping rates to achieve allowable sulfate concentration in reservoir	N/A	N/A	Depends on system configuration

N/A = not applicable

[a]Higher cost includes arsenic treatment, which might be needed for some wells.

[b]Based on 200 ft of piping through unpaved terrain. Does not include monthly water service fee.

[c]Not including pumping and other O&M costs, which would be about the same as for the wells taken out of service.

[d]Cost for bottled water depends on volume provided. Lower cost is for drinking water only. Higher cost includes additional water for cooking.

[e]Cost to treat 1,000 gpm raw water flow with characteristics of Well Water 1 in Table 6. Does not include costs for concentrate and cleaning waste disposal.

APPENDIX A

COST CALCULATIONS FOR PRIVATE WELL SULFATE MITIGATION

APPENDIX A

Bottled Water

According to information received on the phone from Sparkletts (800-453-0293 or www.sparkletts.com) a major supplier of bottled water in Arizona, providing service in Green Valley area, the cost of bottled water is as follows:

3-gal RO bottle - $6.29
5-gal RO bottle - $8.29
5-gal Distilled bottle - $8.79

Water Dispensers:
Heated and cooled water dispenser - $12.78/month
Room temperature and cooled water dispenser - $7.85/month
One-time deposit (refundable) - $5/bottle

For a typical two-person family, the cost of drinking water rental, 15 gallon/4 week, according to Sparkletts, will be approximately:

Three 5-gal RO bottles/4 weeks = $24.87 (typical drinking water demand for a two-person family)

Water dispenser (room temperature and cooled) = $7.85

Total = $32.72 plus 5.6 percent sales tax = $34.55/4 weeks

Five 3-gal bottles/4 weeks = $31.45

Total = $39.30 plus 5.6 percent sales tax = $41.50/4 weeks

Point-of-Use Home Reverse Osmosis

Cost Estimate:
We looked at two GE manufactured RO units GXRM10GBL – 10 gpd capacity, $160 plus tax, and PXRQ15F – 11 gpd capacity, $260 plus tax. Both units are virtually identical in their performance and differ only by the choice of material finishes and colors. The cost of operation is given by GE as $0.18/gal - $0.27/gal and includes the cost of water and changing the filters.

The three-pack replacement filters cost approximately $200. According to GE these filters last up to 6 months or 900 gallons. A safe assumption for this application would be 3 months and 450 gallons. Thus, additional cost of $800/year for the filters per house needs to be added. This cost assumes that the person in the household is able to change the filters without involving a plumber. If a plumber changes the filters are needed, an additional $360/year ($90/visit) must be added to the cost.

Conservative estimate for this option is capital cost of about $200/house plus installation of $300 to $600 for the POU RO system and O&M cost of up to $1,000/year house, depending on performance of the filters.

APPENDIX B

COST CALCULATIONS FOR PUBLIC WELL SULFATE MITIGATION

APPENDIX B

Estimated Costs for Reverse Osmosis (RO) and Electrodialysis Reversal (EDR)

Well Water 1
RO System - 1,000 gpm Influent 200 gpm Concentrate

Component Cost				
Item	**Quantity**	**Unit**	**Unit Cost**	**Cost $**
RO System	1	ls	535,000	535,000
Spares	1	ls	22,000	22,000
Building	1	ls	125,000	125,000
Miscellaneous	1	ls	25,000	25,000
Installation	1	ls	80,000	80,000
	SUBTOTAL 1			**787,000**
Piping (10%)	10	%		78,700
Electrical (15%)	15	%		118,050
Instrumentation (15%)	15	%		118,050
Site Preparation (10%)	10	%		78,700
	SUBTOTAL 3			**393,500**
	SUM SUBTOTAL 2 and 3			**1,180,500**
Non-Construction Costs				
Contractor Indirects - Mobilization, General Conditions, Insurance, O&P (15%)				177,100
Construction Contingency (30%)				354,200
Subtotal				**1,711,800**
Engineering (Design and Construction Phase) Services (12%)				205,400
TOTAL				**1,920,000**

Well Water 1
EDR System - 1,000gpm Influent

Item	Quantity	Unit	Unit Cost	Cost $
RO System	1	ls	885,000	885,000
Spares	1	ls	25,000	25,000
Building	1	ls	140,000	140,000
Miscellaneous	1	ls	25,000	25,000
Installation	1	ls	160,000	160,000
SUBTOTAL 1				**1,235,000**
Piping (10%)	10	%		78,700
Electrical (15%)	15	%		118,050
Instrumentation (15%)	15	%		118,050
Site Preparation (10%)	10	%		78,700
SUBTOTAL 3				**393,500**
SUM SUBTOTAL 2 and 3				**1,628,500**
Contractor Indirects				244,300
Construction Contingency				488,600
Subtotal				**2,361,400**
Engineering				283,400
TOTAL				**2,640,000**

Estimated Costs for Reverse Osmosis (RO) and Electrodialysis Reversal (EDR), continued

Well Water 2
RO System - 1,000 gpm Influent 200 gpm Concentrate

Component Cost				
Item	**Quantity**	**Unit**	**Unit Cost**	**Cost $**
RO System	1	ls	750,000	750,000
Spares	1	ls	22,000	22,000
Building	1	ls	140,000	140,000
Miscellaneous	1	ls	25,000	25,000
Installation	1	ls	90,000	90,000
	SUBTOTAL 1			**1,027,000**
Piping (10%)	10	%		78,700
Electrical (15%)	15	%		118,050
Instrumentation (15%)	15	%		118,050
Site Preparation (10%)	10	%		78,700
	SUBTOTAL 3			**393,500**
	SUM SUBTOTAL 2 and 3			**1,420,500**
Non-Construction Costs				
Contractor Indirects - Mobilization, General Conditions, Insurance, O&P (15%)				213,100
Construction Contingency (30%)				426,200
Subtotal				**2,059,800**
Engineering (Design and Construction Phase) Services (12%)				247,200
TOTAL				**2,310,000**

Well Water 2
EDR System - 1,000gpm Influent

Quantity	Unit	Unit Cost	Cost $
1	ls	1,140,000	1,140,000
1	ls	28,000	28,000
1	ls	160,000	160,000
1	ls	25,000	25,000
1	ls	190,000	190,000
SUBTOTAL 1			**1,543,000**
10	%		78,700
15	%		118,050
15	%		118,050
10	%		78,700
SUBTOTAL 3			**393,500**
SUM SUBTOTAL 2 and 3			**1,936,500**
			290,500
			581,000
		Subtotal	**2,808,000**
			337,000
		TOTAL	**3,150,000**

Estimated Costs for Reverse Osmosis (RO) and Electrodialysis Reversal (EDR), continued

Well Water 3 — RO System - 1,000 gpm Influent 200 gpm Concentrate | Well Water 3 — EDR System - 1,000gpm Influent

Component Cost								
Item	**Quantity**	**Unit**	**Unit Cost**	**Cost $**	**Quantity**	**Unit**	**Unit Cost**	**Cost $**
RO System	1	ls	550,000	550,000	1	ls	1,260,000	1,260,000
Spares	1	ls	22,000	22,000	1	ls	25,000	25,000
Building	1	ls	125,000	125,000	1	ls	180,000	180,000
Miscellaneous	1	ls	35,000	35,000	1	ls	25,000	25,000
Installation	1	ls	90,000	90,000	1	ls	200,000	200,000
	SUBTOTAL 1			**822,000**	**SUBTOTAL 1**			**1,690,000**
Piping (10%)	10	%		78,700	10	%		78,700
Electrical (15%)	15	%		118,050	15	%		118,050
Instrumentation (15%)	15	%		118,050	15	%		118,050
Site Preparation (10%)	10	%		78,700	10	%		78,700
	SUBTOTAL 3			**393,500**	**SUBTOTAL 3**			**393,500**
	SUM SUBTOTAL 2 and 3			**1,215,500**	**SUM SUBTOTAL 2 and 3**			**2,083,500**

Non-Construction Costs	RO	EDR
Contractor Indirects - Mobilization, General Conditions, Insurance, O&P (15%)	182,300	312,500
Construction Contingency (30%)	364,700	625,100
Subtotal	**1,762,500**	**3,021,100**
Engineering (Design and Construction Phase) Services (12%)	211,500	362,500
TOTAL	**1,970,000**	**3,380,000**

APPENDIX C

COST CALCULATIONS FOR MEMBRANE CONCENTRATE DISPOSAL

APPENDIX C

Truck to Mine

Trucks suitable for transporting liquids through a small community are usually the 3,000 gal trucks such as ones used by septic tank howlers or a little larger, 4,000-gal water tanker trucks. To transport 288,000 gallons of concentrate per day (200 gpm), 72 truck-trips would be required assuming use of 4,000 gal trucks.

To estimate the number of trucks and truck drivers required for this operation the following considerations must be addressed:

Conventional Mode of Transportation
Pumping rate to fill and empty the truck - 200 gpm
Time required for filing up – 20 min
Time required for emptying – 20 min
Other operations during fill up – 10 min
Other operations during emptying – 10 min
Speed of travel – 20 miles/hr
Distance to the tailing pond – 3 miles
Travel time on the road – 20 min

Total time required per round trip – 80 min = say 1.5 hrs

Thus, a single round trip will require 1.5 hr and a driver can make at most 5 trips per shift. In such a mode of operation lasting three shifts will be required and the following number of trucks and drivers

Number of truck trips/day – 72
Number of shifts/day – 3
Number of trips per shift – 24
Number of trips per driver – 5
Number of drivers per shift – 24/5 = 5
Total number of drivers – 15
Total number of trucks – 5

Thus, at least 5 trucks will be required, operating three shifts a day to transport the concentrate from the point of generation to the mine tailing pond.

fill-up parking spots and filling pumps will be required.

Estimate of Operating Cost
Making the following assumptions:
Hourly rate for driver – $35/hr
Fuel – $3.50/gal
MPG – 5 miles/gal
Total miles per day – 72*2*3 = 432 miles
Fuel cost, $/day - $302/day
Truck rental fee - $250/day
Truck per mile fee - $0.25/mile

APPENDIX C

Insurance - $17/day

Total = $4,200 labor + $700 = $4,900 per day

Monthly cost = ($4,900)(30 d) = $150,000

Also need a concentrate storage tank.

Rental tanks: each 20,000-gallon tank costs $3,000 per month to rent. At 200 gpm permeate, 1-day storage, need 14 tanks, so $42,000 per month

A 300,000 gallon fixed tank would cost $600,000 (see Table C-1).

Other facilities required for facilitating the trucking operation (not included in costs) are the following:

Storage tank at RO/NF/EDR facility
Parking spaces for loading and unloading the tanker trucks
Pumping equipment for loading at RO/NF/EDR facility
Pumping equipment for unloading at mine tailing pond
Diesel fueling station at the mine tailing pond location (optional).

Convey to Mine in Pipe

See Table C-2 for estimate

APPENDIX C

Table C-1. Capital Cost Estimate for Pumps and Storage Tank to Convey Concentrate to Mine

Description	Quantity	Unit	Unit Cost	Cost Without Markups	GC (10%)	O&P (15%)	B/I (2%)	Cost With Markups*
EARTHWORK								
Excavation - 8-inch water Line	-	CY	10.00	0.00	$ -	$ -	$ -	$ -
Bedding (Type C Material) - 10-inch water line	-	tons	15.00	0.00	$ -	$ -	$ -	$ -
Fill Material (Native) - 10-inch water line	-	CY	10.00	0.00	$ -	$ -	$ -	$ -
			Subtotal Earthwork	**$ -**	*$ -*	*$ -*	*$ -*	**$ -**
PIPE								
8-inch PVC C900 pipe, material and installation only	-	LF	45.00	0.00	$ -	$ -	$ -	$ -
			Subtotal Pipe	**$ -**	**$ -**	**$ -**	**$ -**	**$ -**
SKID MOUNTED BOOSTER PUMP STATION W/ 2-50 hp Vertical Grundfos stainless steel Pumps								
2- skid mounted, 50 hp, vertical Grundfos stainless steel Pumps and Motors, includes: electrical controls and instrumentation; piping; check valves; isolation valves; start-up and training, complete in place	1	LS	75,000.00	75,000.00	$ 7,500.00	$ 12,380.00	$ 1,900.00	$ 96,780.00
13 ft x 15 ft reinforced concrete grade beam foundation, complete in place	5	CY	500.00	2,500.00	$ 250.00	$ 410.00	$ 60.00	$ 3,220.00
12 ft x 14 ft Fiberglass bldg, complete in place	1	EA	30,000.00	30,000.00	$ 3,000.00	$ 4,950.00	$ 760.00	$ 38,710.00
PLC Programming at Start-up	1	LS	10,000.00	10,000.00	$ 1,000.00	$ 1,650.00	$ 250.00	$ 12,900.00
Electrical Work and Power	1	LS	20,000.00	20,000.00	$ 2,000.00	$ 3,300.00	$ 510.00	$ 25,810.00
			Subtotal Pump Station	**$ 137,500.00**	*$ 13,750.00*	*$ 22,690.00*	*$ 3,480.00*	**$ 177,420.00**
MANHOLES								
48-inch Standard Manhole (Type A) 6' deep, complete in place	-	EA	4,000.00	0.00	$ -	$ -	$ -	$ -
48-inch Manhole Barrel, complete in place	-	VF	300.00	0.00	$ -	$ -	$ -	$ -
Ring/Cover, 24-inch, flat, complete in place	-	EA	700.00	0.00	$ -	$ -	$ -	$ -
Concentric Cones (or Eccentric) 24-inch cover, complete in place	-	EA	325.00	0.00	$ -	$ -	$ -	$ -
Reinforced concrete bases/manhole,complete in place	-	EA	1,000.00	0.00	$ -	$ -	$ -	$ -
			Subtotal Manholes	**$ -**	*$ -*	*$ -*	*$ -*	**$ -**
Valves/Fittings								
8-inch gate valve with valve box, complete in place	4	EA	2,000.00	8,000.00	$ 800.00	$ 1,320.00	$ 200.00	$ 10,320.00
Fittings	1	LS	5,000.00	5,000.00	$ 500.00	$ 830.00	$ 130.00	$ 6,460.00
8-Inch Blow off Valve in Prefab manhole Manhole Type "A" - 48 Barrel w/ 36-inch manhole ring and cover	-	EA	5,000.00	0.00	$ -	$ -	$ -	$ -
2-inch combination air valve, includes all piping, fittings and appurtenances, complete in place	-	EA	5,000.00	0.00	$ -	$ -	$ -	$ -
			Subtotal Valves	**$ 13,000.00**	**$ 1,300.00**	**$ 2,150.00**	**$ 330.00**	**$ 16,780.00**
MISC.								
Mobilization/Demobilization	1	LS	54,000.00	54,000.00	$ 5,400.00	$ 8,910.00	$ 1,370.00	$ 69,680.00
300,000 gallon welded steel storage tank, complete in place	1	LS	200,000.00	200,000.00	$ 20,000.00	$ 33,000.00	$ 5,060.00	$ 258,060.00
HMAC Pavement Removal and replacement	-	SY	20.00	0.00	$ -	$ -	$ -	$ -
2-200 gpm sump pumps, 20 ft TDH, 5 Hp in sump, complete in place	1	LS	15,000.00	15,000.00	$ 1,500.00	$ 2,480.00	$ 380.00	$ 19,360.00
Trench Safety (4' wide Trench Box)	-	LF	2.00	0.00	$ -	$ -	$ -	$ -
			Subtotal Misc	**$ 269,000.00**	*$ 26,900.00*	*$ 44,390.00*	*$ 6,810.00*	**$ 347,100.00**

Total No Markups = $ 282,000.00

Estimate w/ Markups	**$ 363,880.00**
30% Contingency	**$109,164**
Total Construction Costs	**$ 473,044.00**
Engineering, Bidding and Construction Management @ 15% of Constr	**$ 70,956.60**
Surveying Costs	**25,000.00**
Geotechnical Costs	**$7,000.00**
Total Project Costs	**$ 576,001**

Markups : 10% General Conditions
15% Overhead and Profit
2% Bonds and Insurance

APPENDIX C

Table C-2. Capital Cost Estimate for Pipe, Pumps and Storage Tank to Convey Concentrate to Mine

Description	Quantity	Unit	Unit Cost	Cost Without Markups	GC (10%)	O&P (15%)	B/I (2%)	Cost With Markups*
EARTHWORK								
Excavation - 8-inch water Line	8,000	CY	10.00	80,000.00	$ 8,000.00	$ 13,200.00	$ 2,020.00	$ 103,220.00
Bedding (Type C Material) - 10-inch water line	4,000	tons	15.00	60,000.00	$ 6,000.00	$ 9,900.00	$ 1,520.00	$ 77,420.00
Fill Material (Native) - 10-inch water line	4,000	CY	10.00	40,000.00	$ 4,000.00	$ 6,600.00	$ 1,010.00	$ 51,610.00
			Subtotal Earthwork	**$ 180,000.00**	*$ 18,000.00*	*$ 29,700.00*	*$ 4,550.00*	**$ 232,250.00**
PIPE								
8-inch PVC C900 pipe, material and installation only	11,000	LF	45.00	495,000.00	$ 49,500.00	$ 81,680.00	$ 12,520.00	$ 638,700.00
			Subtotal Pipe	**$ 495,000.00**	**$ 49,500.00**	**$ 81,680.00**	**$ 12,520.00**	**$ 638,700.00**
SKID MOUNTED BOOSTER PUMP STATION W/ 2-50 hp Vertical Grundfos stainless steel Pumps								
2- skid mounted, 50 hp, vertical Grundfos stainless steel Pumps and Motors, includes: electrical controls and instrumentation; piping; check valves; isolation valves; start-up and training, complete in place	1	LS	75,000.00	75,000.00	$ 7,500.00	$ 12,380.00	$ 1,900.00	$ 96,780.00
13 ft x 15 ft reinforced concrete grade beam foundation, complete in place	5	CY	500.00	2,500.00	$ 250.00	$ 410.00	$ 60.00	$ 3,220.00
12 ft x 14 ft Fiberglass bldg, complete in place	1	EA	30,000.00	30,000.00	$ 3,000.00	$ 4,950.00	$ 760.00	$ 38,710.00
PLC Programming at Start-up	1	LS	10,000.00	10,000.00	$ 1,000.00	$ 1,650.00	$ 250.00	$ 12,900.00
Electrical Work and Power	1	LS	20,000.00	20,000.00	$ 2,000.00	$ 3,300.00	$ 510.00	$ 25,810.00
			Subtotal Pump Station	**$ 137,500.00**	*$ 13,750.00*	*$ 22,690.00*	*$ 3,480.00*	**$ 177,420.00**
MANHOLES								
48-inch Standard Manhole (Type A) 6' deep, complete in place	3	EA	4,000.00	12,000.00	$ 1,200.00	$ 1,980.00	$ 300.00	$ 15,480.00
48-inch Manhole Barrel, complete in place	8	VF	300.00	2,400.00	$ 240.00	$ 400.00	$ 60.00	$ 3,100.00
Ring/Cover, 24-inch, flat, complete in place	3	EA	700.00	2,100.00	$ 210.00	$ 350.00	$ 50.00	$ 2,710.00
Concentric Cones (or Eccentric) 24-inch cover, complete in place	3	EA	325.00	975.00	$ 100.00	$ 160.00	$ 20.00	$ 1,255.00
Reinforced concrete bases/manhole,complete in place	3	EA	1,000.00	3,000.00	$ 300.00	$ 500.00	$ 80.00	$ 3,880.00
			Subtotal Manholes	**$ 20,475.00**	*$ 2,050.00*	*$ 3,390.00*	*$ 510.00*	**$ 26,425.00**
Valves/Fittings								
8-inch gate valve with valve box, complete in place	4	EA	2,000.00	8,000.00	$ 800.00	$ 1,320.00	$ 200.00	$ 10,320.00
Fittings	1	LS	5,000.00	5,000.00	$ 500.00	$ 830.00	$ 130.00	$ 6,460.00
8-Inch Blow off Valve in Prefab manhole Manhole Type "A" - 48 Barrel w/ 36-inch manhole ring and cover	1	EA	5,000.00	5,000.00	$ 500.00	$ 830.00	$ 130.00	$ 6,460.00
2-inch combination air valve, includes all piping, fittings and appurtenances, complete in place	2	EA	5,000.00	10,000.00	$ 1,000.00	$ 1,650.00	$ 250.00	$ 12,900.00
			Subtotal Valves	**$ 28,000.00**	**$ 2,800.00**	**$ 4,630.00**	**$ 710.00**	**$ 36,140.00**
MISC.								
Mobilization/Demobilization	1	LS	54,000.00	54,000.00	$ 5,400.00	$ 8,910.00	$ 1,370.00	$ 69,680.00
300,000 gallon welded steel storage tank, complete in place	1	LS	200,000.00	200,000.00	$ 20,000.00	$ 33,000.00	$ 5,060.00	$ 258,060.00
HMAC Pavement Removal and replacement	2,000	SY	20.00	40,000.00	$ 4,000.00	$ 6,600.00	$ 1,010.00	$ 51,610.00
2-200 gpm sump pumps, 20 ft TDH, 5 Hp in sump, complete in place	1	LS	15,000.00	15,000.00	$ 1,500.00	$ 2,480.00	$ 380.00	$ 19,360.00
Trench Safety (4' wide Trench Box)	11,000	LF	2.00	22,000.00	$ 2,200.00	$ 3,630.00	$ 560.00	$ 28,390.00
			Subtotal Misc	**$ 331,000.00**	*$ 33,100.00*	*$ 54,620.00*	*$ 8,380.00*	**$ 427,100.00**

Total No Markups = $ 1,054,475.00

Estimate w/ Markups	**$ 1,360,615.00**
30% Contingency	**$408,185**
Total Construction Costs	**$ 1,768,799.50**
Engineering, Bidding and Construction Management @ 15% of Constr	**$ 265,319.93**
Surveying Costs	**25,000.00**
Geotechnical Costs	**$7,000.00**
Total Project Costs	**$ 2,066,119**

Markups : 10% General Conditions
15% Overhead and Profit
2% Bonds and Insurance