FREEPORT-McMoRAN
COPPER & GOLD

Freeport-McMoRan Sierrita Inc.
6200 W. Duval Mine Rd.
PO Box 527
Green Valley, Arizona 85622-0527

October 23, 2008

Via Certified Mail # 7007 3020 0001 8578 5416
Return Receipt Requested

Ms. Cynthia S. Campbell
Arizona Department of Environmental Quality
Water Quality Compliance Section
1110 West Washington Street
Phoenix, Arizona 85007-2935

Re: Mitigation Order on Consent Docket No. P-50-06, Feasibility Study

Dear Ms. Campbell:

Freeport-McMoRan Sierrita Inc. (Sierrita) submits three copies of the enclosed Feasibility Study (FS) report for Mitigation Order on Consent Docket No. P-50-06.

Sierrita looks forward to Arizona Department of Environmental Quality's (ADEQ) review of the FS and will submit a Mitigation Plan within 60 days of ADEQ's written approval of the FS. 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.

Sincerely,

Ned Hall

E. L. (Ned) Hall
Chief Environmental Engineer

ELH:ms
20081023_001
Attachment

xc: Joan Card, Arizona Department of Environmental Quality (w/o attachment)
John Broderick, Sierrita
Chad Fretz, Sierrita
Ray Lazuk, Freeport-McMoRan Copper & Gold Inc.
Stuart Brown, Bridgewater Group, Inc.
Jim Norris, Hydro Geo Chem, Inc.

FEASIBILITY STUDY FOR
SULFATE WITH RESPECT TO DRINKING WATER SUPPLIES
IN THE VICINITY OF THE
FREEPORT-MCMORAN SIERRITA INC. TAILING IMPOUNDMENT
MITIGATION ORDER ON CONSENT DOCKET NO. P-50-06

Prepared for:

FREEPORT-MCMORAN SIERRITA INC.
6200 West Duval Mine Road
Green Valley, Arizona 85614

Prepared by:

HYDRO GEO CHEM, INC.
51 West Wetmore Road, Suite 101
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October 22, 2008

FEASIBILITY STUDY FOR SULFATE WITH RESPECT TO DRINKING WATER SUPPLIES IN THE VICINITY OF THE FREEPORT-MCMORAN SIERRITA INC. TAILING IMPOUNDMENT MITIGATION ORDER ON CONSENT DOCKET NO. P-50-06

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Prepared by:

REGISTERED GEOLOGIST CERTIFICATE NO. 30842 JAMES R. NORRIS Date Signed 10/22/08 ARIZONA U.S.A. Expires 12/31/08

James R. Norris
Arizona Registered Geologist No. 30842

Reviewed and Approved by:

Registered Professional Engineer (Civil) CERTIFICATE NO. 23413 STEPHEN B. SMITH Date Signed 10.22.08 ARIZONA U.S.A. Expires: 6/30/10

Stephen B. Smith, P.E.
President and COO

October 22, 2008

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LIST OF ACRONYMS AND ABBREVIATIONS

ACR	Aquifer Characterization Report
ADEQ	Arizona Department of Environmental Quality
ADWR	Arizona Department of Water Resources
amsl	above mean sea level
ASLD	Arizona State Land Department
APP	Aquifer Protection Permit
ARS	Arizona Revised Statutes
B&C	Brown & Caldwell
bgs	below ground surface
CAP	Central Arizona Project
CWC	Community Water Company of Green Valley
EA	Environmental Assessment
FICO	Farmers Investment Co.
FFS	Focused Feasibility Study
FFS wellfield	Focused Feasibility Study wellfield
FS	Feasibility Study
ft	feet
gpm	gallons per minute
GVDWID	Green Valley Domestic Water Improvement District
HGC	Hydro Geo Chem, Inc.
IW wellfield	interceptor wellfield
LQS	Las Quintas Serenas Water Company
MC	mass capture well
Mitigation Order	Mitigation Order on Consent Docket No. P-50-06
MNA	monitored natural attenuation
mg/L	milligrams per liter
M&A	Errol L. Montgomery & Associates
NPV(50)	net present value calculated over 50 years
O&M	operation and maintenance
PDSI	Phelps Dodge Sierrita Inc. (now doing business as Freeport-McMoRan Sierrita Inc.)
PDSM	Phelps Dodge Sierrita Mine (now doing business as Freeport-McMoRan Sierrita Inc.)
PS wellfield	plume stabilization wellfield
PAG	Pima Association of Governments
PUG	Upper Santa Cruz Providers and Users Group
RO	reverse osmosis
Sierrita	Freeport-McMoRan Sierrita Inc.
SC wellfield	source control wellfield
STI	Sierrita Tailing Impoundment
UTME	Universal Transverse Mercator Easting
UTMN	Universal Transverse Mercator Northing
Work Plan	Work Plan to Characterize and Mitigation Sulfate with Respect to Drinking Water Supplies in the Vicinity of the Phelps Dodge Sierrita Tailing Impoundment

1. INTRODUCTION

1.1 Overview of the Feasibility Study

This Feasibility Study (FS) identifies and evaluates alternatives to mitigate sulfate with respect to drinking water supplies in the vicinity of the Sierrita Tailing Impoundment (STI) operated by Freeport-McMoRan Sierrita Inc. (Sierrita) near Green Valley, Arizona (Figures 1 and 2). The mitigation alternatives are evaluated based on their effectiveness, implementability, and cost to identify a recommended alternative. Hydro Geo Chem, Inc. (HGC) conducted the FS and prepared this report under contract to Sierrita.

The FS was conducted pursuant to the Mitigation Order on Consent Docket No. P-50-06 (Mitigation Order) which requires Sierrita (formally doing business as Phelps Dodge Sierrita Inc. [PDSI and PDSM]) to characterize the extent of sulfate in groundwater and to develop a Mitigation Plan to practically and cost effectively provide a drinking water supply to the owner/operator of an existing drinking water supply impacted by sulfate attributable to the STI. The Arizona Department of Environmental Quality (ADEQ) issued the Mitigation Order pursuant to Arizona Revised Statutes (ARS) § 49-286, which authorizes ADEQ to order mitigation measures where it determines a drinking water source is or will be rendered unusable due to impacts from non-hazardous substances (like sulfate). The Mitigation Order requires mitigation of drinking water supplies exceeding 250 milligrams per liter (mg/L) sulfate if the sulfate originates from the STI. Figure 3 shows the extent of the sulfate plume from the STI as of October 2007.

The approach for characterizing the extent of sulfate and for identifying and evaluating mitigation alternatives for the Mitigation Plan is described in the *Work Plan to Characterize and Mitigate Sulfate with Respect to Drinking Water Supplies in the Vicinity of the Phelps Dodge Sierrita Tailing Impoundment* (Work Plan) (HGC, 2006a). The results of studies characterizing the extent of the sulfate plume and hydrogeologic conditions in the vicinity of the plume are reported in the *Aquifer Characterization Report* (ACR) (HGC, 2007a)[1]. The Work Plan identifies the FS as the process for identifying and evaluating potential mitigation alternatives. Pursuant to the Work Plan, the main components of the FS are: identification and screening of potentially applicable mitigation response actions, control technologies, and process options (Section 2); development and screening of mitigation alternatives (Section 3); detailed analysis of mitigation alternatives (Section 4); and recommendation of a preferred mitigation alternative (Section 5). If approved, the preferred mitigation alternative would be implemented under a Mitigation Plan to be submitted to ADEQ within 60 days from date of approval.

The development of mitigation alternatives was based on site-specific data including groundwater chemistry; hydrogeologic conditions; Sierrita's operations infrastructure and land position; and discussions with Sierrita personnel and consultants. Cost and engineering-feasibility information was based on vendor quotes, actual costs for similar work, or best professional judgment. The mitigation alternatives addressed in this FS are based on provisions at ARS § 49-286 pertaining to mitigation of non-hazardous releases. Specifically, ARS § 49-286.A identifies possible mitigation measures as:

[1] The ACR will be revised to address ADEQ's written comments of April 24, 2008. The revised ACR will be submitted to ADEQ.

1. Providing an alternative water supply.

2. Mixing or blending if economically practicable.

3. Economically and technically practicable treatment before ingesting water.

4. Such other mutually agreeable mitigation measures as are necessary to achieve the purposes of this section

ARS § 49-286.B states "The director's selection of mitigation measures shall balance the short-term and long-term public benefits of mitigation with the cost of each alternative measure. The director may only require the least costly alternative if more than one alternative may render water usable as a drinking water source."

These provisions were utilized by including the potential mitigation measures of ARS § 49-286.A into the potentially applicable drinking water supply mitigation alternatives evaluated in the FS. Also, the mitigation alternatives are evaluated based on their potential short- and long-term benefits in comparison to their costs consistent with ARS § 49-286.B

1.2 Site Background

The STI is located approximately 25 miles south of Tucson, east of the Sierrita Mine, and 0.5 to 1.5 miles west of Green Valley in Pima County, Arizona (Figures 1 and 2). The STI covers approximately 3,600 acres.

Sierrita operates groundwater pumping wells along the eastern and southeastern boundaries of the STI to intercept sulfate-bearing seepage before it can flow eastward and mix with groundwater in the regional flow system. These IW-series wells comprise the interceptor well wellfield (IW wellfield) (Figure 3). Water pumped from the IW wellfield is used at the mine, thereby reducing the amount of groundwater needed for mine operations. The development and operation of the STI and the IW wellfield are described in detail by an evaluation of the IW wellfield effectiveness prepared for the Mitigation Order (Errol L. Montgomery & Associates (M&A), 2007). Figure 4 shows the existing IW wellfield wells and existing pipelines operated by Sierrita in the vicinity of the STI.

The effectiveness of the IW wellfield was evaluated based on analysis of groundwater hydraulic gradients, sulfate concentration data, and numerical simulation of groundwater flow in the vicinity of the STI (M&A, 2007). The evaluation determined that the southern portion of the IW wellfield provided effective hydraulic containment of seepage from the STI, but the northern portion did not. Seepage capture at the northern portion of the IW wellfield, from approximately IW-6A northward (Figure 3), is only partially effective because the small saturated thickness of the basin fill aquifer prevents pumping at rates sufficient to develop effective hydraulic capture. In contrast to the north half of the IW wellfield, the greater saturated thickness of the south portion of the wellfield allows the pumping needed to establish effective capture.

A Focused Feasibility Study (FFS) was conducted in response to the findings of the IW wellfield evaluation (HGC, 2007b). The FFS evaluated potential mitigation alternatives for improving the effectiveness of the north portion of the IW wellfield and recommended installation of the FFS wellfield east of the northern half of the STI (Figure 3). The recommendations of the FFS are evaluated further by this Feasibility Study (FS).

1.3 Hydrogeologic Setting

Comprehensive descriptions of the hydrogeology and water quality in the vicinity of the STI are provided in the Work Plan (HGC, 2006a) and the ACR (HGC, 2007a). Hydrogeologic information for the vicinity of the STI and sulfate plume is summarized in this section.

Three generalized hydrogeologic units are identified in the STI area: Recent alluvium, Quaternary and Tertiary basin fill deposits, and the bedrock complex. Recent alluvium is not a significant aquifer because it is typically unsaturated. Basin fill materials are relatively permeable sand and gravel deposits that compose the primary water supply aquifer in the area. The bedrock consists of indurated sedimentary, igneous, and metamorphic rocks that typically have low permeability and do not constitute a significant aquifer.

The basin fill composes the regional aquifer which is the primary source of water to wells in the STI area. The saturated thickness of the basin fill increases eastward from zero at the western basin margin in the vicinity of the STI to more than 1,000 feet in the central part of the basin near Green Valley. Wells in the central part of the basin are capable of pumping rates greater than 1,000 gallons per minute (gpm) due to the combination of large saturated thickness and relatively high permeability of the basin fill.

Groundwater elevations in the third quarter of 2007, a quarter in which geographically extensive data were collected, are shown on Figure 5. Groundwater elevations decrease from west to east in the immediate vicinity of STI, from south to north across the central portion of the study area near Green Valley, and from east to west on the alluvial fan east of the Santa Cruz

River. The overall pattern of groundwater flow indicated by groundwater elevations is consistent with expected regional groundwater flow patterns in the southern portion of the Tucson groundwater basin (e.g. Mason and Bota, 2006; Pima Association of Government, 1983a and 1983b; Davidson 1973).

Based on the data presented on Figure 5, regional groundwater flow is generally from a south-southwest direction to a northeasterly direction in the Green Valley area. As water in the regional aquifer flows northeasterly past the STI it mixes with sulfate-impacted seepage flowing east from the STI, forming the plume addressed by the Mitigation Order.

1.4 Sulfate Distribution

Figure 6 shows the regional distribution of sulfate concentrations in samples collected from wells in the basin fill aquifer. For the purposes of the FS, the term "plume" means the extent of groundwater, both in a horizontal and vertical context, with sulfate concentrations greater than 250 mg/L due to the STI. Groundwater sample results indicate that the northern margin of the plume extends to the vicinity of the MO-2007-1 wells, north of Duval Mine Road and west of La Canada Drive (Figure 3). The eastern margin of the plume is approximately along and west of La Canada Drive.

Groundwater samples with sulfate concentrations less than 50 mg/L sulfate define a north south zone approximately 6 miles long and ranging from 1,400 to 6,000 feet wide east of the sulfate plume. This zone of low sulfate groundwater is centered on Green Valley and extends north of Duval Mine Road along Interstate 19. Sulfate concentrations less than 10 mg/L are indicated in groundwater samples from wells south of the STI and west of Interstate 19. Samples from wells along the channel of the Santa Cruz River east of Interstate 19 have sulfate concentrations ranging between approximately 60 mg/L and 160 mg/L. Sulfate concentrations are generally less than 100 mg/L in samples collected from wells on the alluvial fan from the Santa Rita Mountains east of the Santa Cruz River channel. Groundwater samples collected from wells farthest east on the alluvial fan of the Santa Rita Mountains have sulfate concentrations less than 50 mg/L.

1.5 Feasibility Study Approach

Section III.D of the Mitigation Order stipulates the following:

"PDSI shall submit a Mitigation Plan to ADEQ for review and approval, which identifies and evaluates alternatives (e.g., containment, collection and discharge with or without treatment, institutional controls, alternative water supplies (including, but not limited to a new supply well, use of an existing supply well, modifying the screened interval of an existing supply well, connection to an existing public water supply system, and bottled water), mixing or blending, technically practicable treatment, and no action) to practically and cost effectively provide a drinking water supply that meets applicable drinking water quality standards and with sulfate concentrations less than 250 mg/L to the owner/operator of an existing drinking water supply determined from the characterization described in section III.C of this Order and verified by sampling and analysis to have an average sulfate concentration in excess of 250 mg/L (or other legally enforceable numeric concentration for sulfate which is enacted by statue or rule after the effective date of this Consent Order) as a result of the sulfate plume originating from the PDSM tailing impoundment".

To accomplish the requirements of Section III.D, the FS evaluated three general types of mitigation measures: source control, plume management, and drinking water supply mitigation.

Figure 7 shows the areas of the sulfate plume corresponding to each of the three types of mitigation measures. Each mitigation measure addresses different ways of addressing the sulfate plume; namely, reducing sulfate loading to the regional aquifer from the STI, controlling the migration and reducing the extent of the sulfate plume downgradient of the STI, and mitigating impacts to existing drinking water supplies attributable to sulfate from the STI. Together, the mitigation measures provide a comprehensive response to the sulfate plume and elements of each measure are contained in the mitigation alternatives evaluated by the FS.

The focus of source control is the reduction of sulfate loading from the STI to the regional aquifer. Source control actions consist of technologies that can be implemented to decrease the loading of sulfate from the STI to the regional aquifer. The existing IW wellfield and the proposed FFS wellfield (HGC, 2007b) are considered source control actions because they would capture seepage from the STI at the closest feasible locations, thereby reducing sulfate loading to the regional aquifer. The FS refers to the portion of the sulfate plume that is downgradient of the IW and FFS wellfields as the downgradient plume. Plume management actions seek to monitor and control the future migration and reduce the extent of the downgradient plume. Drinking water supply mitigation constitutes actions that can be taken to provide a source of water with sulfate concentrations less than 250 mg/L at the point of use if an existing drinking water supply were to be impacted by the downgradient plume. As discussed in subsequent sections, the source control, plume management, and drinking water supply mitigation response actions included in the mitigation alternatives are capable of limiting the source loading of sulfate, managing the extent and migration of the sulfate plume, and, if needed, mitigating impacts to existing drinking water supplies consistent with Section III.D of the Mitigation Order.

1.6 Adaptive Management

The mitigation alternatives included in the FS are evaluated over a 50-year period. The 50-year period allows consideration of the potential long-term effectiveness, implementability, and cost of each mitigation alternative under conditions of mine operation and possible mine closure. The development and evaluation of mitigation alternatives for a 50-year period requires making assumptions about future conditions for numerous technical, administrative, and business variables that are uncertain. To manage uncertainties associated with some of the FS assumptions, Sierrita would use an adaptive management approach during mitigation action implementation.

Adaptive management relies on an iterative process of data gathering and analysis to improve decision making in an uncertain environment. For purposes of environmental remediation or mitigation, the process is one of implementing a selected remedial action or actions, evaluating the performance of the action or actions over time having contingent measures available to improve performance if warranted, followed by further evaluating the performance of the system, followed by other contingent measures if warranted, and so on. As stated in Section III.D of the Mitigation Order, "The Mitigation Plan may use an adaptive management approach that allows for the adjustment of mitigation measures from time to time based upon information obtained concerning the performance of implemented mitigation measures."

The implementation of mitigation actions would be undertaken using an adaptive management approach that can remain flexible to respond to scientific (i.e., aquifer characteristics, groundwater monitoring results, or engineering data), administrative (e.g., new laws, evolving water supply constraints, etc.), or business (e.g., changes in mine operating life or production rates, etc.) conditions. Given the uncertainty in the technical, administrative, and business assumptions made to develop mitigation alternatives for the FS, the adaptive management approach will allow for the mitigation alternative to be modified as appropriate in response to new information concerning its performance.

2. INDENTIFICATION AND SCREENNG OF POTENTIALLY APPLICABLE MITIGATION RESPONSE ACTIONS, CONTROL TECHNOLOGIES, AND PROCESS OPTIONS

This section discusses the mitigation action objective and presents a screening analysis of the mitigation response actions, control technologies, and process options that may be used for source control, plume management, and drinking water supply mitigation. Mitigation response actions are generic categories of actions that can be taken to accomplish the mitigation action objective. For example, capture of seepage using wells at the STI, reduction of sulfate in discharge to the STI, and reduction of the water released to the STI are different mitigation response actions for source control. Mitigation response actions can be composed of more than one control technology. In the case of seepage capture with wells, different control technologies such as groundwater pumping or the use of groundwater barriers could be used. Each control technology can consist of one or more process options such as groundwater pumping with vertical wells or horizontal wells. The feasible mitigation response actions, control technologies, and process options are used to develop the mitigation alternatives as described in Section 3.

2.1 Mitigation Action Objective

A mitigation action objective is a qualitative or quantitative statement of the mitigation goal. Per Section III.D of the Mitigation Order, the mitigation objective of this FS is to:

- Practically and cost efficiently provide the owner/operator of an existing drinking water supply impacted by the sulfate plume from the STI with a drinking water supply with sulfate concentrations less than 250 mg/L.

There is no Arizona numeric aquifer water quality standard for sulfate to use as a quantitative mitigation objective. The Mitigation Order adopted a sulfate limit of 250 mg/L for a drinking water supply. Thus, any potential mitigation action will use the Mitigation Order sulfate limit as a numeric cap for the acceptable sulfate concentration at the point of use in an existing drinking water supply.

2.2 Mitigation Response Actions

Mitigation response actions for source control, plume management, and drinking water supply mitigation were identified and evaluated separately. As will be discussed, the evaluations of source control, plume management, and drinking water supply mitigation were conducted by different technical consultants to Sierrita. The results of the evaluations are summarized here to provide a complete description of the range of actions considered for the FS. Table 1 lists the mitigation response actions evaluated by the FS. The mitigation response actions are briefly described below. Detailed descriptions of the response actions are provided by the cited Appendices and reports. Section 2.3 discusses the screening of control technologies and process options for each mitigation response action.

2.2.1 Source Control

Source control response actions include a wide range of technologies that could be implemented to reduce sulfate loading from the STI to the regional aquifer. Source control can be accomplished by either reducing sulfate loading or capturing seepage from the STI, or some combination of the two. The FS distinguishes three types of source control: 1) source control at the STI, 2) downgradient source control, and 3) source control by a new tailing impoundment.

2.2.1.1 Source Control at the STI

Source control at the STI (also called upgradient source control) refers to mitigation response actions that could be implemented upstream of the STI or at the STI to reduce sulfate loading from the STI. Included in source control upstream of the STI are actions that could be taken to reduce the amount of water and/or sulfate in mine processes that discharge to the STI. Included in actions at the STI are actions that could reduce the amount of infiltration into or seepage out of the STI, and actions to reduce the sulfate mass in seepage from the STI. The FS analysis of source control at the STI is based on a source control evaluation by MWH, which is provided in Appendix A.

The following mitigation response actions are evaluated for source control at the STI:

- Sulfate source control for the tailing discharge and stormwater discharge (to the STI)
- Water source control technologies for STI discharge (actions that could potentially reduce the amount of water discharged with the tailing)
- Seepage source control for reclaim pond (actions that could potentially reduce the amount of seepage from the STI reclaim pond during operation)
- Containment (actions that limit infiltration into the STI after closure and enhance the rate of drain down)
- In-situ tailing treatment (actions that could reduce sulfate mobility within the tailing)
- Tailing discharge source control (actions that could eliminate discharge to the STI)

2.2.1.2 Downgradient Source Control

Downgradient source control pertains to mitigation response actions that capture seepage as close as practicable to the STI. Downgradient source control has been practiced at the existing IW wellfield since 1979 (M&A, 2007). The FFS (HGC, 2007b) evaluated the applicability of additional downgradient source control actions for the northern portion of the IW wellfield. The FFS used methods equivalent to this FS and its recommendations are adopted for the analysis of downgradient source control.

Mitigation response actions considered for downgradient source control in the FFS are:

- Groundwater control (actions that establish hydraulic conditions that allow capture of seepage from the STI)
- Water treatment (actions that could be used to remove sulfate from water in-situ or ex-situ)
- Water management (actions that provide for the use of water produced by downgradient source control)

2.2.1.3 Source Control by a New Tailing Impoundment

Source control by a new tailing impoundment is an option because of Sierrita's operational decision to evaluate potential construction of a new tailing impoundment. The installation of a new tailing impoundment would eliminate the discharge of tailing slurry, to the STI and initiate earlier drain down. Because the STI is designed to be free draining to maintain the stability of the tailing, water currently contained in the STI will drain over time after tailing deposition ceases. The process by which tailing moisture drains over time is referred to as drain down. During drain down, seepage from the tailing occurs rapidly at first and then slows over time as the moisture content of the tailing is reduced. The seepage rate during drain down depends on the hydraulic properties of the tailing and the size of the tailing deposit. The importance of a new tailing impoundment as a source control measure is that it would initiate drain down at the STI prior to the end of mining, resulting in an earlier draining of sulfate-bearing water and an earlier reduction of the sulfate load from the STI. Ultimately, the sooner the source is drained and no longer loading sulfate at levels of concern, the shorter the mitigation would be. Additional discussion of the proposed new tailing impoundment and drain down is provided in Sections 2.3.1.3 and 4.1.

2.2.2 Plume Management

Mitigation response actions applicable to plume management are technologies potentially applicable to monitor the downgradient plume, control the risk of exposure to the plume, and manage migration of the plume. Plume management mitigation response actions were evaluated by HGC as reported in Appendix B.

Mitigation response actions evaluated for plume management consist of:

- Institutional actions (actions that reduce potential exposure to the downgradient plume)
- Monitored natural attenuation (MNA) (actions that allow sulfate concentrations in the downgradient plume to decrease in response to natural attenuation processes and monitor its attenuation)
- Groundwater control (actions that establish hydraulic conditions to control plume movement)
- Water treatment (actions that could be used to remove sulfate from water in-situ or ex-situ)
- Water management (actions that provide for the use or storage of water produced by plume management)

2.2.3 Drinking Water Supply Mitigation

Drinking water supply mitigation is directed at mitigating a drinking water supply that becomes impacted by sulfate from the STI. Brown & Caldwell (B&C) evaluated potentially applicable mitigation response actions for drinking water supply mitigation and reported the results in a technical memorandum on interim actions for drinking water supplies (HGC, 2006). B&C's evaluation of mitigation actions for drinking water supplies is reproduced in Appendix C.

Mitigation response actions evaluated for drinking water supply mitigation include:

- Alternate water supply (actions that would replace an impacted supply)
- Water treatment (actions that could remove sulfate from water used for drinking water supply)
- Blending (mixing sulfate-impacted water with non-impacted water to meet the 250 mg/L sulfate limit)

2.3 Identification and Screening of Control Technologies and Process Options

The control technologies and process options that compose the mitigation response actions for source control, plume management, and drinking water supply mitigation were evaluated for their effectiveness, implementability, and cost. Effectiveness refers to the ability and reliability of the technology or process option to meet the mitigation objective over both short- and long-term time horizons, and whether the technology or process option is proven and reliable. Implementability is defined for the screening process as the technical and regulatory feasibility of implementing a technology or process option, given the general site conditions and regulatory constraints (e.g. permitting). Effectiveness and implementability were the primary criteria for the initial screening. For the purposes of the initial screening, cost was evaluated and used as a secondary screening criterion to discriminate between control technologies and process options with substantially equivalent effectiveness and implementability.

Table 1 lists the mitigation response actions, control technologies, and process options evaluated by the FS. Appendices A, B, and C describe the screening evaluations for source control at the STI, plume management, and drinking water supply mitigation, respectively; and discuss the rationale for process option selection. The FFS (HGC, 2007b) provides the screening evaluation for downgradient source control.

The duration of mine operations is a key consideration in the identification and screening of control technologies and process options and the development of mitigation alternatives. The FS uses a 50-year period for evaluation of mitigation alternatives. For purposes of mitigation alternative evaluation and costing it was assumed that the Sierrita Mine will operate through 2042, consistent with the current mine plan. After 2042, the mine would enter post-closure reclamation. The significance of the mine's operational status with respect to the screening analysis and the development of mitigation alternatives is that the water demand for mine use will cease upon closure and water management by mine use would need to be replaced by in-pit storage or treatment for use depending on mitigation pumping rates. It is important to recognize, however, that like all mine plans the Sierrita mine plan will be periodically reevaluated and that the mine could end before or extend past 2042. The sensitivity of each mitigation alternative to changes in mine life is discussed in Section 4.4.2.1.

2.3.1 Source Control

2.3.1.1 Source Control at the STI

MWH evaluated source control actions that could be taken upstream of and at the STI (Appendix A). Six mitigation response actions were evaluated for reduction of sulfate mass loading from the STI: 1) sulfate source control for the tailing discharge and stormwater discharge, 2) water source control for STI discharge, 3) seepage source control for the reclaim pond, 4) containment, 5) in-situ tailing treatment, and 6) tailing discharge source control (Table 1). The evaluation considered 13 control technologies consisting of 19 separate process options.

The physical and chemical characteristics of the STI impose significant limitations on the effectiveness of potential source control actions. Factors that limit potential source control actions at the STI are summarized below and described in detail in Appendix A.

- Technologies that can remove sulfate from the tailing prior to discharge into the STI, such as removal of the molybdenum roaster scrubber discharge, which contains calcium sulfate, would not significantly reduce sulfate mass loading from the STI because the tailing contains solid phase gypsum that could solubilize and release sulfate to the water it contacts.

- Technologies capable of reducing the water content of the tailing discharge, such as paste and filtered tailing processes, are very expensive to build and operate. For example, a filtered tailing process capable of reducing the moisture content to range of 18 percent to 29 percent (by volume) is estimated to have a capital cost on the order of $20 million and an additional operating cost of $200 million per year. In addition, these technologies are difficult to implement. Soft conditions on top of the STI limit the ability of heavy equipment to drive on it, thus potentially requiring that tailing be temporarily managed in another location until the surface of the STI is dry enough to allow for a new technology to be implemented. A major implementability consideration with these technologies is the potential for fugitive dust emissions.

- The need to maintain free draining conditions for the stability of the impoundment limits the use of liners that could minimize seepage into the tailing from the reclaim pond.

- The fine grain size of the tailing and its unsaturated condition makes extraction of seepage from the tailing ineffective and impracticable.

- The large size (3,600 acres) of the STI makes it impractical and expensive to implement in-situ treatment technologies.

Given the constraints imposed by the size and characteristics of the STI, the most practical and cost effective measures to limit sulfate loading from the STI are those that reduce the amount of water discharging to the STI, reduce the amount of seepage from the reclaim pond, and reduce the amount of water that infiltrates into the STI after closure.

MWH indentified the most practical and cost effective source control options upstream and at the STI as

- Reduce Amargosa Pond overflows by installing lined storage ponds
- Reduce Duval Canal discharges by installing a lined stormwater pond
- Control reclaim pond location to reduce seepage
- Optimize reclaim pond pumping to increase solution recovery
- Soil cap at closure to limit future infiltration
- Stormwater controls at closure to limit future run-on and infiltration

Discharge controls at Amargosa Pond and Duval Canal would reduce stormwater related discharges to the STI, but may only have a minor impact on sulfate loading because stormwater discharge is only 2 percent of the annual sulfate loading to the STI. Operational controls at the reclaim pond to reduce infiltration from the pond by controlling the pond location and by reclaim pond pumping to reduce the solution volume are effective at reducing seepage at the reclaim pond but not other portions of the STI. A soil cap and stormwater controls on final closure of the STI would minimize potential future infiltration to reduce the rate and duration of drain down.

2.3.1.2 Downgradient Source Control

The extraction of seepage close to the STI is a type of source control that has already been implemented downgradient of the STI. The existing IW wellfield has been operated since 1979 for this purpose. The effectiveness of the IW wellfield was evaluated for the Mitigation Order (M&A, 2007). As discussed in Section 1.2, the southern portion of the IW wellfield was found to be effective at containing seepage but the northern portion was not. The cause of ineffective pumping in the northern half of the IW wellfield is that shallow bedrock conditions occur there and the saturated thickness of the basin fill is too small to allow adequate pumping. The bedrock is deeper and the saturated thickness is greater in the southern half of the IW wellfield. The saturated thicknesses of the basin fill increases east of the STI.

The FFS (HGC, 2007b) evaluated mitigation response actions, control technologies, and process options for controlling seepage from the northern portion of the IW wellfield (Table 1). The FFS recommended continued operation of the IW wellfield with the exception of wells pumping less than 40 gpm and installation of additional pumping wells east of the STI (Figure 3) where the saturated thickness of the basin fill is greater and can sustain pumping sufficient to capture seepage from the north part of the STI. The wells east of the STI are called the FFS wellfield and would be located on county right-of-way or private land.

The FFS evaluated several options for controlling seepage from the northern interceptor wellfield. Among the options was one that considered placing extraction wells on Arizona State Land Department (ASLD) property east of the STI (Figures 3 and 4). The FFS evaluation showed that placing wells on ASLD property would have a higher cost due to ASLD water pumping fees and a longer permitting timeframe than placing wells east of ASLD property. For the conditions evaluated by the FFS, the cost of pumping groundwater from ASLD property was 65 percent higher than the cost of source control pumping from wells on county or private land east of the ASLD property. Although subsequent discussion with ASLD indicates that current permitting timeframes are less than what was assumed for the FFS, the recommended FFS alternative of placing the FFS wellfield east of ASLD property was retained for the FS because of its lower cost consistent with ARS § 49-286.B.

The FFS evaluated mitigation response actions, control technologies, and process options for a 25-year period only, assuming active mining operations. The FS developed additional information on water treatment and water management actions that could be taken in the event that mitigation pumping continues after mine closure.

Water treatment options identified by the FFS consisted of the membrane treatment techniques of reverse osmosis (RO), electrodialysis reversal, and nanaofiltration. Water treatment options have been further evaluated to identify a specific water treatment process for the purpose of cost estimation for the FS. Appendix D contains an analysis of water treatment by MWH. The analysis identifies RO as the most effective and implementable treatment options should water treatment be needed. RO is now identified as the preferred water treatment process option for downgradient source control.

Water management options identified by the FFS consisted of mine use during mine life and water treatment for use at the end of mine life. Additional analysis of water management options applicable in a post-mine period evaluated the possibility of storing and evaporating solutions in the Sierrita pit after closure. In-pit storage would discharge untreated mitigation water, RO reject water, or other treatment residuals to the Sierrita pit. In-pit storage would maintain the pit as a hydraulic sink to provide containment of solutions stored in the pit. A hydraulic sink condition occurs when the water elevation in the pit is lower than the water elevation in the surrounding aquifer, thereby creating a lower head in the pit which causes groundwater to flow into the pit and prevents pit water from flowing into the surrounding aquifer. Hydraulic sink conditions can be maintained by managing the water elevation in the pit lake relative to the water elevation in the surrounding aquifer. In-pit storage is feasible provided the inflow rate of mitigation water does not cause too much filling. Thus, the potential applicability of in-pit storage for water management depends on the expected flow rates over time during the mitigation. Appendix E contains an analysis of in-pit storage conducted by MWH. The feasibility of in-pit storage is discussed further in Section 4.3 in the context of specific remedial alternatives.

In-pit storage would be an effective water management option depending on the magnitude of mitigation flows over time. In-pit storage is implementable with standard pump and pipeline equipment. Sierrita would conduct in-pit water management actions in compliance with applicable groundwater regulations. The cost of in-pit storage would be significantly less than water treatment because it has relatively low infrastructure and operating requirements.

In-pit storage of solutions is an effective, implementable, and inexpensive way to manage solutions generated by the mitigation after mining ends. Although not considered by the FFS, in-pit storage and evaporation is now identified as a water management process option for downgradient source control.

Based on the recommendations of the FFS and the preceding discussion, the process options retained for downgradient source control are:

- Vertical wells at the IW wellfield
- Vertical wells east of the IW wellfield and off of ASLD land (i.e., the FFS wellfield)
- Pump water to the mine for use without treatment
- In-pit water storage if mine use is infeasible
- Water treatment by RO for use if mine use and in-pit storage are infeasible

The increase in pumping needed to provide source control could be offset by a reduction in the amount of water pumped from the Canoa Ranch wellfield consistent with the anticipated mining production rate (as mining rates increase or decrease, the amount of water usage will also increase or decrease). Thus, downgradient source control pumping would not result in an increase in the amount of groundwater pumping for mine use under current mining production rates, and would reduce the pumping of unimpacted groundwater upgradient of Green Valley.

The IW and FFS wellfields would have to operate until the mass loading in seepage from the STI is reduced to such a level that downgradient source control is no longer needed. After tailing discharge to the STI ceases, the impoundment will begin the process of drain down and the seepage rate from the STI will decrease as tailing pore water drains out of it by gravity. As discussed in Section 4 and Appendix F, drain down will take several decades due to the hydraulic properties of the tailing and the size of the impoundment. As described in Appendix F, drain down would occur more rapidly if it were initiated sooner. For example; calculations described in Appendix F indicate that if drain down were to start in 2016 (the possible start date for a new tailing impoundment as discussed in Section 2.3.1.3), it would take approximately 10 years to reduce the seepage rate by 50 percent and 30 years to reduce it by 90 percent. In contrast if drain down were to start in 2043, after the assumed end of mining, 50 percent and 90 percent reductions in seepage take approximately 16 years and 60 years, respectively.

Water management for downgradient source control would consist of mine use of impacted water during the mine life and in-pit storage and/or water treatment for use after mine life. Sierrita would conduct post-mine life water management actions in compliance with applicable groundwater regulations.

2.3.1.3 New Tailing Impoundment

Sierrita is evaluating the construction of a new tailing impoundment. To be cost effective and implementable, a new tailing impoundment would need to be near to the mine site and not miles away. Sierrita conducted a prescreening level evaluation of potential tailing storage sites. The evaluation identified a site immediately west of the STI based on it proximity, the local topography, projections of tailing storage capacity, and potential dam geometry. Figure 8 shows the general location of the proposed new tailing impoundment. Land at the site is owned primarily by ASLD. The location of the new tailing impoundment is extremely important for project feasibility because the construction/energy costs of a remote location would make the project infeasible.

Development of a new tailing impoundment would be a significant and lengthy process consisting of land acquisition, permitting, geotechnical investigation, economic analysis, engineering, and construction each of which would need to be completed successfully for the project to come to fruition. Specific work that would be required includes:

- Land acquisition negotiation with ASLD
- Investigations of the geology and surface water hydrology of the site
- Condemnation drilling to demonstrate the lack of subsurface mineral resources
- Scoping of environmental permitting requirements and completion of environmental surveys for compliance with potentially applicable programs such as the Endangered Species Act, Clean Water Act Section 404, National Historic Preservation Act
- Studies to support application for an Arizona Aquifer Protection Permit (APP)
- Evaluation of tailing management and deposition techniques
- Tailing stability analysis
- Tailing impoundment design and construction

Because there are many steps and issues involved in developing a new tailing impoundment, there are uncertainties associated with actually implementing a new tailing impoundment and the timeframe for implementation. For the purposes of mitigation alternative evaluation and cost estimating, it is assumed that a new tailing impoundment could be ready for operation in 2016. However, the actual timeframe could be somewhat longer or shorter depending on the time required to acquire the needed property and obtain permits. Although development of a new tailing impoundment is being undertaken as an operational project, a new tailing impoundment would have a significant impact on sulfate mitigation because the earlier that tailing deposition ceases and drain down is initiated the less source control pumping would be needed over the long term and shorter would be the duration of source control. For this reason, a new tailing impoundment is considered a potentially applicable process option for incorporation into mitigation alternatives.

2.3.2 Plume Management

Plume management response actions are evaluated in Appendix B. Plume management considered 10 control technologies consisting of 14 process options. The process options retained for development of mitigation alternatives are:

- Ongoing groundwater monitoring at monitoring and drinking water supply wells
- MNA by in-situ mixing of impacted groundwater with dilute groundwater and recharge
- Vertical wells for groundwater pumping
- Pumping water to the mine for use without treatment
- In-pit storage if mine use is infeasible
- Water treatment by RO for use if mine use and in-pit storage are infeasible
- Blending

MNA and groundwater pumping to control the extent and magnitude of the plume are the primary plume management actions. MNA would not control migration of the downgradient plume. Instead, the plume would continue to migrate and be diluted by mixing with unimpacted groundwater and recharge.

Groundwater pumping with vertical wells would be implemented to control the migration of sulfate by extracting impacted groundwater. For the purposes of the FS, it is assumed that pumping would be conducted pursuant to Sierrita's Type 2 Non-Irrigation Grandfathered;

Groundwater Right, a Poor Quality Groundwater Withdrawal Permit, or some other right as may be developed in the future. Two general plume management approaches are considered for groundwater pumping: plume stabilization and enhanced mass removal.

Plume stabilization would be achieved by pumping at the leading edge of the plume or other locations at a rate sufficient to minimize or prevent further migration of the downgradient plume. Plume stabilization would require pumping sulfate impacted groundwater at approximately the same rate at which it flows to the leading edge of the plume. Assuming the IW and FFS wellfields are in place, a wellfield for plume stabilization would need to operate until MNA could be implemented. Although plume stabilization can control migration of the downgradient plume, it may take a long time for existing groundwater concentrations in the downgradient plume to decline.

Mass removal is an approach that could be used in conjunction with plume stabilization. As used in this FS, mass removal refers to pumping from locations within the plume to remove sulfate mass in such a way as to reduce sulfate mass in the plume and reduce the extent of the plume.

Ongoing groundwater monitoring at monitor and drinking water supply wells would be employed as part of both MNA and groundwater pumping to assess the attenuation of the plume, the performance of the extraction systems, and the quality of drinking water supplies. Additional groundwater monitoring wells would be installed if needed to adequately monitor the downgradient plume.

Similar to the management of water for downgradient source control, the management of water for plume management would consist of mine use of impacted water during mine life and in-pit storage and/or water treatment for use after mine life. The increase in pumping needed for plume management would be offset by a reduction in the amount of water pumped from the Canoa Ranch wellfield consistent with anticipated mining production rates. Thus, plume management pumping would not result in an increase in the amount of groundwater pumping for mine use under current mining production rates, and would reduce the pumping of unimpacted groundwater upgradient of Green Valley. Sierrita would conduct post-mine life water management actions in compliance with applicable groundwater regulations.

2.3.3 Mitigation of Drinking Water Supplies

Appendix C evaluates potential mitigation actions for drinking water supplies ranging in size from private wells serving one or several families to public drinking water supplies with a large customer base. The evaluation considered 10 control technologies containing 12 process options for drinking water supply mitigation. Process options retained for developing mitigation alternatives are:

- Well modification to eliminate sulfate-bearing zones
- Well replacement
- Connection to alternative water supply
- Recommission the Esperanza wellfield
- Bottled water
- Point-of-use RO
- Full-house RO
- RO treatment at wellhead
- Nanofiltration treatment at wellhead
- Electrodialysis treatment at wellhead
- Blending

The mitigation appropriate for a private well would depend on site-specific conditions, although process options that are most likely to be used are supplying bottled water, well replacement, connection to an alternate water supply, and water treatment. Water treatment could consist of point-of-use or full-house RO. Sierrita would work with the owner of an impacted water supply well to determine the most appropriate mitigation.

Mitigation of a large public water supply would be more complex due to the number of affected parties, the large capacity of public supply wells, and the need to comply with regulations related to drinking water supplies. Process options potentially applicable to large public water supplies include well modification to eliminate the sulfate bearing zone, well replacement, recommissioning of the Esperanza wells, blending, and water treatment. Water treatment could consist of point-of-use treatment, full-house RO, or well-head treatment depending on the need. There are several potentially applicable technologies for long-term well-head treatment including RO, nanaofiltration, and electrodialysis reversal. Of these, RO has the shortest lead time (3 months) for implementation (Appendix C). Sierrita would work with the operator of an impacted water supply to determine the most appropriate mitigation.

The drinking water supply mitigation options were retained as a contingency in case an existing drinking water supply was to become impacted. None of the mitigation alternatives evaluated in the FS rely on drinking water mitigation.

2.4 Summary of Process Options Retained to Develop Mitigation Alternatives

The following process options were retained for use in developing mitigation alternatives:

- Source Control at STI
  - Reduce Amargosa Pond overflows by installing lined storage ponds
  - Reduce Duval Canal discharges by installing a lined stormwater pond
  - Control reclaim pond location to reduce seepage
  - Optimize reclaim pond pumping to increase solution recovery
  - Soil cap at closure to limit future infiltration
  - Stormwater controls at closure to limit future run-on and infiltration

- Downgradient Source Control
  - Vertical wells at the IW wellfield
  - Vertical wells distal from the IW wellfield
  - Pump water to the mine for use without treatment
  - In-pit storage if mine use is infeasible
  - Water treatment by RO for use if mine use and in-pit storage are infeasible
  - Blending

- Source Control by New Tailing Impoundment

- Plume Management
  - Ongoing groundwater monitoring at monitoring and drinking water supply wells
  - MNA by in-situ mixing of impacted groundwater with dilute groundwater and recharge
  - Vertical wells for groundwater pumping
  - Pumping water to the mine for use without treatment
  - In-pit storage if mine use is infeasible
  - Water treatment by RO for use to if mine use and in-pit storage are infeasible
  - Blending

- Drinking Water Supply Mitigation
  - Well modification to eliminate sulfate-bearing zones
  - Well replacement

- Connection to alternative water supply
- Recommission the Esperanza wellfield
- Bottled water
- Point-of-use RO
- Full-house RO
- RO treatment at wellhead
- Nanofiltration treatment at wellhead
- Electrodialysis treatment at wellhead
- Blending

The process options retained for source control, plume management, and drinking water supply mitigation provide an array of techniques that can be used to accomplish the mitigation objective. The potentially applicable process options will allow a range of mitigation alternatives to be developed consistent with Section III.D of the Mitigation Order and includes the mitigation measures identified in ARS § 49-286.

3. DEVELOPMENT AND SCREENING OF MITIGATION ALTERNATIVES

Mitigation alternatives are combinations of mitigation response actions, control technologies, and process options that can potentially meet the mitigation objective. This section formulates and describes mitigation alternatives consisting of process options retained by the screening evaluation described in Section 2. Section 3.1 describes the general approach of the mitigation alternatives and the basic process options constituting them. Section 3.2 compares the mitigation alternatives. Section 4 provides a detailed description and analysis of the mitigation alternatives, which evaluates their effectiveness, implementability, and cost.

3.1 Development of Mitigation Alternatives

Technologies and process options retained by the screening evaluation (Table 1) were combined to develop five mitigation alternatives which are described in Section 3.1.2 through 3.1.6 (Table 2). The mitigation alternatives were formulated to provide a range of mitigation measures that would have different outcomes and associated costs. In this way, a range of potential mitigation alternatives would be available for evaluation as required by Section III.D of the Mitigation Order.

The mitigation alternatives employ source control actions that include a combination of actions upstream and at the STI, seepage capture with wells, and the potential development of a new tailing impoundment; and use plume management strategies ranging from MNA to groundwater pumping to control plume migration and reduce plume extent. Drinking water supply mitigation is an "if needed" contingency in each alternative.

3.1.1 Common Elements

In the process of developing mitigation alternatives, certain source control, plume management, and drinking water mitigation actions were the same for all alternatives. For example, all the mitigation alternatives include the same elements of source control upstream of and at the STI and downgradient pumping at the FFS wellfield (HGC, 2007b). The alternatives also contain the same groundwater monitoring actions for plume management. Finally, all the alternatives include drinking water supply as an "if needed" contingency. The mitigation actions that are common to all the mitigation alternatives are called "base case" actions. The mitigation alternatives differ from each other by the source control and plume management actions added to the base case actions.

The base case mitigation actions for source control, plume management, and existing drinking water supply mitigation are as follows:

- Source control
  - Pump STI seepage at the IW and FFS wellfields
  - Use mitigation water at mine during mine life
  - In-pit storage or water treatment by RO for use after mine life
  - Install lined ponds to eliminate discharges from Duval Canal and Amargosa Pond
  - Pump the reclaim pond to control its location and volume to reduce seepage into the STI
  - Install soil cap and stormwater controls at final reclamation

- Plume Management
    - o Conduct ongoing groundwater monitoring to evaluate mitigation effectiveness and quality of drinking water supplies

- Drinking Water Supply Mitigation Consistent with ARS § 49-286 and the Mitigation Order
    - o Well modification
    - o Well replacement
    - o Connection to alternative water supply
    - o Recommission Esperanza wells
    - o Bottled water
    - o Point-of-use, full-house, or wellhead water treatment
    - o Blending

Conceivably, the mitigation objective of practically and cost effectively providing a drinking water supply with sulfate concentrations less than 250 mg/L to the owner/operator of an existing drinking water supply (Section 2.1) could be met by drinking water supply mitigation alone. That is, actions could be taken to mitigate existing drinking water supplies if they were to become impacted by implementing one or more of the measures in ARS § 49-286.A. However, the FS developed mitigation alternatives spanning a spectrum of possible measures by including different source control and plume management actions. Some of these actions fall within the category of measures that may be required only by "mutual agreement" under ARS § 49-286.A. Thus, the mitigation alternatives evaluated by the FS can achieve the mitigation objective in different ways consistent with Section III.D of the Mitigation Order. The mitigation alternatives are summarized in Table 2 and described more fully in Section 3.1.2 through 3.1.6. For the purposes of the FS, the mitigation alternatives assume the Sierrita Mine will continue to operate through 2042.

3.1.2 Alternative 1 – Source Control and Monitored Natural Attenuation

Alternative 1 would use MNA for plume management and includes the base case mitigation actions for source control, plume management, and drinking water supply mitigation. Under Alternative 1 it is assumed that tailing would be discharged to the STI throughout the duration of mine life. Alternative 1 would implement source control upstream of and at the STI, and contain seepage from the STI at the IW and FFS wellfields as described in the prior section. It would also allow the downgradient plume to naturally attenuate. Under the natural attenuation approach sulfate concentrations in the downgradient plume would reduce over time due to mixing with unimpacted regional groundwater flow along the margin of the plume and with unimpacted infiltration in the footprint of the plume. Groundwater monitoring would be conducted to track the plume and to evaluate the rate of attenuation. If an existing drinking water supply had the potential to become impacted by the plume it would be mitigated using one or more of the measures identified in Appendix C.

3.1.3 Alternative 2 – Source Control and Plume Stabilization

Alternative 2 would use groundwater pumping for plume stabilization as the approach to plume management and includes the base case mitigation actions for source control, plume management, and drinking water supply mitigation. Under Alternative 2 it is assumed that tailing would be discharged to the STI throughout the duration of mine life. Groundwater pumping would be conducted at the northern portion of the plume to prevent further movement of the downgradient plume towards existing wells. Because groundwater pumping would prevent the plume from migrating there would be no impact to existing drinking water supply wells which are currently unimpacted (HGC, 2006b). Sulfate concentrations in the downgradient plume would decrease gradually over time as unimpacted water sweeps through the zone between the IW and FFS wellfields and wells at the leading edge of the plume.

Alternative 2 consists of:

- Base Case Source Control, Plume Management, and Drinking Water Supply Mitigation (Section 2.1)
- Plume Management
  - Groundwater pumping to prevent downgradient movement of the plume
  - Mine use of water during mine life and in-pit storage and/or water treatment for use after mine life
- Drinking Water Supply Mitigation
  - Drinking water supply mitigation would not be needed if plume management is effective, but is available as a contingency

3.1.4 Alternative 3 – Source Control, Plume Stabilization, and Mass Removal

Alternative 3 would use a mass removal strategy in conjunction with plume stabilization for plume management. Alternative 3 includes the base case source control, plume management, and drinking water supply mitigation actions; groundwater pumping at the leading edge of the plume to prevent further downgradient movement, and pumping within the downgradient plume for sulfate mass removal. Under Alternative 3 it is assumed that tailing would be discharged to the STI throughout the duration of mine life. In addition to stabilizing the leading edge of the plume, Alternative 3 would increase sulfate mass removal within the plume in an effort to reduce the footprint of the downgradient plume and potentially eliminate the need for plume management pumping after the end of mine life.

Pumping within the downgradient plume would remove sulfate mass at a faster rate than Alternative 2 and would induce a greater degree of flushing by unimpacted water. Under Alternative 3, the plume would not migrate downgradient or impact existing drinking water supplies.

Alternative 3 consists of:

- Base Case Source, Control, Plume Management, and Drinking Water Supply Mitigation (Section 2.1)
- Plume Management
  - Groundwater pumping to prevent downgradient migration of the plume
  - Groundwater pumping within the plume to potentially eliminate the need for plume management pumping before or after the end of mine life by maximizing sulfate removal during mine operations
  - Mine use of water during mine life and in-pit storage and/or water treatment for use after mine life
- Drinking Water Supply Mitigation
  - Drinking water supply mitigation would not be needed if plume management is effective, but is available as a contingency

3.1.5 Alternative 4 – New Tailing Impoundment, Source Control, and Plume Stabilization

Alternative 4 would use the base case source control, plume management, and drinking water supply mitigation actions; a new tailing impoundment in 2016 to eliminate operation of the

STI; and groundwater pumping for plume stabilization. Alternative 4 contains the same mitigation actions as Alternative 2 plus a new tailing impoundment for source control. Under Alternative 4 plume management pumping would prevent the downgradient migration of the plume. Therefore, there should be no impacts to existing drinking water supply wells which are currently unimpacted (HGC, 2006b). The cessation of tailing discharge to the STI would allow drain down to begin earlier, reducing the amount of seepage that will need to be captured during and after the end of mine life.

Alternative 4 consists of:

- Base Case Source Control, Plume Management, and Drinking Water Supply Mitigation (Section 2.1)
- Source Control
    - New tailing impoundment
- Plume Management
    - Groundwater pumping to prevent downgradient movement of the plume
    - Mine use of water during mine life and in-pit storage and/or water treatment for use after mine life
- Drinking Water Supply Mitigation
    - Drinking water supply mitigation would not be needed if plume management is effective, but is available as a contingency

3.1.6 Alternative 5 – New Tailing Impoundment, Source Control, Plume Stabilization, and Mass Removal

Alternative 5 would use the base case source control, plume management, and drinking water supply mitigation actions; a new tailing impoundment in 2016 to eliminate operation of the STI; plume stabilization; and mass removal. Alternative 5 contains the same mitigation actions as Alternative 3 plus a new tailing impoundment for source control. Plume management pumping would prevent downgradient plume migration under Alternative 5. Therefore, there should be no impacts to existing drinking water supplies which are currently unimpacted (HGC, 2006b). Alternative 5 is a combination of aggressive plume management and a new tailing impoundment. The cessation of tailing discharge to the STI would allow drain down to begin earlier, reducing the amount of seepage that will need to be captured during and after mine life.

Alternative 5 consists of:

- Base Case Source Control, Plume Management, and Drinking Water Supply Mitigation (Section 2.1)
- Source Control
  - New tailing impoundment
- Plume Management
  - Groundwater pumping to prevent downgradient migration of the plume
  - Groundwater pumping within the plume to potentially eliminate the need for plume management pumping before or after the end of mine life by maximizing sulfate removal during mine operations
  - Mine use of water during mine life and in-pit storage and/or water treatment for use after mine life.

- Drinking Water Supply Mitigation
    - Drinking water supply mitigation would not be needed if plume management is effective, but is available as a contingency

3.2 Comparison of Mitigation Alternatives

Alternatives 1 through 5 address the mitigation objective through the use of different combinations of source control, plume management, and drinking water supply mitigation actions. The alternatives would each provide the same minimum level of mitigation because they each adopt the same base case source control, plume management, and contingent drinking water supply mitigation actions (Section 2.1). The alternatives differ primarily in the use or not of a new tailing impoundment for source control, the degree of groundwater pumping for plume management, and the type of post-mine water management.

The base case source control seeks to reduce water loading to the STI and to capture seepage from the STI at the IW and FFS wellfields as close as feasible to the STI. Although certain source control options have the potential to reduce the amount of water that infiltrates into the STI, there is no feasible way of stopping infiltration (Appendix A). Thus, infiltration into STI is expected to continue until tailing deposition ceases. Once tailing deposition ceases, seepage from the STI will decline over time but will continue for several decades as drain down progresses, although a majority of the drain down occurs in the first 25 years. Alternatives 1 through 5 would rely on the IW and FFS wellfields to capture and control STI seepage, including drain down, during and after the life of mine. Drain down would start at the end of mine life in Alternatives 1, 2, and 3. As discussed in Section 2.3, mining was assumed to end in 2042 for purposes of mitigation alternative evaluation and cost estimating. Drain down could start much earlier for Alternatives 4 and 5 which include the new tailing impoundment being evaluated by Sierrita. As discussed in Section 2.3.1.3, for the purposes of mitigation alternative evaluation and cost estimating it was assumed that a new tailing impoundment could be available by 2016. The actual timing of startup of a new tailing impoundment is difficult to predict given land acquisition and permitting uncertainties. The early start of drain down in Alternatives 4 and 5 would result in significantly less seepage and sulfate loading from the STI at the end of mine life and a significantly shorter duration of source control pumping compared to Alternatives 1, 2, and 3.

The base case plume management uses groundwater monitoring to track the location and movement of the plume, to evaluate mitigation action performance, and to determine the need to implement mitigation actions at existing drinking water supplies. Alternative 1 would use natural attenuation and groundwater monitoring for plume management (i.e., MNA). Alternative 1 would monitor the plume and implement drinking water supply mitigation if the monitoring results indicate that an existing drinking water supply could become impacted. Plume management for Alternatives 2 and 4 would stabilize the movement of the downgradient plume by pumping at the northern edge of the plume. Alternatives 3 and 5 use plume management consisting of plume stabilization pumping and mass removal pumping within the plume to reduce the extent and sulfate mass of the downgradient plume. The plume will migrate downgradient in Alternative 1, but is not expected to migrate downgradient under Alternatives 2 through 5. As described in Section 4, numerical simulations of groundwater flow and sulfate transport were used to develop conceptual wellfield designs for the alternatives, to evaluate the performance of the alternatives, and to provide a basis for cost estimation.

The quantity of water pumped for the alternatives will vary as a function of the source control and plume management actions adopted for the alternative. In all the alternatives, the water produced by source control and plume management would be used for mining during mine operations. After mine operations permanently cease, the water would be stored in the Sierrita pit if flow rates are relatively low or treated by RO, or another method, for use. The end use of any treated water would depend upon constraints imposed by the water rights or permits in effect at the time.

Contingent drinking water supply mitigation is part of the base case assumption for each alternative. The downgradient plume will migrate in Alternative 1, the MNA scenario, but not Alternatives 2 through 5. Because plume migration would continue under Alternative 1, there is a possibility that an existing drinking water supply could need mitigation. Alternatives 2 through 5 are not expected to need drinking water supply mitigation of existing wells because the plume does not migrate, but mitigation is available as a contingency if needed.

In summary, the alternatives provide a range of approaches that could mitigate the sulfate plume in different ways consistent with Section III.D of the Mitigation Order. The approaches range from MNA (Alternative 1), to groundwater pumping that would stabilize the movement of the downgradient plume with or without implementation of a new tailing impoundment (Alternative 2 and 4, respectively), to an aggressive groundwater pumping program that would reduce the sulfate mass of the downgradient plume in an attempt to reduce the size of the plume footprint with or without a new tailing impoundment (Alternatives 3 and 5, respectively).

4. DETAILED ANALYSIS OF MITIGATION ALTERNATIVES

The detailed analysis of mitigation alternatives evaluates the effectiveness, implementability, and cost of the proposed mitigation alternatives. The mitigation alternatives are individually evaluated to determine their effectiveness, implementability, and cost, and evaluated in comparison to one another to identify the relative short- and long-term benefits and costs of the alternatives in accordance with ARS § 49-286.

The mitigation alternatives identified in Section 3.2 were evaluated by a three-step process. First, the groundwater flow and sulfate transport model reported in the ACR (HGC, 2007a) was modified to project future pumping and recharge through the year 2060 so that the model could be used to simulate future plume migration (the version of the model reported in the ACR only included historical and current pumping and recharge rates from 1940 through 2006). The numerical model was used to interactively simulate various wellfield designs to identify well locations and pumping rates that would achieve the source control and plume management objectives for each alternative. Once a wellfield design was determined, the numerical simulation of the mitigation alternatives allowed evaluation of plume behavior over a 50-year period for each alternative. Second, preliminary conceptual designs were developed for the facilities required by each alternative. The conceptual designs considered the pumping locations and volumes, water routing, and infrastructure requirements needed to implement the alternatives. Third, a cost model of each mitigation alternative was developed based on estimates of the capital and operation and maintenance (O&M) expenditures that would be needed to construct and operate the facilities identified in the conceptual design for a period of

50 years. This evaluation process provided information on the effectiveness, implementability, and cost of the mitigation alternatives.

The numerical model used to simulate the mitigation alternatives is discussed in Section 4.1 and described in detail in Appendix F. Section 4.2 describes the cost analysis methodology. Section 4.3 provides a description and analysis of individual mitigation alternatives. Section 4.4 is a comparative analysis of the mitigation alternatives.

4.1 Numerical Modeling of Mitigation Alternatives

A numerical model of groundwater flow and sulfate transport was used to simulate the mitigation alternatives. The numerical simulations were used to estimate well locations and pumping rates for source control and groundwater management actions, to develop preliminary conceptual designs for wellfields and related infrastructure, to predict hydraulic and mass loads for water management, and to predict future sulfate concentrations under each mitigation alternative. Numerical modeling for the FS included simulation of the IW and FFS wellfields for source control; groundwater pumping for plume management; future pumping for water supply, agricultural, and mining uses in the vicinity of the plume; and the potential future recharge of Central Arizona Project (CAP) water.

The construction and calibration of the numerical model for groundwater flow and sulfate transport are described in detail by HGC (2007a). The numerical model was constructed using MODFLOW-SURFACT version 3.0 (Hydro Geologic, Inc., 1996). MODFLOW-SURFACT is based on the widely used United States Geological Survey modeling program MODFLOW (McDonald and Harbaugh, 1988). The numerical model was calibrated to measured water levels and spatial and temporal trends in sulfate concentration in the vicinity of the STI, including a 66-year record of groundwater pumping (1940 through 2006) and a 47-year record of tailing emplacement. In the ACR (HGC, 2007a), the calibrated model was used to simulate development of the sulfate plume through the end of 2006.

Numerical modeling for the FS consisted of simulating conditions from 2007 into the future. Modifications made to the model in order to conduct predictive simulations included the addition of specifications for projected future pumping and recharge (including STI seepage) and modifications of layer thickness and hydraulic conductivity in certain areas to allow model stability. Appendix F discusses the modifications made to the predictive model. The predictive simulations were run to 2060 to evaluate 50 years of mitigation assuming the mitigation would become operational in 2010. The results of predictive simulations for each mitigation alternative are presented in the analysis of individual mitigation alternatives (Section 4.3) and Appendix G.

Estimates of future pumping in the model domain were obtained from a compilation and analysis of future water use by the Upper Santa Cruz Providers and Users Group (PUG) (PUG, 2008). PUG (2008) provides estimated future pumping for existing mining, agricultural, and water supplies and users including Sierrita, Farmers Investment Co. (FICO), Community Water Company of Green Valley (CWC), Green Valley Domestic Water Improvement District (GVDWID), Sahuarita Water Company, Farmers Water Co., Las Quintas Serenas Water Company (LQS), and Quail Creek Water Company. PUG (2008) also provides estimates of potential major users that are expected to develop pumping in the future but are not yet active. Potential major users identified by PUG (2008) and included in the model are Mission Peaks Development, Twin Buttes Properties, ASLD Trust Land, and Rosemont Copper Company. The potential major users are included in the model to account for the projected growth in water usage at new developments.

Sierrita's groundwater use is estimated to be approximately 16,600 gpm through 2009 when water use is expected to increase for a scheduled increase in mine production. The FS assumes that water use is estimated to be 17,240 gpm from 2010 through the end of mine life, although future changes in mining rate could alter these pumping rates. The FS also assumes that the volume of groundwater pumped for sulfate mitigation will be offset by a one-to-one reduction of Sierrita's water supply pumping at the Canoa Ranch wellfield. The offset of mitigation pumping means that during mining operations there would be no net change in the amount of groundwater pumping by Sierrita for mining use over what is expected to be pumped (during mine operations) under current mine planning assumptions. Instead, pumping would be partially relocated from Canoa Ranch to the area of the sulfate plume as needed for mitigation. The relocation of pumping would have the beneficial effect of increasing the volume of unimpacted groundwater in the aquifer upgradient of Green Valley, while reducing the volume of impacted groundwater in the plume. As noted in Section 2.3, mine plans are periodically reevaluated. Thus, assumptions on Sierrita's future water use, including the required pumping from the Canoa Ranch wellfield, are subject to change depending on mine operations.

Future changes to STI seepage and recharge were also estimated for input to the numerical model. Sierrita plans to increase mine and mill production in 2010. The production change will increase the delivery of tailing and water to the STI. As described in Appendix F, seepage from the STI is expected to increase following the production increase. Numerical simulations of the alternatives indicated that additional source control wells would be needed in the southern IW wellfield to capture the increased seepage. As discussed in Sections 4.3.1 through 4.3.5, the additional wells are included in the source control assumptions for Alternatives 1 through 5.

At the conclusion of tailing deposition, the drain down of pore water stored in the STI will commence. The rate of drain down continuously declines over time such that most of the drain down occurs in the first 25 years after tailing deposition ends, after which drain down rates are relatively slow. The drain down rate and volume depend on the physical properties of the tailing and the duration and volume of tailing deposition. The mitigation alternatives consider two different times for the start of drain down from the STI. Drain down would start at the end of mine life in Alternatives 1, 2, and 3. Drain down would start earlier in Alternatives 4 and 5 because these alternatives assume a new tailing impoundment would be constructed. The numerical modeling of mitigation alternatives included the projected future seepage from the STI due to the production increase in 2010 and drain down as described in Appendix F.

The recharge of CAP water in the Green Valley area is under consideration by local water users and providers. CAP recharge was included in the simulations based on the projections in PUG (2008) and Erwin (2008). The recharge site assumed in the model is about a mile east of the Santa Cruz River in Section 29, Township 17 South, Range 14 East as reported by Bureau of Reclamation (2008). An important consideration regarding the potential recharge of CAP water is that CAP water contains sulfate in excess of the Mitigation Order action level of 250 mg/L. For example, the 24 month average (August 2006 to July 2008) sulfate concentration measured in CAP water at the San Xavier pump plant (the southern most sampling point for CAP water) is 266 mg/L (Appendix F). The recharge of water containing sulfate in excess of the Mitigation Order action level needs to be carefully planned so that the recharge does not create a new sulfate plume or impact mitigation of the existing sulfate plume.

Effort was made in the FS to use the best available water extraction and recharge projections for the major groundwater users of the area so that the projections of future conditions could be as accurate as possible based on current knowledge. Nonetheless, quantifying long-term, future projections of the location, timing, and magnitude of future pumping and recharge in a developing area such as Green Valley is difficult and subject to considerable uncertainty. Significant differences between the actual future pumping and recharge and the assumptions in the model can result in differences between the model predictions and actual conditions.

4.2 Cost Analysis Methodology

A detailed cost analysis was made for each mitigation alternative based on the expected permitting and design, procurement, construction, and O&M activities required to implement and operate the alternative. Capital and O&M costs are calculated over a 50-year period from

January 2009 through December 2058 to determine the total non-discounted cost (the sum of expenditures over time without discounting the time value of money) and the 50-year net present value (NPV(50)) of each alternative over both mining and post-mine conditions. The 50-year period includes 16 years of mitigation after the assumed mine closure. A discount rate of 7.8 percent and an escalation rate of 2.4 percent are used to calculate the NPV(50) (these rates are consistent with parameters used by Sierrita for internal environmental decision-making purposes). For costing purposes, initial capital expenditures are assumed to occur in 2009, and O&M is assumed to start in 2010. Expenditures of capital for water treatment are assumed to occur in 2042, the last year of mine operation assumed for costing purposes, with water treatment O&M beginning in 2043.

The cost model developed for each alternative includes the source control, plume management, and drinking water supply mitigation actions required for the alternative. Cost estimates are developed for pumping and water management for the source control and plume management specifications of the alternatives. Certain source control actions are considered Sierrita operational projects to be implemented, permitted, and financed by Sierrita as part of the mining operation. Sierrita operational projects were not included in the analysis of mitigation costs. The upgradient source controls such as reclaim pond pumping, surface water controls, and final reclamation (Section 2.3.1.1) were excluded from the mitigation costs because they are operational projects that will be implemented under Sierrita's APP and reclamation programs rather than the Mitigation Order. Downgradient source control pumping at the IW wellfield was not included in the mitigation alternative costs during mine life because these are existing operational wells used for water supply and seepage control. The O&M costs for the IW wellfield are included in the mitigation alternative costs after mine closure when there is no operational function for them. The new tailing impoundment included as source control in Alternatives 4 and 5 is not included in the cost estimate because it is a mine facility to be developed under Sierrita's mine plan and permitted under a modification of Sierrita's APP.

Capital costs of the mitigation included permitting, surveying, access leases, engineering design, and construction (wells, pump installation, electrical service, pipelines) needed to implement the alternative. Capital costs were based as much as possible on vendor quotes developed specifically for the FS and FFS (HGC, 2007b). The placement, sizing, and quantity of capital items such as wells, pumps, and pipelines were based on preliminary conceptual designs developed from pumping specifications indicated by the results of numerical simulation of the alternatives. The capital cost of water treatment was based on the MWH's cost estimate for RO treatment (Appendix D).

Mitigation O&M costs included power, equipment replacement, labor, and ongoing fees. Fees included in O&M are discussed in Section 4.2.1. Wellfield and pipeline O&M costs were based on the actual costs of running the IW wellfield in 2006 including labor, repair/replacement of equipment, electricity for pumps, well and pump repair/replacement, and consulting services. The water treatment O&M is based on MWH's estimate for operation of an RO treatment system (Appendix D).

The FS cost estimates were developed from preliminary engineering calculations, industry experience, current professional rates, cost and rate data from Sierrita, water treatment cost estimates from MWH (Appendix D), and vendor quotations where possible. The level of accuracy of the water extraction and conveyance systems (capital/O&M) is on the order of plus or minus 35 percent. Water treatment/residual management costs (capital/O&M) are reported by MWH to be plus or minus 40 percent.

The cost analyses for Alternatives 1 through 5 are discussed in Sections 4.3.1 through 4.3.5, respectively. Cost spreadsheets for each alternative are contained in Appendix H.

4.2.1 Water Fees

Sierrita pays annual water fees to ADWR and FICO for the amount of groundwater it pumps. These fees are an operational cost that Sierrita would incur for mine water supply regardless of the location of pumping. Groundwater pumped for the mitigation will be used for mine supply during operations. Because the mitigation pumping will be offset gallon per gallon with a reduction of the mine supply pumping at Canoa Ranch, there would be no net increase in mine supply pumping or the associated fees. For this reason, the ADWR and FICO fees are considered operational costs during mine life and are included in the cost of the mitigation alternatives only after mining water use stops at the end of 2042. The annual ADWR fee for water pumped pursuant to Sierrita's water rights and permits is $3.00 per acre-foot. The annual FICO fee varies based on groundwater withdrawal. For the purpose of the FS cost estimate, the annual FICO fee is assumed to be $150,000.

4.2.2 Credits

Current operational expenditures that would be avoided under the mitigation alternatives are credited to the alternatives to estimate the net additional cost of the alternative over current operations. The cost model for each alternative includes an O&M credit during the life of mine for the costs avoided by shifting pumping from the Canoa Ranch wells to the mitigation wells exclusive of the IW wells. The annual cost savings from the reduction of pumping at Canoa Ranch is applied as a credit to the alternatives during the mine life only.

4.3 Analysis of Individual Mitigation Alternatives

The mitigation alternatives generally described in Section 3 and Table 2 are described more fully in this section. The detailed analysis of individual mitigation alternatives describes the conceptual models developed for the alternatives using numerical simulations to identify well locations and pumping rates that accomplish the objectives of the alternatives. The wellfield and pipeline assumptions for the alternatives are presented along with a schedule of groundwater pumping rates over time. The results of numerical simulation of the mitigation alternative specifications are used to illustrate the effectiveness of the alternatives by showing the predicted location of the sulfate plume over time. The implementability of the mitigation alternatives is described based on expected permitting requirements, implementation timeframes, and technological constraints. The cost of the alternatives is provided based on the estimation methodology described in Section 4.2.

MWH used a water balance model to quantitatively evaluate the feasibility of in-pit storage for post-mine mitigation flows predicted for Alternatives 3 and 5 from 2043 through 2116 (Appendix E). The water balance model considered mitigation inflows, groundwater inflows, incident precipitation, and surface water inflows to the pit, and evaporation from the pit over time. As will be discussed in the descriptions of the individual mitigation alternatives that follow, the post-mine mitigation flow rates predicted for Alternatives 3 and 5 differ significantly. Alternative 3 represents relatively high post-mine mitigation flows that start at 9,360 gpm in 2043 and decline to 2,600 gpm in 2090. Alternative 5 represents relatively low post-mine mitigation flows that start at 2,560 gpm in 2043 and decline to 2,460 in 2081. Because of the relatively low post-mine flow of Alternative 5, the need to maintain post-mine pumping to meet the mitigation objective would be evaluated every five years against switching to MNA.

The water balance analyses indicates that even the relatively high predicted mitigation flows of Alternative 3 could be added to the pit over the next 100 years and still maintain the pit as a hydraulic sink. However, although the water elevation in the pit under Alternative 3 is predicted to be approximately 200 feet below the level in the surrounding aquifer after 100 years, in-pit storage of mitigation flows at the magnitude of Alternative 3 may not be applicable given uncertainty in water balance parameters and the decision to maintain additional freeboard in the pit as a safety factor. The water elevation in the pit under Alternative 5 is predicted to be approximately 600 feet below the surrounding aquifer after 100 years. Thus, in-pit storage is considered applicable for mitigation flows of the magnitude of Alternative 5.

There is insufficient information to place strict boundaries on the magnitude of flow that could be managed by in-pit storage until additional analysis is completed. Based on the information in Appendix E, an initial flow of 5,000 gpm is preliminarily selected as an upper limit of flow considered to be appropriate for in-pit management for the purposes of the FS. However, additional evaluation of in-pit storage may determine that a different level of flow may be appropriate for in-pit storage.

4.3.1 Alternative 1 – Source Control and Monitored Natural Attenuation

Alternative 1 would implement only the base case actions for source control, plume management, and contingent drinking water supply mitigation (Section 3.1). Under Alternative 1 it is assumed that tailing would be discharged to the STI throughout the rest of mine life. Downgradient source control would capture seepage from the STI by pumping at the IW and FFS wellfields, and would minimize infiltration and runon to the STI for source control at the STI. Alternative 1 would use MNA and groundwater monitoring for plume management. Figure 9 shows the wells and pipelines required for Alternative 1. Table 3 contains the pumping specification for Alternative 1.

Downgradient source control would consist of pumping at the existing IW wellfield, installation of four additional source control (SC) wells in the southern IW wellfield, and installation of six wells for the FFS wellfield. In addition to the existing IW wells, numerical modeling of future conditions, including simulation of seepage due to the production increase in 2010, indicated that four additional wells (SC-1 through SC-4), are needed to maintain capture in the southern IW wellfield. The FFS wellfield would consist of six production wells (FFS-1 through FFS-6) to be installed in a north-south array on county right-of-way or private land as described by HGC (2007b). The FFS well locations and pumping rates were revised from those in HGC (2007b) based on simulations with the updated model. Approximately 4,860 gpm would be pumped at the IW wellfield, 1,500 gpm at the SC wellfield, and 3,150 gpm at the FFS wellfield (Table 3). Pumping rates would be constant during mine life. The total simulated mitigation pumping decreases from 9,510 gpm to 9,360 gpm at mine closure in 2043 and then decreases again to 8,010 gpm in 2051 (Table 3) because the STI seepage rate decreases as drain down progresses and less pumping is required to maintain capture.

A review of existing Sierrita infrastructure indicates that water from the SC and FFS wells would best be conveyed to the mine for use via a new pipeline that connects to the existing IW wellfield pipeline at the southeast corner of the STI. Water from the FFS wells would be piped to the IW wellfield pipeline through a new pipeline that would be installed across ASLD property along the right-of-way of the existing Esperanza pipeline and then south along the east side of the STI (Figure 9). The SC wells would be connected directly into the new pipeline.

In addition to downgradient source control, Alternative 1 would provide source control at the STI by reducing current infiltration into the impoundment by increasing reclaim pond pumping and decreasing the amount of surface water discharge to the STI. The potential for future infiltration into the STI after mine closure would be controlled by surface water controls and a soil cover for final reclamation of the STI.

Plume management for Alternative 1 would consist of MNA and groundwater monitoring. Long-term groundwater monitoring at existing and future monitoring wells would be used to evaluate plume attenuation over time. Groundwater monitoring would also be performed to determine if a water supply mitigation action needs to be implemented because there is a potential for an existing water supply to become impacted by the plume. Long-term groundwater monitoring data would be used to confirm the performance of Alternative 1 and make operational decisions during the mitigation. The mitigation alternative would be operated using the principles of adaptive management to evaluate new information as it becomes available and make modifications to the mitigation alternative, such as adjusting pumping rates or installing additional extraction wells, as determined to be necessary by operational experience and/or modeling.

Water pumped for source control would be managed for use at the mine during mine life. Mitigation pumping at approximately 9,360 gpm would be needed after mine closure because seepage from the STI is predicted to persist past the end of mine life. Because the post-mine pumping rate is more than can be managed by in-pit storage, it is assumed that an RO water treatment facility would be constructed at Sierrita for water management. The end use of the treated water would depend upon the water rights or permits in place at the time. Blending may also be applicable for water management and is included as a contingency, but was not included in the cost of Alternative 1. The RO reject rate of approximately 2,340 gpm is low enough to be managed by in-pit storage.

Figure 10 shows the predicted extent of the sulfate plume after 50 years of Alternative 1. The simulated sulfate plume extent shown on Figure 10 is based on the maximum sulfate concentration across the three model layers. The downgradient extent of the plume is predicted to migrate approximately one mile north of its present location over the 50-year period. The simulation results indicate that the plume moves toward but does not reach the LQS drinking water supply wells ST-5, ST-6, and ST-7. The simulation results for Alternative 1 predict that the eastern extent of the plume does not expand, and that existing water supply wells operated by CWC and GVDWID are not impacted.

If, however, groundwater monitoring indicated that an existing drinking water supply could become impacted by the downgradient migration of the plume, the supply would be mitigated per ARS § 49-286 and the Mitigation Order. Subject to site-specific constraints, long-term mitigation actions would likely entail blending, connection to an alternative water supply, or water treatment.

Effectiveness

Alternative 1 would attain the mitigation objective of providing a drinking water supply with sulfate concentrations less than 250 mg/L. Existing drinking water supply wells are not predicted to be impacted, although the downgradient plume does approach the LQS supply wells after 50 years of Alternative 1 being implemented.

Downgradient source control pumping would be effective at containing seepage from the STI at the IW, FFS, and SC wellfields as indicated by the results of particle tracking simulations shown in Appendix G. Because the FFS wells are inside the sulfate plume, pumping the FFS wellfield creates an internal groundwater sink that prevents seepage from the STI from flowing past the capture zone of the FFS wellfield to the downgradient aquifer. Pumping the FFS wellfield also would decrease the driving force for eastward migration of the sulfate plume toward existing water supply wells in Green Valley. Source control pumping for Alternative 1 would need to continue through and after mine life to capture seepage from the STI. Mixing between the plume and unimpacted groundwater is not predicted to be sufficient to completely attenuate the downgradient plume during the 50-year simulation timeframe of Alternative 1. Although source control pumping under Alternative 1 decreases some of the mass of sulfate in the downgradient plume, it is insufficient to draw the eastern portion of the downgradient plume back and the northern portion of the downgradient plume would continue to migrate northward. This continued northward migration is not predicted to impact existing drinking water supply wells within the 50-year simulation period. Overall, the northern extent of the downgradient plume increases compared to the current distribution of sulfate, while the southeastern and eastern extents decrease.

Implementability

There are no significant technical barriers expected for implementation of Alternative 1. Potential administrative constraints on implementation could be developing timely access and permits for work on county right-of-way, private land, and ASLD property; issues associated with water level effects due to mitigation wells; and constraints on certain post-mine end uses of treated water depending on the water rights and permits in effect at the time. An analysis of water level effects related to mitigation pumping is provided in Section 4.4.2.4.

Upgradient source control actions at the STI could be implemented within 12 months. The SC wells can be implemented on Sierrita property. The FFS wellfield would require lead time for design, land access negotiation, and permitting. Preliminary analysis of land status indicates that the FFS extraction wells and header pipeline could be installed on county right-of-way or private land. Alternative 1 would use ASLD land for the pipeline corridor from the FFS wells to the IW wellfield pipeline. The new pipeline would be installed along the existing right-of-way for the Esperanza pipeline, which would require permitting and negotiation with ASLD regarding the right-of way. ASLD land may also be needed for some manifold piping connecting the southern FFS wells. Use of county right-of-way or private land for installation of basic infrastructure (e.g., wellfields including roads, drilling pads, pipeline corridors, and electric service) would require necessary permitting and approvals. Obtaining land access for well installation and pipelines is expected to take 6 to 12 months. Wellfield and pipeline design, procurement, and construction are expected to take 12 to 18 months once access is secured. The total time expected to implement Alternative 1 is approximately 18 to 30 months.

Cost

Alternative 1 has an estimated initial capital cost of $10.8 million, a non-discounted cost of $173 million, and an NPV(50) of $37.1 million. Alternative 1 costs include pre-construction costs, capital costs, O&M costs, and replacement/repair costs for the facilities required for the alternative, including the FFS and SC wells. As described in Section 4.2, the Alternative 1 cost estimate does not include source control at the STI (Section 2.3.2.2) which is being conducted under Sierrita's APP and reclamation programs. Table 4 summarizes the costs of Alternative 1. A detailed summary of estimated costs for Alternative 1 is presented in Appendix H.

The estimated initial pre-construction costs include: surveying and federal and state permitting that may be required for construction of drilling pads; electrical lines; access roads and piping runs; archeological survey; and endangered species survey. Also included are costs associated with engineering design and construction drawing/specifications for: electrical installations; wellhead instrumentation; control and telemetry; piping and valves; and groundwater extraction wells.

Initial capital costs include: drilling and construction of the SC and FFS wellfields; pump assembly and installation; overhead power lines; electrical equipment, materials and installation; discharge piping and installation; and construction/project management.

Annual O&M costs during mine life include electrical power for the SC and FFS wellfields, additional electrical power required by the IW wellfield pump station, supplies, labor, groundwater monitoring, and consulting. The savings in Canoa Ranch wellfield O&M costs expected for reducing Canoa Ranch pumping by the amount of water pumped from the SC and FFS wells is estimated at $1.49 million per year and was applied as an O&M credit during mine life. Annual O&M costs after mine life include costs associated with continued pumping of the IW wellfield.

Annual supplies and labor costs for the wellfields are estimated from IW wellfield costs incurred during 2006 (Appendix H). These supply and labor costs are assumed to be proportional to the number of associated wells. The 0.48 cost factor in Appendix H is, therefore, the ratio of the number of additional mitigation wells to the number of existing IW wells in 2006 (i.e., 10 additional mitigation wells/21 existing IW wells), multiplied by the sum of 2006 operating supplies costs ($35,000) and labor costs ($114,000), totaling $149,000 (Appendix H).

Annual costs associated with the repair and/or replacement of materials and equipment include labor, piping, pumps, and motors. Repair and replacement costs are also estimated using IW wellfield costs in 2006. These repair and replacement costs are assumed to be proportional to the total flow rate. The 0.78 and 0.75 cost factors provided in Appendix H are, therefore, the ratio of additional mitigation flow to flow from IW wells in 2006 (i.e., 4,650 gpm additional mitigation flow/6,000 gpm IW flow; 4,500 gpm additional mitigation flow/6,000 gpm IW flow), multiplied by the sum of 2006 equipment/materials repair and/or replacement costs ($97,000), well/pump repair and/or replacement costs ($325,000), additional fabrication costs ($75,000), and maintenance and repair labor costs ($210,000), totaling $707,000 (Appendix H).

Alternative 1 assumes that water treatment would be needed after the end of mine life. The estimated costs for water treatment included capital for installation of an RO water treatment facility and O&M for future operations. The capital cost for water treatment is $31.8 million for the 9,360 gpm flow indicated by the numerical simulation. O&M consists of electricity, labor, and materials for operation of the RO plant. Assuming mining ceases in 2042, the O&M costs of post-mine pumping would decline somewhat after 2050 due to a decrease in pumping in the SC and FFS wells because source control pumping is decreased due to the reduction of STI seepage over time caused by drain down starting in 2043. As discussed in Section 2.3, the actual duration of mining could be different than what was assumed for purposes of mitigation alternative evaluation and cost estimation.

4.3.2 Alternative 2 – Source Control and Plume Stabilization

Alternative 2 would add groundwater pumping for plume management to the base case actions for source control, plume management, and contingent drinking water supply mitigation. Under Alternative 2 it is assumed that tailing would be discharged to the STI throughout the duration of mine life. Alternative 2 proposes pumping at the IW, FFS, and SC wellfields for downgradient source control, and would minimize infiltration into the STI for source control at the STI. Alternative 2 would use four plume stabilization (PS) wells to be located in the northern portion of the plume to pump groundwater and stabilize the northward extent of the plume. Numerical simulations indicate that pumping along the eastern boundary of the plume is not needed to prevent eastward migration of the plume. Groundwater monitoring and contingent drinking water supply mitigation are included in Alternative 2. Figure 11 shows a conceptual layout of facilities for Alternative 2. Table 5 contains pumping specifications for Alternative 2.

Downgradient source control would consist of pumping at the existing IW wellfield, installation of four additional wells in the southern IW wellfield, and installation of six wells for the FFS wellfield. In addition to the existing IW wellfield, numerical modeling of future conditions, including simulation of seepage due to the production increase in 2010, indicated that the SC wellfield (SC-1 through SC-4) is needed to maintain capture in the southern IW wellfield. The FFS wellfield would consist of six production wells (FFS-1 through FFS-6) to be installed in a north-south array on county right-of-way or private property as described by HGC (2007b). The FFS well locations and pumping rates were revised from those in HGC (2007b) based on simulations with the updated model. Initially, approximately 4,860 gpm would be pumped at the IW wellfield, 1,500 gpm at the SC wellfield, and 3,100 gpm at the FFS wellfield (Table 5).

Pumping rates at the IW, SC, and FFS wellfields would be constant during mine life and for several years after the assumed mine closure in 2042. The simulated pumping rate source control pumping decreases from 9,460 gpm to 8,010 gpm in 2051 (Table 5) because seepage rates from the STI progressively decrease as drain down progresses and require less pumping to maintain capture. The pumping rates at the IW, SC, and FFS wellfields after the assumed end of mining would be the minimum needed to maintain capture for source control.

A review of existing Sierrita infrastructure indicates that water from the SC and FFS wells would best be conveyed to the mine for use via a new pipeline that connects to the existing IW wellfield pipeline at the southeast corner of the STI. Water from the FFS wells would be piped to the IW wellfield pipeline through a new pipeline that would be installed across ASLD property along the right-of-way of the existing Esperanza pipeline and then south along the east side of the STI (Figure 11). The SC wellfield would be connected directly into the new pipeline.

Alternative 2 also includes source control at the STI by reducing current infiltration into the impoundment by increasing reclaim pond pumping and decreasing the amount of surface water discharge to the STI. Potential future infiltration after mine closure would be controlled by surface water controls and a soil cover for final reclamation of the STI.

Plume management for Alternative 2 would consist of plume stabilization pumping and groundwater monitoring. Plume stabilization pumping would be conducted at four wells (PS-1 through PS-4) near the leading edge of the downgradient plume. Numerical simulation of Alternative 2 indicates that initially pumping the PS wellfield at 2,300 gpm (Table 5) would prevent downgradient plume migration. The pumping rate at the PS wellfield decreases from 2,300 gpm to 1,500 gpm over time because the first few years require higher pumping rates while capture is established and subsequent years require less pumping as source control pumping decreases the hydraulic load to the PS wellfield. The PS wellfield at the leading edge would be located on private land or county right-of-way near and north of Duval Mine Road and west of La Canada Drive (Figure 11). A pipeline would be constructed from the PS wellfield to the FFS wellfield pipeline to convey water to the mine for use.

Long-term groundwater monitoring at existing and future monitoring wells would be used to evaluate plume attenuation over time. Groundwater monitoring would also be performed to determine if a water supply mitigation action needs to be implemented because there is a potential for an existing water supply to become impacted by the plume. Long-term groundwater monitoring data would be used to confirm the performance of the alternative and make operational decisions during the mitigation. The mitigation alternative would be operated using the principles of adaptive management to evaluate new information as it becomes available and make modifications to the mitigation alternative, such as adjusting pumping rates or installing additional extraction wells, as determined to be necessary by operational experience and/or modeling.

Water pumped for source control and plume management would be managed for use at the mine during mine life. Mitigation pumping at approximately 10,960 gpm would be needed after mine closure because seepage from the STI is predicted to persist past the end of mine life and the downgradient plume is not predicted to be attenuated. Because the post-mine pumping rate is more than can be managed by in-pit storage, it is assumed that an RO water treatment facility would be constructed at Sierrita for water management. The end use of treated water would depend upon the water rights or permits in place at the time. Blending may also be applicable for water management and is included as a contingency, but was not included in the cost of Alternative 2. The RO reject rate of approximately 2,740 gpm is low enough to be managed by in-pit storage.

The simulated sulfate plume extent after 50 years of Alternative 2 is shown on Figure 12. The simulated sulfate plume extent shown on Figure 12 is based on the maximum sulfate concentration across the three model layers. The northern portion of the downgradient plume is predicted to remain relatively stable during Alternative 2 while the eastern and southeastern portions of the plume are predicted to move westward toward the FFS wells. The combination of downgradient source control pumping and plume stabilization pumping are predicted to keep the northern portion of the downgradient plume within its current approximate footprint. Based on the simulation results, the eastern and southeastern extents of the plume decrease over time and sulfate impacts are not predicted at existing drinking water supply wells operated by LQS, CWC, and GVDWID. Drinking water supply mitigation is not predicted to be needed under Alternative 2, but would be provided as a contingency per ARS § 49-286 and the Mitigation Order if groundwater monitoring indicates that an existing drinking water supply could become impacted.

Effectiveness

Alternative 2 would attain the mitigation objective of providing a drinking water supply with sulfate concentrations less than 250 mg/L. Because the plume footprint does not increase, the existing drinking water supply wells of LQS, CWC, and GVDWID are not predicted to be impacted in Alternative 2.

Alternative 2 would effectively contain seepage from the STI at the IW, FFS, and SC wellfields and stabilize the downgradient plume at the PS wellfield as indicated by the results of particle tracking simulations shown in Appendix G. The downgradient plume is not predicted to migrate beyond its current approximate limits. Because the FFS wells are inside the sulfate plume, pumping the FFS wellfield creates an internal groundwater sink that prevents seepage from the STI from flowing past the capture zone of the FFS wellfield to the downgradient aquifer. Pumping the FFS wellfield would also decrease the driving force for eastward migration of the sulfate plume towards existing water supply wells in Green Valley. Pumping at the PS wellfield would exert some additional influence in driving the downgradient plume northward, but pumping rates are specified to match the groundwater flux such that downgradient movement of the plume does not occur. Alternative 2 would effectively decrease the mass of sulfate in the plume by extraction at the IW, SC, FFS, and PS wellfields such that the northern extent of the downgradient plume does not increase compared to the current distribution of sulfate and the eastern and southeastern extents of the plume decrease. The numerical simulation indicates that pumping would need to continue at the IW, SC, FFS, and PS wellfields after the 50-year simulation period because seepage from the STI may be too large to stop source control pumping and the downgradient plume has not attenuated enough to discontinue plume stabilization pumping.

Implementability

There are no significant technical barriers expected for implementation of Alternative 2. Potential administrative constraints on implementation could be developing timely access and permits for work on county right-of-way, private land, and ASLD property; issues associated with water level effects due to mitigation wells; and constraints on certain post-mine end uses of treated water depending on the water rights and permits in effect at the time. An analysis of water level effects related to mitigation pumping is provided in Section 4.4.2.4.

Upgradient source control actions at the STI can be implemented within 12 months. The SC wellfield can be implemented on Sierrita property. The FFS wellfield would require lead time for design, land access negotiation, and permitting. Preliminary analysis of land status indicates that the FFS extraction wells and header pipeline could be installed on county right-of-way or private land. Alternative 2 would use ASLD land for the pipeline corridor from the FFS wells to the IW wellfield pipeline. The new pipeline would be installed along the existing right-of-way for the Esperanza pipeline, which would require permitting and negotiation with ASLD regarding the right-of way. ASLD land may also be needed for some manifold piping connecting the southern FFS wells. The PS wellfield at the leading edge of the downgradient plume would require lead time for design, land access negotiation, and permitting. Alternative 2 would build a pipeline from the PS wellfield to the pipeline that would be developed for the FFS wellfield. Use of county right-of-way or private land for installation of basic infrastructure (e.g., wellfields including roads, drilling pads, pipeline corridors, and electric service) would require necessary permitting and approvals. Obtaining land access for well installation and pipelines is expected to take 12 to 18 months. Wellfield and pipeline design, procurement, and construction are expected to take 12 to 18 months once access is secured. The total time expected to implement Alternative 2 is approximately 24 to 36 months.

Cost

Alternative 2 has an estimated initial capital cost of $16.0 million, a non-discounted cost of $207 million, and an NPV(50) of $49.1 million. The Alternative 2 costs include pre-construction costs, capital costs, O&M costs, and replacement/repair costs for the facilities required for the alternative. As described in Section 4.2, the Alternative 2 cost estimate does not include source control at the STI (Section 2.3.2.2) which is being conducted under Sierrita's APP and reclamation programs. Table 6 summarizes the costs of Alternative 2. A detailed summary of estimated costs for Alternative 2 is presented in Appendix H.

The estimated initial pre-construction costs include: surveying and federal and state permitting that may be required for construction of drilling pads; electrical lines; access roads and piping runs; archeological survey; and endangered species survey. Also included are costs associated with engineering design and construction drawing/specifications for: electrical installations; wellhead instrumentation; control and telemetry; piping and valves; and groundwater extraction wells.

Initial capital costs include: well drilling and construction of the SC, FFS, and PS wellfields; pump assembly and installation; overhead power lines; electrical equipment, materials, and installation; discharge piping and installation; and construction/project management.

Annual O&M costs during mine life include: electrical power for the SC, FFS, and PS wellfields; additional electrical power required by the IW wellfield pump station; supplies; labor; groundwater monitoring; and consulting. The savings in Canoa Ranch wellfield O&M costs expected for reducing Canoa Ranch pumping by the amount of water pumped from the SC, FFS, and PS wellfields is estimated at $2.1 million per year and was applied as an O&M credit during mine life. Annual O&M costs after mine life include costs associated with continued pumping of the IW wells.

Annual supplies and labor costs for the wellfields are estimated from IW wellfield costs incurred during 2006 (Appendix H). These supply and labor costs are assumed to be proportional to the number of associated wells. The 0.67 cost factor in Appendix H is, therefore, the ratio of the number of additional mitigation wells to the number of existing IW wells in 2006 (i.e., 14 additional mitigation wells/21 existing IW wells), multiplied by the sum of 2006 operating supplies costs ($35,000) and labor costs ($114,000), totaling $149,000 (Appendix H).

Annual costs associated with the repair and/or replacement of materials and equipment include labor, piping, pumps, and motors. Repair and replacement costs are also estimated using IW wellfield costs in 2006. These repair and replacement costs are assumed to be proportional to the total flow rate. The 1.15 and 1.02 cost factors provided in Appendix H are, therefore, the ratio of additional mitigation flow to flow from IW wells in 2006 (i.e., 6,900 gpm additional mitigation flow/6,000 gpm IW flow; 6,100 gpm additional mitigation flow/6,000 gpm IW flow), multiplied by the sum of 2006 equipment/materials repair and/or replacement costs ($97,000), well/pump repair and/or replacement costs ($325,000), additional fabrication costs ($75,000), and maintenance and repair labor costs ($210,000), totaling $707,000 (Appendix H).

Alternative 2 assumes that water treatment will be required after the end of mine life. The estimated costs for water treatment included capital for installation of an RO water treatment facility and O&M for future operations. The capital cost for water treatment is $34.9 million for the 10,960 gpm flow indicated by the numerical simulation. O&M consists of electricity, labor and materials for operation of the RO plant. Assuming mining ceases in 2042, the O&M costs of post-mine pumping and treatment would decline somewhat after 2050 because pumping at the SC and FFS wellfields is decreased due to the reduction of STI seepage over time caused by drain down starting in 2043. As discussed in Section 2.3, the actual duration of mining could be different than what was assumed for the purposes of mitigation alternative evaluation and cost estimation.

4.3.3 Alternative 3 – Source Control, Plume Stabilization, and Mass Removal

Alternative 3 is an aggressive plume management strategy that would stabilize the leading edge of the plume and remove sulfate from within the plume to reduce its footprint by the end of mine life. Under Alternative 3 it is assumed that tailing would be discharged to the

STI throughout the duration of mine life. Alternative 3 proposes the same upgradient and downgradient source control actions as Alternatives 1 and 2. Alternative 3 would use the PS wellfield at the northern edge of the plume for plume stabilization, and would maximize pumping at the FFS wellfield while using two additional mass capture (MC) wells east of the FFS wellfield to increase mass removal. Numerical simulations indicate that pumping along the eastern boundary of the plume is not needed to prevent eastward migration of the plume. Groundwater monitoring and contingent drinking water supply mitigation are included in Alternative 3. Figure 13 shows a conceptual layout of the well and pipeline facilities that would be installed for Alternative 3. Table 7 contains pumping specifications for Alternative 3.

The objective of Alternative 3 is to pump as much water from the downgradient plume as can be used at the mine so as to accelerate the removal of sulfate mass from the plume during mine life. Therefore, pumping rates for Alternative 3 during mine life are greater than those needed for source control pumping and plume stabilization pumping alone.

Downgradient source control would consist of pumping at the existing IW wellfield, installation of four additional wells in the southern IW wellfield, and installation of six wells for the FFS wellfield. In addition to the existing IW wellfield, numerical modeling of future conditions, including simulation of seepage due to the production increase in 2010, indicated that the SC wellfield (SC-1 through SC-4) is needed to maintain capture in the southern IW wellfield. The FFS wellfield would consist of six production wells (FFS-1 through FFS-6) to be installed in a north-south array on county right-of-way or private property as described by HGC (2007b). The FFS well locations and pumping rates were revised from those in HGC (2007b) based on simulations with the updated numerical model. Initially, approximately 4,860 gpm would be pumped at the IW wellfield, 1,600 gpm at the SC wellfield, and 5,450 gpm at the FFS wellfield (Table 7). The pumping rates at the FFS wellfield would be higher than needed for source control pumping alone because Alternative 3 also uses the FFS wellfield for plume management pumping. Pumping rates at the IW, FFS, and SC wellfields would be decreased from 11,910 gpm to 11,810 gpm in 2031, 9,360 gpm in 2043, and 8,110 gpm in 2051 (Table 7). The pumping rates at the IW, SC, and FFS wellfields after the assumed end of mine life would be the minimum needed to maintain capture for source control. The simulated pumping rate at the IW, FFS, and SC wellfields decrease in 2051 because seepage rates from the STI decrease as drain down progresses and require less pumping to maintain capture.

A review of existing Sierrita infrastructure indicates that water from the SC and FFS wells would best be conveyed to the mine for use via a new pipeline that connects to the existing IW wellfield pipeline at the southeast corner of the STI. Water from the FFS wells would be piped to the IW wellfield pipeline through a new pipeline that would be installed across ASLD property along the right-of-way of the existing Esperanza pipeline and then south along the east side of the STI (Figure 13). The SC wellfield would be connected directly into the new pipeline.

Alternative 3 also includes source control at the STI by reducing current infiltration into the impoundment by increasing reclaim pond pumping and decreasing the amount of surface water discharge to the STI. Potential future infiltration after mine closure would be controlled by surface water controls and a soil cover for final reclamation of the STI.

Plume management for Alternative 3 would consist of mass capture pumping, plume stabilization pumping, and groundwater monitoring. Mass capture pumping would be conducted by pumping the FFS wellfield at high rates and by pumping MC-1 and MC-2 east of the FFS wellfield. Plume stabilization pumping would be conducted at four wells (PS-1 through PS-4) near the northern edge of the downgradient plume. Numerical simulation of Alternative 3 indicates that initially pumping 1,500 gpm at the MC wellfield, pumping 2,300 gpm at the PS wellfield, and pumping the FFS wellfield at higher rates than necessary to capture seepage from the STI (Table 7) would prevent downgradient plume migration and would reduce the plume footprint over time. The total simulated pumping rates at the MC and PS wellfields decrease from 3,800 gpm to 2,600 gpm over time to adjust to changing hydraulic and water quality conditions. At the end of mine life assumed for the FS the downgradient plume is sufficiently attenuated that pumping at the MC and PS wellfields can be discontinued. The MC and PS wellfields would be located on private land or county right-of-way near and north of Duval Mine Road and west of La Canada Drive (Figure 13). A pipeline would be constructed from the MC and PS wells to the FFS wellfield pipeline to convey water to the mine for use.

Long-term groundwater monitoring at existing and future monitoring wells would be used to evaluate plume attenuation over time. Groundwater monitoring would also be performed to determine if a water supply mitigation action needs to be implemented because there is a potential for an existing water supply to become impacted by the plume. Long-term groundwater monitoring data would be used to confirm the performance of the alternative and make operational decisions during the mitigation. The mitigation alternative would be operated using the principles of adaptive management to evaluate new information as it becomes available and make modification to the mitigation alternative, such as adjusting pumping rates or installing additional extraction wells, as determined to be necessary by operational experience and/or modeling.

Water pumped for source control and plume management would be managed for use at the mine during mine life. Source control pumping at approximately 9,360 gpm would be needed after mine closure because seepage from the STI is predicted to persist past the end of mine life although plume management pumping would no longer be needed. Because the post-mine pumping rate is more than can be managed by in-pit storage, it is assumed that an RO water treatment facility would be constructed at Sierrita for water management. The end use of treated water would depend upon the water rights or permits in place at the time. Blending may also be applicable for water management and is included as a contingency, but was not included in the cost of Alternative 3. The RO reject rate of approximately 2,340 gpm is low enough to be managed by in-pit storage.

The simulated sulfate plume extent after 50 years of Alternative 3 is shown on Figure 14. The simulated sulfate plume extent shown on Figure 14 is based on the maximum sulfate concentration across the three model layers. The simulation results indicate that the northern portion of the downgradient plume is largely eliminated after 50 years of Alternative 3 except for a small zone around the PS wellfield that is detached from the main plume and that the 250 mg/L sulfate contour of the main plume is approximately coincident with the IW, SC, and FFS wellfields. Pumping for downgradient source control, plume stabilization, and mass capture are predicted to contain seepage from the STI, eliminate the northern portion of the downgradient plume, and decrease the eastern and southeastern extents of the plume over time. Based on the simulation results, the footprint of the downgradient plume decreases over time and sulfate impacts are not predicted for existing drinking water supply wells operated by LQS, CWC, and GVDWID. Drinking water supply mitigation is not predicted to be needed under Alternative 3, but would be provided as a contingency per ARS § 49-286 and the Mitigation Order if groundwater monitoring indicates that a drinking water supply could become impacted.

Effectiveness

Alternative 3 would attain the mitigation objective of providing a drinking water supply with sulfate concentrations less than 250 mg/L. Because plume management pumping would prevent downgradient migration of the plume and the eastern and southeastern extents of the plume decrease over time, existing drinking water supply wells are not predicted to be impacted in Alternative 3.

Alternative 3 would effectively contain seepage from the STI at the IW, FFS, and SC wellfields as indicated by the results of particle tracking simulation shown in Appendix G. Alternative 3 would reduce the extent of the downgradient plume overtime to the extent practicable by pumping to maximize mass capture at the PS, MC, and FFS wells. Because the FFS wells are inside the sulfate plume, pumping the FFS wellfield creates an internal groundwater sink that prevents seepage from the STI from flowing past the capture zone of the FFS wellfield to the downgradient aquifer. Pumping the FFS wellfield would also decrease the driving force for eastward migration of the sulfate plume toward existing water supply wells in Green Valley. Pumping at the PS wellfield will exert some additional influence in driving the downgradient plume northward, but pumping rates are specified to match the volumetric flux such that downgradient movement of the plume does not occur. Alternative 3 would effectively decrease the mass of sulfate in the plume by extraction at the PS, MC, and FFS wellfields such that the northern, eastern, and southeastern extents of the downgradient plume are reduced to the locations of the IW, FFS, and SC wellfields with the exception of a small residual zone near the PS wellfield.

The numerical simulation indicates that pumping at the IW, SC, and FFS wells would be needed after the 50-year simulation period because seepage from the STI may be too large to stop source control pumping. However, Alternative 3 would eliminate pumping at the PS and MC wellfields at the assumed end of mine life and reduce source control pumping to the minimum needed to contain seepage from the STI. A simulation of Alternative 3 was run for a 100-year time period to examine the fate of the small detached zone of sulfate that may remain in the vicinity of the PS wellfield at the end of the 50-year evaluation period. The simulation results show that the zone of sulfate persists over time, migrates approximately 3,500 feet northward beneath the Twin Buttes tailing impoundment, and decreases in size. The residual zone of sulfate is not predicted to migrate to or impact existing drinking water supply wells. MNA would be an appropriate action for this residual detached portion of the sulfate plume.

Implementability

There are no significant technical barriers expected for implementation of Alternative 3. Potential administrative constraints on implementation could be developing timely access and permits for work on county right-of-way, private land, and ASLD property; issues associated with water level effects due to mitigation wells; and constraints on certain post-mine end uses of treated water depending on the water rights and permits in effect at the time. An analysis of water level effects related to mitigation pumping is provided in Section 4.4.2.4.

Upgradient source control actions at the STI can be implemented within 12 months. The SC wellfield can be implemented on Sierrita property. Preliminary analysis of land status indicates that the FFS extraction wells and header pipeline could be installed on county right-of-way or private land. Alternative 3 would use ASLD land for the pipeline corridor from the FFS wells to the IW wellfield pipeline. The new pipeline would be installed along the existing right-of-way for the Esperanza pipeline, which would require permitting and negotiation with ASLD regarding the right-of way. ASLD land may also be needed for some manifold piping connecting the southern FFS wells. The PS and MC wellfields in the downgradient plume would require lead time for design, land access negotiation, and permitting. Alternative 3 would build a pipeline from the PS and MC wellfields to the pipeline that would be developed for the FFS wellfield. Use of county right-of-way or private land for installation of basic infrastructure (e.g., wellfields including roads, drilling pads, pipeline corridors, and electric service) would require necessary permitting and approvals. Obtaining land access and permits is expected to take up to 12 to 18 months. Wellfield and pipeline design, procurement, and construction are expected to take 12 to 18 months once access is secured. The total time expected to implement Alternative 3 is 24 to 36 months.

Cost

Alternative 3 has an estimated initial capital cost of $20.6 million, a non-discounted cost of $208 million, and an NPV(50) of $58.0 million. The Alternative 3 costs include pre-construction costs, capital costs, O&M costs, and replacement/repair costs for the facilities required for the alternative. As described in Section 4.2, the Alternative 3 cost estimate does not include source control at the STI (Section 2.3.2.2) which is being conducted under Sierrita's APP and reclamation programs. Table 8 summarizes the costs of Alternative 3. A detailed summary of estimated costs for Alternative 3 is presented in Appendix H.

The estimated initial pre-construction costs include: surveying and federal and state permitting that may be required for construction of drilling pads; electrical lines; access roads and piping runs; archeological survey; and endangered species survey. Also included are costs associated with engineering design and construction drawing/specifications for: electrical installations; wellhead instrumentation; control and telemetry; piping and valves; and groundwater extraction wells.

Initial capital costs include: well drilling and construction of the SC, FFS, PS, and MC wellfields; pump assembly and installation; overhead power lines; electrical equipment, materials, and installation; discharge piping and installation; and construction/project management.

Annual O&M costs during mine life include: electrical power for the SC, FFS, PS, and MC wellfields; additional electrical power required by the IW wellfield pump station; supplies;

labor; groundwater monitoring; and consulting. The savings in Canoa Ranch wellfield O&M costs expected for reducing Canoa Ranch pumping by the amount of water pumped from the SC, FFS, PS, and MC wellfields is estimated to range from $3.1 million to $3.5 million per year and was applied as an O&M credit during mine life. Annual costs after mine life include costs associated with continued pumping of the IW wells.

Annual supplies and labor costs for the wellfields are estimated from IW wellfield costs incurred during 2006 (Appendix H). These supply and labor costs are assumed to be proportional to the number of associated wells. The 0.76, 0.71, and 0.48 cost factors in Appendix H are, therefore, the ratio of the number of additional mitigation wells to the number of existing IW wells (i.e., 16 additional wells/21 existing IW wells; 15 additional wells/21 existing IW wells; 10 additional wells/21 existing IW wells) in 2006, multiplied by the sum of 2006 operating supplies costs ($35,000) and labor costs ($114,000), totaling $149,000 (Appendix H).

Annual costs associated with the repair and/or replacement of materials and equipment include labor, piping, pumps, and motors. Repair and replacement costs are also estimated using IW wellfield costs in 2006. These repair and replacement costs are assumed to be proportional to the total flow rate. The 1.81, 1.59, and 0.75 cost factors provided in Appendix H are, therefore, the ratio of additional mitigation flow to flow from IW wells in 2006 (i.e., 10,850 gpm additional mitigation flow/6,000 gpm IW flow; 9,550 gpm additional mitigation flow/6,000 gpm IW flow; 4,500 gpm additional mitigation flow/6,000 gpm IW flow), multiplied by the sum of 2006 equipment/materials repair and/or replacement costs ($97,000), well/pump repair and/or replacement costs ($325,000), additional fabrication costs ($75,000), and maintenance and repair labor costs ($210,000), totaling $707,000 (Appendix H).

Alternative 3 assumes that water treatment will be required after the end of mine life. The estimated costs for water treatment included capital for installation of an RO water treatment facility and O&M for future operations. The capital cost for water treatment is $31.8 million for the 9,360 gpm flow indicated by the numerical simulation. O&M consists of electricity, labor and materials for operation of the RO plant. Assuming mining ceases in 2042, the O&M costs of post-mine pumping and treatment would decline somewhat after 2050 because pumping at the SC and FFS wellfields is decreased due to the reduction of STI seepage over time caused by drain down starting in 2043.

4.3.4 Alternative 4 – New Tailing Impoundment, Source Control, and Plume Stabilization

Alternative 4 would include a new tailing impoundment to replace use of the STI for source control. Otherwise, Alternative 4 has the same source control, plume management, and contingent drinking water supply mitigation actions as Alternative 2. Under Alternative 4 it is assumed that tailing would be discharged to the STI until development of a new tailing impoundment. Alternative 4 proposes pumping at the IW, FFS, and SC wellfields for downgradient source control, would control infiltration into the STI for source control at the STI, and would develop a new tailing impoundment. Alternative 4 would use four new wells at the PS wellfield near the northern edge of the plume to pump groundwater for plume stabilization for plume management. Numerical simulations indicate that pumping along the eastern boundary of the plume is not needed to prevent eastward migration of the plume. Groundwater monitoring and contingent drinking water supply mitigation are included in Alternative 4. Figure 15 shows a conceptual layout of facilities that would be installed for Alternative 4. Table 9 contains pumping specifications for Alternative 4. The pumping specifications for Alternative 4 differ from those of Alternative 2 because they account for drain down assuming the new tailing impoundment is available for use starting in 2016 in Alternative 4. As discussed in Section 2.3.1.3, the timing of implementation of a new tailing impoundment is uncertain because of the need to acquire land and the necessary permits.

Downgradient source control would consist of pumping at the existing IW wellfield, installation of four additional source control wells in the southern IW wellfield, and installation of six wells for the FFS wellfield. In addition to the existing IW wellfield, numerical modeling of future conditions, including simulation of seepage due to the production increase in 2010, indicated that the SC wellfield (SC-1 through SC-4) is needed to maintain capture in the southern IW wellfield. The FFS wellfield would consist of six production wells (FFS-1 through FFS-6) to be installed in a north-south array on county right-of-way or private property as described by HGC (2007b). The FFS well locations and pumping rates were revised from those in HGC (2007b) based on simulations with the updated model. Initially, approximately 4,860 gpm would be pumped at the IW wellfield, 1,500 gpm at the SC wellfield, and 3,100 gpm at the FFS wellfield (Table 9). The total simulated pumping rate at the IW, SC, and FFS wellfields would decrease over time from 9,460 gpm to 2,660 gpm in response to decreased seepage from the STI that would result as drain down progresses after the cessation of tailing deposition at the STI.

The pumping rates at the IW, SC, and FFS wellfields after the assumed end of mining would be the minimum needed to maintain capture for source control.

A review of existing Sierrita infrastructure indicates that water from the SC and FFS wells would best be conveyed to the mine for use via a new pipeline that connects to the existing IW wellfield pipeline at the southeast corner of the STI. Water from the FFS wells would be piped to the IW wellfield pipeline through a new pipeline that would be installed across ASLD property along the right-of-way of the existing Esperanza pipeline and then south along the east side of the STI (Figure 15). The SC wellfield would be connected directly into a new pipeline.

Alternative 4 proposes source control at the STI by reducing current infiltration into the impoundment by increasing reclaim pond pumping and decreasing the amount of surface water discharge to the STI. Potential future infiltration after mine closure would be controlled by surface water controls and a soil cover for final reclamation of the STI. A new tailing impoundment to replace the STI is included in Alternative 4.

Plume management for Alternative 4 would consist of plume stabilization pumping and groundwater monitoring. Plume stabilization pumping would be conducted at the PS wellfield (PS-1 through PS-4) near the northern edge of the downgradient plume. Numerical simulation of Alternative 4 indicates that initially pumping the PS wellfield at 2,300 gpm (Table 9) would prevent significant downgradient plume migration. The pumping rate at the PS wellfield decreases from 2,300 gpm to 1,400 gpm over time because the first few years require higher pumping rates while capture is established and subsequent years require less pumping as source control pumping decreases the hydraulic load at the PS wellfield. The PS wellfield at the leading edge would be located on private land or county right-of-way near and north of Duval Mine Road and west of La Canada Drive (Figure 15). A pipeline would be constructed from the PS wellfield to the FFS wellfield pipeline to convey water to the mine for use.

Long-term groundwater monitoring at existing and future monitoring wells would be used to evaluate plume attenuation over time. Groundwater monitoring would also be performed to determine if a water supply mitigation action needs to be implemented because there is a potential for an existing water supply to become impacted by the plume. Long-term groundwater monitoring data would be used to confirm the performance of the alternative and make operational decisions during the mitigation. The mitigation alternative would be operated using the principles of adaptive management, including the use of contingent measures, to evaluate new information as it becomes available and make modification to the mitigation alternative, such as adjusting pumping rates or installing additional extraction wells, as determined to be necessary by operational experience and/or modeling.

Water pumped for source control and plume management would be managed for use at the mine during mine life. Mitigation pumping at approximately 4,060 gpm would be needed after mine closure because seepage from the STI is predicted to persist past the end of mine life and the downgradient plume is not predicted to be attenuated. The post-mine pumping rate is low enough to be managed by in-pit storage. Thus, it assumed that after mine life mitigation water can be discharged into the Sierrita pit. Because the STI seepage rate would be expected to decrease over time, the need to maintain pumping at the IW wells would be evaluated every five years to determine if continued pumping is needed, versus MNA, to meet the mitigation objective.

The simulated sulfate plume extent after 50 years of Alternative 4 is shown on Figure 16. The simulated sulfate plume extent shown on Figure 16 is based on the maximum sulfate concentration across the three model layers. The northern portion of the downgradient plume is predicted to remain relatively stable during Alternative 4 while the eastern and southeastern portions of the plume are predicted to move westward toward the FFS wells. The combination of downgradient source control pumping and plume stabilization pumping are predicted to keep the northern portion of the downgradient plume within its current approximate footprint. Based on the simulation results, the eastern and southeastern extents of the plume decrease over time and sulfate impacts are not predicted at existing drinking water supply wells operated by LQS, CWC, and GVDWID. Drinking water supply mitigation is not predicted to be needed under Alternative 4, but would be provided as a contingency per ARS § 49-286 and the Mitigation Order if groundwater monitoring indicates that a drinking water supply could become impacted.

Effectiveness

Alternative 4 would attain the mitigation objective of providing a drinking water supply with sulfate concentrations less than 250 mg/L. Because the plume footprint does not increase, the existing drinking water supply wells of LQS, CWC, and GVDWID are not predicted to be impacted in Alternative 4.

Alternative 4 would effectively contain seepage from the STI at the IW, FFS, and SC wellfields and stabilizes the downgradient plume at the PS wellfield as indicated by the results of particle tracking simulations shown in Appendix G. The new tailing impoundment in Alternative 4 significantly reduces the volume of seepage from the STI over time. The downgradient plume is not predicted to migrate beyond its current approximate limits. Because the FFS wells are inside the sulfate plume, pumping the FFS wellfield creates an internal groundwater sink that prevents seepage from the STI from flowing past the capture zone of the FFS wellfield to the downgradient aquifer. Pumping the FFS wellfield would decrease the driving force for eastward migration of the sulfate plume toward existing water supply wells in Green Valley. Pumping at the PS wellfield would exert some additional influence in driving the downgradient plume northward, but pumping rates are specified to match the groundwater flux such that downgradient movement of the plume does not occur. Alternative 4 would effectively decrease the mass of sulfate in the plume by extraction at the source control and plume stabilization wells such that the area of the northern extent of the downgradient plume does not increase compared to the current distribution of sulfate and the eastern and southeastern extents of the plume decrease. The numerical simulation indicates that pumping at the IW, SC, FFS, and PS wellfields would need to continue after the 50-year simulation period because seepage from the STI may be too large to stop source control pumping and the downgradient plume has not attenuated enough to discontinue plume stabilization pumping.

Implementability

There are no significant technical barriers expected for implementation at this time, although siting, land acquisition, and permitting of a new tailing impoundment are critical steps that would need to be favorably resolved for full implementation. Potential administrative constraints on implementation could be developing timely acquisition of land for a new tailing impoundment; access and permits for work on county right-of-way, private land, and ASLD property; issues associated with water level effects due to mitigation wells; and constraints on certain post-mine end uses of treated water depending on the water rights and permits in effect at the time. An analysis of water level effects related to mitigation pumping is provided in Section 4.4.2.4.

Sierrita is evaluating options for a new tailing impoundment. Site selection, permitting, design, and construction of the new tailing impoundment are expected to continue through 2015, although there are a large number of land acquisition and permitting uncertainties that could delay implementation of a new tailing impoundment as described in Section 2.3.1.3. Acquisition and permitting of ASLD land for the new tailing impoundment are critical to development of a new tailing impoundment. A preliminary discussion with ASLD indicates that, conceptually, acquisition of the needed land may be possible pending completion of certain requirements for evaluation of the property. However, a new tailing impoundment may not be feasible if land acquisition is not possible.

Upgradient source control actions at the STI can be implemented within 12 months except for capping and final drainage design, which would be implemented once the new tailing impoundment is operational. The SC wellfield can be implemented on Sierrita property. The FFS wellfield requires lead time for design, land access negotiation, and permitting. Preliminary analysis of land status indicates that the FFS extraction wells and header pipeline could be installed on county right-of-way or private land. Alternative 4 would use ASLD land for the pipeline corridor from the FFS wells to the IW wellfield pipeline. The new pipeline would be installed along the existing right-of-way for the Esperanza pipeline, which would require permitting and negotiation with ASLD regarding the right-of way. ASLD land may also be needed for some manifold piping connecting the southern FFS wells. The PS wellfield at the leading edge of the downgradient plume requires lead time for design, land access negotiation, and permitting. Alternative 4 would build a pipeline from the PS wellfield to the pipeline that would be developed for the FFS wellfield. Use of county right-of-way or private land for installation of basic infrastructure (e.g., wellfields including roads, drilling pads, pipeline corridors, and electric service) would require necessary permitting and approvals. Obtaining land access for well installation and pipelines is expected to take 12 to 18 months. Wellfield and pipeline design, procurement, and construction are expected to take 12 to 18 months once access is secured. The total time expected to implement the pumping systems for Alternative 4 is approximately 24 to 36 months. It is assumed that seven years are required to develop the new tailing impoundment. However, this timeframe is uncertain given issues associated with land acquisition and permitting.

Cost

Alternative 4 has an estimated initial capital cost of \$16.0 million, a non-discounted cost of \$71.7 million, and an NPV(50) of \$32.4 million. The Alternative 4 costs include pre-construction costs, capital costs, O&M costs, and replacement/repair costs for the facilities required for the alternative. As described in Section 4.2, the Alternative 4 cost estimate does not include source control at the STI (Section 2.3.2.2) which is being conducted under Sierrita's APP and reclamation programs and does not include the new tailing impoundment which is an operations project under Sierrita's mine plan and APP. Table 10 summarizes the costs of Alternative 4. A detailed summary of estimated costs for Alternative 4 is presented in Appendix H.

The estimated initial pre-construction costs include: surveying and federal and state permitting that may be required for construction of drilling pads; electrical lines; access roads and piping runs; archeological survey; and endangered species survey. Also included are costs associated with engineering design and construction drawing/specifications for: electrical installations; wellhead instrumentation; control and telemetry; piping and valves; and groundwater extraction wells.

Initial capital costs include: well drilling and construction of the SC, FFS, and PS wellfields; pump assembly and installation; overhead power lines; electrical equipment, materials, and installation; discharge piping and installation; and construction/project management.

Annual O&M costs during mine life include: electrical power for the SC, FFS, and PS wellfields; additional electrical power required by the IW wellfield pump station; supplies; labor; groundwater monitoring; and consulting. The savings in Canoa Ranch wellfield O&M costs expected for reducing Canoa Ranch pumping by the amount of water pumped from the SC, FFS, and PS wellfields is estimated to range from $1.5 million to $2.1 million per year and was applied as an O&M credit during mine life. Annual costs after mine life include costs associated with continued operation of the IW wells. The cost analysis assumed 15 years of continued operation of the IW wellfield, although the need to maintain IW wellfield pumping will be evaluated every five years.

Annual supplies and labor costs for the wellfields are estimated from IW wellfield costs incurred during 2006 (Appendix H). These supply and labor costs are assumed to be proportional to the number of associated wells. The 0.67, 0.62, and 0.43 cost factors in Appendix H are, therefore, the ratio of the number of additional mitigation wells to the number of existing IW wells in 2006 (i.e., 14 additional mitigation wells/21 existing IW wells; 13 additional mitigation wells/21 existing IW wells; 9 additional mitigation wells/21 existing IW wells), multiplied by the sum of 2006 operating supplies costs ($35,000) and labor costs ($114,000), totaling $114,000 (Appendix H).

Annual costs associated with the repair and/or replacement of materials and equipment include labor, piping, pumps, and motors. Repair and replacement costs are also estimated using IW wellfield costs in 2006. These repair and replacement costs are assumed to be proportional to the total flow rate. The 1.15, 0.80, and 0.40 cost factors provided in Appendix H are, therefore, the ratio of additional mitigation flow to flow from IW wells in 2006 (i.e., 6,800 gpm additional mitigation flow/6,000 gpm IW flow; 4,800 gpm additional mitigation flow/6,000 gpm IW flow; 2,400 gpm additional mitigation flow/6,000 gpm IW flow), multiplied by the sum of 2006 equipment/materials repair and/or replacement costs ($97,000), well/pump repair and/or replacement costs ($325,000), additional fabrication costs ($75,000), and maintenance and repair labor costs ($210,000), totaling $707,000 (Appendix H).

Alternative 4 assumes that water management would be required at the end of mine life. Water pumped after the assumed mine life would be discharged to the Sierrita pit for management. There are only minor engineering and construction cost required to implement in-pit management because capital infrastructure in terms of piping and pumping systems would be in place from the mining operation. Assuming mining ceases in 2043, the O&M costs of post-mine pumping would consist of electricity, labor and materials for operation of wellfields and conveyance of water to the pit.

4.3.5 Alternative 5 – New Tailing Impoundment, Source Control, Plume Stabilization, and Mass Removal

Alternative 5 would include implementation of a new tailing impoundment to replace use of the STI for source control. Otherwise, Alternative 5 has the same source control, plume management, and contingent drinking water supply mitigation actions as Alternative 3. Under Alternative 5 it is assumed that tailing would be discharged to the STI until development of a new tailing impoundment. Alternative 5 is an aggressive plume management strategy that would stabilize the northern edge of the plume and remove sulfate from within the plume to reduce its extent by the end of mine life. Alternative 5 would use the PS wellfield at the northern edge of the plume for plume stabilization while maximizing sulfate mass removal within the downgradient plume by increased pumping at the FFS and MC wellfields for mass capture. Groundwater monitoring and contingent drinking water supply mitigation are included in Alternative 5. Figure 17 shows a conceptual layout of the well and pipeline facilities that would be installed for Alternative 3. Table 11 contains pumping specifications for Alternative 5. The pumping specifications for Alternative 5 differ from those of Alternative 3 because they account for drain down starting in 2016 in Alternative 5 rather than in 2043 as in Alternative 3. The pumping specification for Alternative 5 also differ from those of Alternative 4, which account for early drain down because Alternative 4 includes plume stabilization pumping for plume management.

The objective of Alternative 5 is to pump as much water from the downgradient plume as can be used at the mine so as to accelerate the removal of sulfate mass from the plume during mine life. Therefore, pumping rates for Alternative 5 are greater than those needed for source control pumping and plume stabilization pumping alone. Alternative 5 would implement a new tailing impoundment to allow early drain down of the STI. As discussed in Section 2.3.1.3, the timing of implementation of a new tailing impoundment is uncertain because of the need to acquire land and the necessary permits.

Downgradient source control would consist of pumping at the existing IW wellfield, installation of four additional source control wells in the southern IW wellfield, and installation of six wells for the FFS wellfield. In addition to the existing IW wellfield, numerical modeling of future conditions, including simulation of seepage due to the production increase in 2010, indicated that the SC wellfield (SC-1 through SC-4) is needed to maintain capture in the southern IW wellfield. The FFS wellfield would consist of six production wells (FFS-1 through FFS-6) to be installed in a north-south array on county right-of-way or private property as described by HGC (2007b). The FFS well locations and pumping rates were revised from those in HGC (2007b) based on simulations with the updated model. Initially, approximately 4,860 gpm would be pumped at the IW wellfield, 1,600 gpm at the SC wellfield, and 5,450 gpm at the FFS wellfield (Table 11). The pumping rates at the FFS wellfield would be higher than needed for source control pumping alone because Alternative 5 also uses the FFS wells for plume management pumping. The total simulated pumping rate at the IW, SC, and FFS wellfields decreases from 11,910 gpm to 2,560 gpm over time in response to decreased seepage from the STI that would result as drain down progresses after cessation of the at the STI. Pumping rates at the IW, SC, and FFS wellfields after the assumed end of mine life would be the minimum needed to maintain capture for source control.

A review of existing Sierrita infrastructure indicates that water from the SC and FFS wells would best be conveyed to the mine for use via a new pipeline that connects to the existing IW wellfield pipeline at the southeast corner of the STI. Water from the FFS wells would be piped to the IW wellfield pipeline through a new pipeline that would be installed across ASLD property along the right-of-way of the existing Esperanza pipeline and then south along the east side of the STI (Figure 17). The SC wellfield would be connected directly into the new pipeline.

Alternative 5 also includes source control at the STI by reducing current infiltration into the impoundment by increasing reclaim pond pumping and decreasing the amount of surface water discharge to the STI. Potential future infiltration after mine closure would be controlled by surface water controls and a soil cover for final reclamation of the STI. A new tailing impoundment to replace the STI is included in Alternative 5.

Plume management for Alternative 5 would consist of mass capture pumping, plume stabilization pumping and groundwater monitoring. Mass capture pumping would be conducted by pumping the FFS wellfield at high rates and by pumping at two additional mass capture wells (MC-1 and MC-2) east of the FFS wellfield. Plume stabilization pumping would be conducted at four wells (PS-1 through PS-4) near the northern edge of the downgradient plume. Numerical simulation of Alternative 5 indicates that initially pumping 1,500 gpm at the MC wellfield, pumping 2,300 gpm at the PS wellfield, and pumping the FFS wellfield at higher rates than necessary to capture seepage from the STI (Table 11) would prevent downgradient plume migration and would reduce the plume extent over time. The total simulated pumping rates at the MC and PS wellfields decrease from 3,800 gpm to 2,500 gpm over time to adjust to changing hydraulic and water quality conditions. At the end of mine life assumed for the FS, the downgradient plume is sufficiently attenuated and pumping at the MC and PS wellfields would be discontinued. The MC and PS wells would be located on private land or county right-of-way near and north of Duval Mine Road and west of La Canada Drive (Figure 17). A pipeline would be constructed from the MC and PS wells to the FFS wellfield pipeline to convey water to the mine for use.

Long-term groundwater monitoring at existing and future monitoring wells would be used to evaluate plume attenuation over time. Groundwater monitoring would also be performed to determine if a water supply mitigation action needs to be implemented because there is a potential for an existing drinking water supply to become impacted by the plume. Long-term groundwater monitoring data would be used to confirm the performance of the alternative and make operational decisions during the mitigation. The mitigation alternative would be operated using the principles of adaptive management, including the use of contingent measures, to evaluate new information as it becomes available and make modifications to the mitigation alternative, such as adjusting pumping rates or installing additional extraction wells, as determined to be necessary by operational experience and/or modeling.

Water pumped by the source control and plume management would be managed for use at the mine during mine life. Mitigation pumping at approximately 2,560 gpm would be needed after mine closure because seepage from the STI is predicted to persist past the end of mine life, although plume management pumping would no longer be needed. The post-mine pumping rate is low enough to be managed by in-pit storage. Thus, it is assumed that after mine life the water can be discharge into the Sierrita pit. Because STI seepage should decrease over time, the need to maintain pumping at the IW wellfield would be evaluated every five years to determine if continued pumping is needed, versus MNA, to meet the mitigation objective.

The simulated sulfate plume extent distribution after 50 years of Alternative 5 is shown on Figure 18. The simulated sulfate plume extent shown on Figure 18 is based on the maximum sulfate concentration across the three model layers. The simulation results indicate that the northern portion of the downgradient plume is largely eliminated after 50 years of Alternative 5 except for a small zone around the PS wellfield that is detached from the main plume and that the 250 mg/L sulfate contour of the main plume approximately coincident with the IW, SC, and FFS wellfields. Pumping for downgradient source control, plume stabilization, and mass capture are predicted to contain seepage from the STI, largely eliminate the northern portion of the downgradient plume, and decrease the eastern and southeastern extents of the plume over time. Based on the simulation results, the footprint of the downgradient plume decreases over time and sulfate impacts are not predicted for existing drinking water supply wells operated by LQS, CWC, and GVDWID. Drinking water supply mitigation is not predicted to be needed under Alternative 5, but would be provided as a contingency per ARS § 49-286 and the Mitigation Order if groundwater monitoring indicates that a drinking water supply could become impacted.

Effectiveness

Alternative 5 would attain the mitigation objective of providing a drinking water supply with sulfate concentrations less than 250 mg/L. Because the plume management pumping would prevent downgradient migration of the plume and the eastern and southeastern extents of the plume decrease over time, existing drinking water supply wells are not predicted to be impacted in Alternative 5.

Alternative 5 would effectively contain seepage from the STI at the IW, FFS, and SC wellfields as indicated by the results of particle tracking simulations shown in Appendix G. Alternative 5 would reduce the extent of the downgradient plume over time to the extent practicable by pumping to maximize mass capture at the PS, MC, and FFS wellfields. Because the FFS wells are inside the sulfate plume, pumping the FFS wellfield creates an internal groundwater sink that prevents seepage from the STI from flowing past the capture zone of the FFS wellfield to the downgradient aquifer. Pumping the FFS wellfield would decrease the driving force for eastward migration of the sulfate plume toward existing water supply wells in Green Valley. Pumping at the PS wellfield will exert some additional influence in driving the downgradient plume northward, but pumping rates are specified to match the volumetric flux such that downgradient movement of the plume does not occur. Alternative 5 would effectively decrease the mass of sulfate in the plume by extraction at the PS, MC, and FFS wellfields such that the northern, eastern, and southeastern extents of the downgradient plume are reduced to the locations of the IW, FFS, and SC wellfields with the exception of a small residual zone near the PS wellfield.

The numerical simulation indicates that pumping at the IW, SC, and FFS wells would be needed after the 50-year simulation period because seepage from the STI may be too large to stop source control pumping. However, Alternative 5 would eliminate pumping at the PS and MC wellfields at the assumed end of mine life and reduce source control pumping to the minimum needed to contain seepage from the STI. A simulation of Alternative 5 was run for a 100-year time period to examine the fate of the small detached zone of sulfate that may remain in the vicinity of the PS wellfield at the end of the 50-year evaluation period. The simulation results show that the zone of sulfate persists over time migrates northward approximately 3,500 feet beneath the Twin Buttes tailing impoundment, and decreases in size. The residual zone of sulfate is not predicted to migrate to or impact existing drinking water supply wells. MNA would be an appropriate action for this residual portion of the sulfate plume.

Implementability

There are no significant technical barriers expected for implementation at this time, although siting, land acquisition, permitting or a new tailing impoundment are critical steps that would need to be favorably resolved for full implementation. Potential administrative constraints on implementation could be developing timely acquisition of land for a new tailing impoundment; access and permits for work on county right-of-way, private land, and ASLD property; issues associated with water level effects due to mitigation wells; and constraints on certain post-mine end uses of treated water depending on the water rights and permits in effect at the time. An analysis of water level effects related to mitigation pumping is provided in Section 4.4.2.4.

Sierrita is evaluating options for a new tailing impoundment. Site selection, permitting, design, and construction of the new tailing impoundment are expected to continue through 2015, although there are a large number of land acquisition and permitting uncertainties that could delay implementation of a new tailing impoundment as described in Section 2.3.1.3. Acquisition and permitting of ASLD land for the new tailing impoundment are critical to development of a new tailing impoundment. A preliminary discussion with ASLD indicates that, conceptually, acquisition of the needed land may be possible pending completion of certain requirements for evaluation of the property.

Upgradient source control actions at the STI can be implemented within 12 months except for capping and final drainage design, which would be implemented once the new tailing impoundment is operational. The SC wellfield can be implemented on Sierrita property. Preliminary analysis of land status indicates that the FFS extraction wells and header pipeline could be installed on county right-of-way or private land. Alternative 5 would use ASLD land for the pipeline corridor from the FFS wells to the IW wellfield pipeline. The new pipeline would be installed along the existing right-of-way for the Esperanza pipeline, which would require permitting and negotiation with ASLD regarding the right-of way. ASLD land may also be needed for some manifold piping connecting the southern FFS wells. The PS and MC wellfields in the downgradient plume are require lead time for design, land access negotiation, and permitting. Alternative 5 would build a pipeline from the PS and MC wellfields to the pipeline that would be developed for the FFS wellfield. Use of county right-of-way or private land for installation of basic infrastructure (e.g., wellfields including roads, drilling pads, pipeline corridors, and electric service) would require necessary permitting and approvals. Obtaining land access and permits is expected to take up to 12 to 18 months. Wellfield and pipeline design, procurement, and construction are expected to take 12 to 18 months once access is secured. The total time expected to implement the pumping systems of Alternative 5 is 24 to 36 months. It is assumed that seven years are required to develop the new tailing impoundment. However, the timeframe is uncertain given issues associated with land acquisition and permitting.

Cost

Alternative 5 has an estimated initial capital cost of $20.6 million, a non-discounted cost of $81.4 million, and an NPV(50) of $42.6 million The Alternative 5 costs include pre-construction costs, capital costs, O&M costs, and replacement/repair costs for the facilities required for the alternative. As described in Section 4.2, the Alternative 5 cost estimate does not include source control at the STI (Section 2.3.2.2) which is being conducted under Sierrita's APP and reclamation programs and does not include the new tailing impoundment which is an operations project under Sierrita's mine plan and APP. Table 12 summarizes the costs of Alternative 5. A detailed summary of estimated costs for Alternative 5 is presented in Appendix H.

The estimated initial pre-construction costs include: surveying and federal and state permitting that may be required for construction of drilling pads; electrical lines; access roads and piping runs; archeological survey; and endangered species survey. Also included are costs associated with engineering design and construction drawing/specifications for: electrical installations; wellhead instrumentation; control and telemetry; piping and valves; and groundwater extraction wells.

Initial capital costs include: well drilling and construction of the SC, FFS, PS, and MC wellfields; pump assembly and installation; overhead power lines; electrical equipment, materials, and installation; discharge piping and installation; and construction/project management.

Annual O&M costs during mine life include: electrical power for the SC, FFS, PS, and MC wellfields; additional electrical power required by the IW wellfield pump station; supplies; labor; groundwater monitoring; and consulting. The savings in Canoa Ranch wellfield O&M costs expected for reducing Canoa Ranch pumping by the amount of water pumped from the SC, FFS, PS, and MC wellfields is estimated to range from $2.4 million to $3.4 million per year and was applied as an O&M credit during mine life. Annual O&M costs after mine life include costs associated with continued operation of the IW wells. The cost analysis assumed 15 years of continued operation of the IW wellfield, although the need to maintain the IW wellfield pumping will be evaluated every five years.

Annual supplies and labor costs for the wellfields are estimated from IW wellfield costs incurred during 2006 (Appendix H). These supply and labor costs are assumed to be proportional to the number of associated wells. The 0.76, 0.67, and 0.24 cost factors in Appendix H are, therefore, the ratio of the number of additional mitigation wells to the number of existing IW wells in 2006 (i.e., 16 additional mitigation wells/21 existing IW wells; 14 additional mitigation wells/21 existing IW wells; 5 additional mitigation wells/21 existing IW wells), multiplied by the sum of 2006 operating supplies costs ($35,000) and labor costs ($114,000), totaling $149,000 (Appendix H).

Annual costs associated with the repair and/or replacement of materials and equipment include labor, piping, pumps, and motors. Repair and replacement costs are also estimated using IW wellfield costs in 2006. These repair and replacement costs are assumed to be proportional to the total flow rate. The 1.81, 1.30, and 0.17 cost factors provided in Appendix H are, therefore, the ratio of additional flow to flow from IW wells in 2006 (i.e.,10,850 gpm additional mitigation flow/6,000 gpm IW flow; 7,800 gpm additional mitigation flow/6,000 gpm IW flow; 1,000 gpm additional mitigation flow/6,000 gpm IW flow), multiplied by the sum of 2006 equipment/materials repair and/or replacement costs ($97,000), well/pump repair and/or replacement costs ($325,000), additional fabrication costs ($75,000), and maintenance and repair labor costs ($210,000), totaling $707,000 (Appendix H).

Alternative 5 assumes that water management would be required at the end of mine life. Water pumped after the assumed mine life would be discharged to the Sierrita pit for management. There are only minor engineering and construction cost required to implement in-pit management because capital infrastructure in terms of piping and pumping systems would be in place from the mining operation. Assuming mining ceases in 2043, the O&M costs of post-mine pumping would consist of electricity, labor and materials for operation of wellfields and conveyance of water to the pit.

4.4 Comparative Analysis of Mitigation Alternatives

This section compares the relative short- and long-term benefits and costs of the mitigation alternatives consistent with ARS § 49-286. Benefits are discussed in terms of relative effectiveness and implementability. Cost is described by the non-discounted cost and NPV(50) of the alternatives. Table 13 compares the effectiveness, implementability, and cost of the mitigation alternatives.

4.4.1 Effectiveness

Consistent with Section III.D of the Mitigation Order, the alternatives use different source control and plume management actions to meet the mitigation objective. The mitigation alternatives span a spectrum of potential measures ranging from source control, MNA, and drinking water supply mitigation to plume containment and mass reduction. Beyond the threshold requirement of meeting the mitigation objective, the relative effectiveness and benefits of the mitigation alternatives include the degree to which they prevent sulfate from migrating into unaffected areas, reduce the extent of the plume, minimize overall mitigation pumping, reduce the duration and magnitude of source control pumping, and remove sulfate mass.

4.4.1.1 Mitigation Objective

Alternatives 1 through 5 would all be effective at meeting the mitigation objective of providing a drinking water supply with sulfate concentrations less than 250 mg/L to owners/operators of existing water supplies. Alternative 1 is not predicted to impact existing drinking water supply wells. However, because the plume is allowed to migrate under Alternative 1, drinking water supply mitigation would be available as a contingency if groundwater monitoring indicated that an existing drinking water supply could become impacted. Alternatives 2 through 5 are comparable at meeting the mitigation objective by maintaining or reducing the extent of the plume so as to protect currently unimpacted existing drinking water supply wells.

4.4.1.2 Prevention of Sulfate Migration to Unaffected Areas

Mitigation alternatives that limit plume migration to unaffected areas provide short- and long-term benefits with respect to reducing the risk to existing drinking water supplies located downgradient of the plume. Simulation results for Alternatives 1 through 5 indicate that existing drinking water supplies are not predicted to be impacted in the 50-year simulation timeframe used to model the alternatives. Figure 19 shows the predicted sulfate distribution in 2060 for the different mitigation alternatives. The sulfate plume would not migrate to the east toward the existing CWC and GVDWID wells under any of the alternatives. The sulfate plume would migrate to the north to the vicinity of the LQS supply wells in 50 years under Alternative 1, but is not predicted to reach the wells. Alternatives 2 through 5 would not allow the downgradient plume to migrate to the north into unimpacted areas because these alternatives do not allow plume migration beyond its current northern extent. Alternatives 2 through 5 are considered to be equally effective in controlling plume migration to unaffected areas. Alternative 1 is the least effective at controlling plume migration to unaffected areas.

4.4.1.3 Reduction of Plume Extent

The reduction of plume extent provides short- and long-term benefits with respect to restoring groundwater quality and protecting drinking water supplies. Under Alternative 1 the extent of the plume would increase over time. Alternatives 2 and 4 would largely maintain the current approximate footprint of the plume; under these alternatives only the southeastern extent of the plume would reduce over time. Alternatives 3 and 5 would substantially reduce the extent of the downgradient plume over time (Figure 19). Thus, Alternatives 3 and 5 are judged to have a greater degree of effectiveness at reducing plume extent and restoring the aquifer quality than the other alternatives. Alternatives 2 and 4 would be the next most effective at reducing plume extent. Alternative 1 would be the least effective because the extent of the plume would increase. Although Alternatives 3 and 5 would have better effectiveness in reducing the plume extent, the high pumping rates of these alternatives during mine life would have more potential short-term drawdown impacts on existing wells than would pumping under Alternatives 1, 2, and 3 (Section 4.4.2.4).

4.4.1.4 Minimization of Mitigation Pumping

Water conservation is important to Sierrita and the community. Alternatives that minimize mitigation pumping while accomplishing the mitigation objective provide the benefit of conserving the groundwater resource. Alternatives 1 through 5 are equivalent with respect to the volume of groundwater pumped during mine life because all mitigation water would be used for mine supply and would partially offset mine pumping which would occur regardless of the mitigation. In this way, the mitigation alternatives do not increase the net pumping by Sierrita during mining, but instead relocate the pumping for mine supply to the sulfate plume. Thus, all the alternatives are equally effective in the short-term in minimizing mitigation pumping during mining. Alternatives 3 and 5, however, would provide an additional short- and long-term benefit in that they use more impacted water for mining use and leave more unimpacted water in the aquifer at Canoa Ranch than would Alternatives 1, 2, and 4.

The effectiveness of the mitigation alternatives with the respect to minimizing mitigation pumping is different over the long-term due to the amount of pumping required after the assumed end of mine life. Alternatives 4 and 5 would have the least mitigation pumping at the end of mine life, 3,820 gpm, and 2,420 gpm, respectively. In contrast, pumping at the end of mine life for Alternatives 1, 2, and 3 at 9,360 gpm, 10,960 gpm, and 9,360 gpm, respectively; would be several times greater than pumping for Alternatives 4 and 5. Furthermore, Alternatives 1, 2, and 3 would have high rates of pumping beyond the 50-year evaluation period, whereas Alternatives 4 and 5 would have decreasing pumping because of the advanced state of drain down under Alternatives 4 and 5. Alternative 5 would have the potential to pump the least amount of water at the end of mining compared to Alternative 4 because Alternative 5 would remove the downgradient plume during mine operations while Alternative 4 would need to continue pumping the downgradient plume even if source control could be discontinued. Alternative 5 is judged to provide the greatest long-term benefit because it would pump the least water at the end of mine life and less overall water over the post-mine lifetime of the mitigation action than Alternatives 1 through 4.

4.4.1.5 Duration and Magnitude of Source Control Pumping

All the alternatives use source control pumping to control seepage from the STI. Alternatives that reduce the duration and magnitude of source control pumping would have a long-term benefit in that they would reduce the length of time that source control needs to be operated and maintained, and reduce the total amount of water that needs to be pumped for source control. Under Alternatives 1, 2, and 3, source control pumping would need to continue until mining ceases and for many tens of years thereafter. If land acquisition and permitting are successful, Alternatives 4 and 5 would implement a new tailing impoundment to stop sulfate mass loading to the STI and start drain down sooner than Alternatives 1 through 3. Thus, Alternatives 4 and 5 would avoid 27 years of sulfate mass loading to the STI and would allow a significant amount of drain down to be captured at the IW, FFS, and SC wellfields prior to the end of mine life. Alternatives 4 and 5 would reduce the duration of source control compared to Alternatives 1, 2, and 3 because the duration of drain down is the rate limiting factor determining the length of source control. This is evidenced by the significantly lower source control pumping rates at the end of mine life for Alternatives 4 and 5 than the other alternatives (Tables 3, 5, 7, 9, and 11). Alternatives 4 and 5 would, therefore, provide a greater long-term benefit than

Alternatives 1 through 3 due to the reduction in the duration and magnitude of source control pumping possible with Alternatives 4 and 5.

4.4.1.6 Net Sulfate Mass Removal

As describe in Appendix G, the net sulfate mass removal is the difference between the sulfate mass removed by mitigation pumping and the sulfate mass that enters the aquifer from the STI during the 50-year simulation period. The net sulfate mass removal of the alternatives influences the duration and magnitude of source control and plume management pumping because the higher the net sulfate mass removal, the less sulfate mass there is left in the system (the STI and the aquifer) to require mitigation.

Figure 25 shows the net sulfate mass removal of the mitigation alternatives. The predicted net sulfate mass removed by Alternatives 1, 2, 3, 4, and 5 after 50 years is approximately 550,990 tons, 463,260 tons, 307,490 tons, 234,880 tons, and 88,130 tons, respectively. Alternative 5 would remove significantly more sulfate mass than would be input to the aquifer from the STI compared to Alternatives 1 through 4. Alternative 5 would have the highest net sulfate mass removal because it would close the STI and start drain down to reduce the long-term seepage from the STI sooner than Alternatives 1, 2, and 3 and because it would pump more sulfate-impacted water for use in mining than Alternative 4.

4.4.1.7 Summary of Effectiveness

The effectiveness and benefits of the mitigation alternatives are judged based their ability to meet the mitigation objective, prevent sulfate migrating into unaffected areas, reduce plume extent, minimize of overall mitigation pumping, reduce the duration and magnitude of source control pumping, and maximize net sulfate mass removal. In summary, the effectiveness of the mitigation alternatives is as follows:

- Alternatives 1 through 5 would all meet the mitigation objective.
- Alternatives 2 through 5 are comparable at preventing expansion of the plume into unaffected areas through the use of plume management pumping to control the plume.
- Alternatives 3 and 5 would provide the most effective reduction of plume extent and groundwater quality restoration over time.
- Alternatives 3 and 5 would maximize use of impacted water in mining and leave more unimpacted water in the aquifer during mining while Alternative 5 would also result in the least amount of post-mine mitigation pumping and thereby provide a long-term benefit of reducing mitigation pumping.
- Alternatives 4 and 5 would be the most effective alternatives at reducing the duration and magnitude of source control pumping due to their implementation of a new tailing impoundment and the early start of drain down which reduces seepage from the STI.
- Alternative 5 would have the highest net sulfate mass removal. Because of its high net sulfate mass removal, Alternative 5 would be the most advanced of the mitigation alternatives in terms of progress to a point at which MNA could be implemented, particularly if drain down occurs faster than predicted or if the mine operates for longer than assumed.

Alternative 5 would attain more of the effectiveness criteria than any of the alternatives considered. For this reason, Alternative 5 is judged to be the most effective alternative and to provide the greatest short- and long-term benefits.

4.4.2 Implementability

Implementability refers to the relative difficulty of and the availability of resources for meeting the technical and administrative requirements needed to permit, design, build, and operate the mitigation alternatives. The implementability of process options used by the mitigation alternatives was assessed by the screening of potentially applicable mitigation actions (Section 2). This section focuses on the implementability of the mitigation alternatives themselves.

4.4.2.1 Technical Implementability

Alternatives 1 through 5 are all technically implementable in that the technologies they would employ are generally reliable and commonly used in mitigation and remediation. Implementation of the alternatives would require technical design and construction projects that are typical of groundwater pumping and treatment actions. There are no developing technologies used by the alternatives.

The alternatives differ in their degree of complexity and the size of the pumping and piping infrastructure required for implementation. Alternative 1 is the least technically difficult to implement because it has the fewest number of wells and least amount of new pipeline of the alternatives. Alternatives 3 and 5 are the most technically difficult to implement in that they have the largest number of wells and pipeline lengths that need to be developed. Although the alternatives range in complexity, the design and construction of the wellfield, pipeline, water treatment, and supporting infrastructure of the alternatives requires engineering and construction skills that are readily available in the marketplace.

Alternatives 4 and 5 require the design and construction of a new tailing facility. The new tailing facility would be a significant engineering and construction project. Options for tailing impoundment design are relatively well known and expertise is available for the development of a new tailing impoundment. The new tailing impoundment required for Alternatives 4 and 5 is technically implementable.

The water management specifications of Alternatives 1 through 5 are technically implementable. The pumping specifications of all the alternatives are within Sierrita's current projections of water demand for mine use. Reverse osmosis water treatment is technically implementable for water management at the end of mine life if it is needed for Alternatives 1, 2, and 3. Use of the Sierrita pit for management of the RO brine reject in Alternatives 1, 2, and 3 and for management of mitigation water in Alternatives 4 and 5 is technically feasible at the projected flow rates.

The technical implementability of the alternatives would be sensitive to the demand for mine water. Should water demand at the mine cease temporarily or decline significantly prior to mine closure, some of the alternatives are easier to scale back than others. Alternative 1 would be the least sensitive to the demand for mine water because it has the lowest pumping requirements. Alternatives 2 and 4 would be the next most sensitive because they pump more than Alternative 1 and less than Alternatives 3 and 5. Alternatives 3 and 5 would be the most sensitive because they require the largest water demand at the mine. If water demand at the mine were to drop during mine life, Alternatives 3 and 5 would be the easiest alternatives to modify because pumping for mass removal within the downgradient portion of the plume could be reduced without jeopardizing source control or allowing the downgradient plume to migrate. Alternatives 2 and 4 would be difficult to modify without allowing the downgradient plume to migrate. Alternative 1 would be difficult to modify without loosing some source control.

The groundwater and drinking water supply monitoring included in all the alternatives is technically implementable for monitoring the effectiveness of the mitigation and assessing water supplies for sulfate. Although simulations of mitigation alternatives indicate that no existing drinking water supply wells would be impacted in the first 50 years of the alternatives, drinking water supply mitigation actions per ARS § 49-286 and the Mitigation Order are available and technically implementable if groundwater monitoring indicates that an impact could occur.

All the alternatives are capable of being modified in the future, even with respect to the demand for mine water. Groundwater monitoring data will be used throughout the mitigation to assess the performance of the mitigation and to determine whether additional actions are warranted to meet the mitigation objective. As described in Section III.D of the Mitigation Order, Sierrita would implement the mitigation using an adaptive management approach, including the use of contingent measures, that can remain flexible to respond to scientific (i.e., groundwater monitoring or engineering data), administrative (e.g., new laws or evolving water supply constraints), or business (e.g., changes in mine production rates or mine life) conditions. Examples of instances for which adaptive management could be used are the potential need to modify pumping if the aquifer response to pumping or the rate of drain down differ significantly from predictions or if the timing of a new tailing impoundment or mine closure differ significantly from assumed conditions.

4.4.2.2 Administrative Implementability

The administrative implementability of the alternatives refers to the level of regulatory agency or private party interactions needed for land purchases, permitting, and gaining access or right-of-way for construction and operation of the alternative.

The permitting requirements of the alternatives are similar with respect to upgradient source control, downgradient source control, and plume management. Upgradient source control and the IW wellfield are implementable on Sierrita property without additional permitting. Downgradient source control at the FFS wellfield requires acquisition of access to county right-of-way or private property to install wells and pipelines for all the alternatives. The pipeline between the FFS wellfield and the STI would be installed on existing right-of-way through ASLD property. Alternatives 2, 3, 4 and 5 which require wells in addition to the IW, FFS, and SC wellfields would need to establish access to private property or right-of-way on county land. These actions will require permits from ASLD for access and from Pima County for right-of-way and construction. Preliminary discussions with ASLD and Pima County indicate there are no special requirements for the necessary permits.

Access to the land needed for the pumping and pipeline requirements of the mitigation alternatives is a significant aspect of the implementability of the alternatives. Each alternative requires the same land access for installation of the FFS wellfield. Alternatives 2, 3, 4, and 5 require a greater degree of access and right-of-way acquisition than Alternative 1 because they propose wells in addition to the FFS wells. Plume management well sites and pipeline corridors for Alternatives 2 through 5 will require acquisition either by lease, purchase, or right-of-way permit. The access requirements for Alternatives 2 and 4 are less than for Alternatives 3 and 5 which use more wells and pipelines than Alternatives 2 and 4. The access requirements pumping and pipeline requirements of Alternative 2 through 5 are significant, but not more complicated than those for other types of pipeline installation projects.

The administrative implementability of groundwater pumping and water management during mine life is comparable for all mitigation alternatives. The mine holds water rights appropriate for the withdrawal of groundwater for use in mining operations. The administrative implementability of groundwater pumping after mine life is comparable for all mitigation alternatives because mitigation pumping is a mining activity. The administrative implementability of certain potential end uses for treated water that would be generated under Alternatives 1, 2, and 3 would be sensitive to groundwater rights and permits under which the water is pumped. The administrative implementability of in-pit water management for Alternatives 4 and 5 is comparable and would be regulated under Sierrita's APP.

The biggest difference in the implementability of the alternatives is associated with the new tailing impoundment. Alternatives 4 and 5 would require an increased level of administrative activities compared to Alternatives 1 through 3 because of the need to obtain land access for a new tailing impoundment site and to permit the impoundment under the APP program. Implementation of a new tailing impoundment for Alternatives 4 and 5 requires acquisition of ASLD land for the impoundment, permitting, and completion of a large number of environmental and geotechnical studies prior to design and construction. Although implementation of a new tailing impoundment is a significant undertaking as discussed in Section 2.3.1.3, there appears to be no administrative requirements that would make a new tailing impoundment infeasible except for the unavailability of ASLD land, inability to obtain the required permits, or factors, such as unique site characteristics, that could increase capital and operating costs to the point that implementation would be infeasible.

4.4.2.3 Implementation Timeframes

The different levels of land access and construction needed for the mitigation alternatives result in different implementation timeframes. The implementation timeframes estimated for the pumping and piping systems of the mitigation alternatives are:

- Alternative 1 - 18 to 30 months
- Alternative 2 - 24 to 36 months
- Alternative 3 - 24 to 36 months
- Alternative 4 - 24 to 36 months
- Alternative 5 - 24 to 36 months

Alternatives 4 and 5 are assumed to take until 2016 to fully implement the land acquisition, permitting, environmental and geotechnical studies, design, and construction tasks for a new tailing impoundment. However, because there are many steps and issues involved in developing a new tailing impoundment, there are significant uncertainties associated with implementing a new tailing impoundment and the timeframe for implementation. The actual timeframe for implementing a new tailing impoundment could be somewhat longer or shorter than the seven years assumed for the FS depending on the time required to acquire the needed property and obtain permits. Installation and operation of the pumping and piping requirements of Alternatives 4 and 5 would be undertaken during development a new tailing impoundment.

The mitigation alternatives are estimated to be comparable in their implementation timeframes because the need to negotiate access and permits for the FFS wellfield is common to all the alternatives. Alternatives 2 through 5 have slightly longer implementation timeframes than Alternative 1 due to their additional well site and pipeline requirements.

4.4.2.4 Potential Water Level Changes Due to the Mitigation Alternatives

An aspect of implementability is the degree to which the alternatives might potentially change water levels in the vicinity of the plume. The numerical model was used to predict future water levels for each alternative. The water level change of each alternative was determined by comparing the predicted future water levels for the alternatives to the predicted future water levels for a reference case consisting of projected future pumping and recharge in the absence of the mitigation alternative. The reference case included the expected increase in STI seepage in 2010, the seepage decline due to drain down after tailing deposition ceases, and the future pumping and recharge projected by PUG (2008), and assumes that Canoa Ranch and the IW wellfields would be pumped at their 2007 rates until the end of mine life. After mine life the reference case considers that there would be no pumping at the Canoa Ranch and IW wells. Comparison of the reference case to the mitigation alternatives shows the net change in predicted water level attributable to the mitigation alternatives. The net predicted water level change would be independent of changes due to non-mitigation pumping and recharge in the area.

Figures 20, 21, 22, 23, and 24 show the predicted water level changes of Alternatives 1, 2, 3, 4, and 5, respectively. The water level changes are predicted for three times: 2020, 2040 prior to mine closure, and 2060 after mine closure. The simulation results predict that mitigation pumping during mine life would cause a net decrease in groundwater levels in the vicinity of the plume with respect to the reference case and that the reduction of pumping at Canoa Ranch would result in a net water level increase in groundwater levels upgradient of Green Valley compared to the reference case. Water level declines during mine life would be due to operation of the FFS, SC, PS, and MC wells only because pumping at the IW wells is included in the reference case. Predicted water level increases at Canoa Ranch would be due to decreasing Canoa Ranch pumping by the amount of pumping at the FFS, SC, PS, and MC wells during mine life. In general, the predicted water level declines decrease with distance from the mitigation wells and the predicted water level increases decrease with distance from the Canoa Ranch wells. After mine life, water level changes are due to pumping the IW, FFS, SC, PS, and MC wells per the specifications of the alternatives (Tables 3, 5, 7, 9, and 11).

Existing water supply wells ST-7, CWC-9, CWC-6, and GVDWID-1 were evaluated for potential water level changes because these well are closest to the mitigation wellfields where water level declines should be greatest. Table 14 summarizes predicted water level declines at these wells due to the mitigation alternatives. The greatest water level declines in 2040, prior to mine closure, are predicted for Alternatives 3 and 5. In 2060, after mine closure, the greatest water level declines (25 to 55 feet) are predicted for Alternatives 1, 2, and 3. Alternatives 4 and 5 are predicted to have lower water level decline (less than 25 feet) after mine closure than do Alternatives 1, 2, and 3. Overall, Alternative 5 is predicted to have the least water level decline (10 to 20 feet) after mine closure.

Interpretation of the significance of the predicted water level declines requires evaluation of the difference in future saturated thickness at affected wells and the possible reduction in well efficiency due to the declines. The maximum predicted water level decline in year 2060 ranges from 50 to 55 feet (Table 14). In general, the maximum predicted water level decline of 55 feet is less than 15 percent of the current saturated casing lengths of the wells evaluated. This level of decline in the phreatic surface is not expected to significantly reduce well productivity.

4.4.2.5 Summary of Implementability

All the mitigation alternatives are anticipated to be technically and administratively implementable. With the exception of Alternative 1, all the alternatives have comparable implementation timeframes of 24 to 36 months for extraction systems. Alternative 1 has a shorter timeframe of 18 to 30 months due to its lower well and pipeline requirements compared to the other alternatives. The overall implementation timeframes for Alternatives 4 and 5 would be longer than for the other alternatives, because development of a new tailing impoundment would take approximately seven years assuming land acquisition and permitting can be accomplished in a reasonable time frame. Development of a new tailing impoundment would be done while the extraction systems are implemented.

Similarly, all the alternatives are comparable with respect to the administrative implementability of the extraction systems. Where they differ is in the administrative implementability of a new tailing impoundment under Alternatives 4 and 5. As was discussed in Section 2.3.1.3, a number of activities will need to be completed, including land acquisition and permitting, before a new tailing impoundment can be constructed.

The mitigation alternatives would all reduce water levels in the vicinity of the sulfate plume and increase water levels in the Canoa Ranch area during mine life. Water level decreases in the vicinity of the plume are inevitable for any mitigation strategy using groundwater pumping to control the plume. Of the alternatives, Alternative 5 is predicted to have the lowest overall post-mine water level declines and, therefore, provides a benefit in terms of minimizing the post-mine water level impacts of the mitigation.

4.4.3 Cost

Table 15 summarizes costs for the mitigation alternatives. A discussion of the costs is provided below.

4.4.3.1 Non-Discounted and Net Present Value Costs

The total non-discounted cost of Alternatives 1, 2, 3, 4, and 5 is estimated to be $173 million, $207 million, $208 million, $71.7 million, and $81.4 million, respectively. The highest non-discounted total project cost is estimated for Alternative 3 at a value of $208 million. The lowest total project cost is estimated for Alternative 4 at $71.7 million. Alternatives 4 and 5 are relatively close in cost, but are only 35 percent to 47 percent of the cost of Alternatives 1, 2, and 3. The significantly lower cost of Alternatives 4 and 5 is because pumping at the assumed end of mine life can be managed by in-pit storage rather than by water treatment. The cost evaluation does not cover the total cost of the mitigation alternatives to reach MNA because the cost evaluation accounts for only 50 years of mitigation. The long-term non-discounted cost for Alternatives 1, 2, and 3 to reach MNA would likely be significantly greater than for Alternatives 4 and 5 because Alternatives 1, 2, and 3 would have longer drain down times and would still have high pumping and treatment requirements at the end of 50 years.

The NPV(50) of Alternatives 1, 2, 3, 4, and 5 is estimated at $37.1 million, $49.1 million, $58.0 million, $32.4 million, and $42.6 million, respectively. The lowest NPV(50) is estimated for Alternative 4 at $32.4 million, which also had the lowest total non-discounted cost. The highest NPV(50) of $58.0 million is estimated for Alternative 3. In Alternatives 1, 2, and 3 a significant portion of the cost in the NPV(50) is due to post-mine pumping and water treatment which do not begin until the year 2043, and, therefore, are heavily discounted in the NPV calculation.

The total non-discounted cost provides a better estimate of the absolute level of expenditure for the mitigation alternatives than does the NPV(50) which accounts for the time value of money. Thus, the NPV(50) is subject to uncertainty in assumptions regarding the timing of expenditures and the effective interest rate, whereas the non-discounted cost is not. Alternative 4 is the lowest cost mitigation alternative and Alternative 5 the second lowest cost mitigation alternative based on the total non-discounted cost.

4.4.3.2 Cost Effectiveness

As was discussed in Section 4.4.1, Alternative 5 would have the most effective source control and plume management compared to the other mitigation alternatives considered. Another measure of the mitigation alternatives is their cost effectiveness with respect to the cost per unit of net sulfate mass removed. Dividing the total non-discounted cost of the mitigation alternatives (Section 4.4.3.1) by the net sulfate mass removed after 50 years (Section 4.4.1.6) yields the following cost per unit of net sulfate mass removed for Alternatives 1, 2, 3, 4, and 5, respectively: $1,960 per ton, $880 per ton, $680 per ton, $155 per ton, and $147 per ton.

Although Alternative 4 has a slightly lower non-discounted cost than Alternative 5, Alternative 5 has the highest net sulfate mass removal, the lowest cost per unit of net sulfate mass removed, and meets more of the effectiveness criteria than Alternative 4 (Section 4.4.1). On this basis, Alternative 5 is considered the most cost effective mitigation alternative.

5. RECOMMENDED MITIGATION ALTERNATIVE

Table 13 compares the effectiveness, implementability, and cost of the five mitigation alternatives. The mitigation alternatives all meet the mitigation objective of providing a drinking water supply with sulfate concentrations less than 250 mg/L, but do so using different combinations of source control, plume management, and drinking water supply mitigation actions. The selection of a recommended mitigation alternative considered guidance at ARS § 49-286 pertaining to mitigation of non-hazardous releases. ARS § 49-286.A identifies possible mitigation measures as:

1. Providing an alternative water supply.
2. Mixing or blending if economically practicable.
3. Economically and technically practicable treatment before ingesting water.
4. Such other mutually agreeable mitigation measures as are necessary to achieve the purposes of this section

ARS § 49-286.B states "The director's selection of mitigation measures shall balance the short-term and long-term public benefits of mitigation with the cost of each alternative measure. The director may only require the least costly alternative if more then one alternative may render water usable as a drinking water source."

The contingent water supply mitigation provisions of the mitigation alternatives satisfy the provisions of ARS § 49-286.A. To characterize the short- and long term benefits of the mitigation alternatives, the effectiveness and implementability of the mitigation alternatives were evaluated with respect to the following factors as discussed in Section 4:

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- Practically and cost efficiently provide the owner/operator of an existing drinking water supply impacted by the sulfate plume from the STI with a drinking water supply with sulfate concentrations less than 250 mg/L
- Control of plume migration
- Reduction of plume extent
- Minimization of mitigation pumping
- Duration and magnitude of source control pumping
- Net sulfate mass removal
- Technical implementability
- Administrative implementability
- Potential water level changes due to the mitigation alternatives

On consideration of the benefits and costs of the mitigation alternatives, and consistent with ARS § 49-286, Alternative 5 is recommended as the preferred alternative because it would provide superior effectiveness (Section 4.4.1), the least amount of long-term water level impact (Section 4.4.2.4), and greater cost effectiveness (Section 4.4.3.2) compared to the other alternatives considered.

Sierrita would implement Alternative 5 using an adaptive management approach consistent with Section III.D of the Mitigation Order. The adaptive management approach, which includes the use of contingent measures, would allow the mitigation to respond to scientific (i.e., groundwater monitoring results or engineering data), administrative (e.g., new laws or evolving water supply constraints, etc.), or business (e.g., changes in mine production rates or mine life) conditions. Given the uncertainty in the technical, administrative, and business assumptions made to develop mitigation alternatives for the FS, the adaptive management approach will allow for the recommended mitigation alternative to be modified as appropriate in response to new information concerning its implementability (i.e., the ability to purchase, permit, and cost effectively construct a new tailing impoundment, which is the underlying basis for the effectiveness of the recommended alternative), performance, or operating conditions. Because the long-term seepage rates under the recommended alternative would dictate the need to maintain post-mine mitigation pumping, the performance of the mitigation would be evaluated every five years after mine closure to determine whether mitigation pumping is needed, versus MNA, to meet the mitigation objective.

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7. LIMITATIONS

The information and conclusions presented in this report are based upon the scope of services and information obtained through the performance of the services, as agreed upon by HGC and the party for whom this report was originally prepared. Results of any investigations, tests, or findings presented in this report apply solely to conditions existing at the time HGC's investigative work was performed and are inherently based on and limited to the available data and the extent of the investigation activities. No representation, warranty, or guarantee, express or implied, is intended or given. HGC makes no representation as to the accuracy or completeness of any information provided by other parties not under contract to HGC to the extent that HGC relied upon that information. This report is expressly for the sole and exclusive use of the party for whom this report was originally prepared and for the particular purpose that it was intended. Reuse of this report, or any portion thereof, for other than its intended purpose, or if modified, or if used by third parties, shall be at the sole risk of the user.

TABLES

TABLE 1
Mitigation Actions, Control Technologies, and Process Options Evaluated for Alternative Development Mitigation Actions

Mitigation Response Action	Control Technology	Process Option	Effectiveness	Implementability	Cost	Evaluation
SOURCE CONTROL AT STI (see Appendix A for screening analysis)						
Sulfate Source Control for the Tailing Discharge and Stormwater Discharge (to the STI)	Tailing Discharge Source Control	Substitute NaHS with cyanide in concentrator	Ineffective; although NaHS accounts for 19% of annual sulfate load to STI, substitution of NaHS with cyanide may not reduce sulfate loading to groundwater due to potential dissolution of gypsum within tailing	Implementable, but use of cyanide poses potential environmental risks	High	Rejected because of environmental risk associated with use of cyanide and low effectiveness in reducing sulfate loading to groundwater
		Removal of CaSO4 from molybdenum roaster scrubber discharge	Ineffective; although treatment of moly roaster scrubber discharge is 52% of annual sulfate load to STI, removal of CaSO4 from discharge may not reduce sulfate loading to groundwater due to potential dissolution of gypsum within tailing	Implementable with current technology and equipment	High	Rejected because of low effectiveness in reducing sulfate loading to groundwater
		Removal of pyrite from tailing by construction of additional flotation plant	Ineffective because pyrite oxidation in the tailing is expected to be a negligible source of sulfate	Implementable	High	Rejected because ineffective
		Reduce pyrite reactivity	Ineffective because high saturation needed to reduce oxygen flux to reactive pyrite would increase the water content of the impoundment and seepage	Questionable implementability because tailing saturation affects impoundment stability	Medium	Rejected because ineffective
	Stormwater Discharge Source Control	Reduce Amargosa Pond overflows by installing lined storage pond	Moderately effective; although lined pond would eliminate source of water and sulfate to STI it may not substantially reduce sulfate loading to groundwater because stormwater discharge is only 2 % of annual sulfate mass load to the STI	Implementable	Medium	Retain for alternative development
		Reduce Duval Canal discharge by installing lined stormwater pond	Moderately effective; although lined pond would eliminate source of water and sulfate to STI it may not substantially reduce sulfate loading to groundwater because stormwater discharge is only 2 % of annual sulfate mass load to the STI	Implementable	Medium	Retain for alternative development
Water Source Control for STI Discharge	Paste Tailing	Reduce water discharge to STI using paste thickeners to reduce tailing water content to 40%	Effective; would reduce the amount of water discharged to STI and initiate earlier draindown and reduction in sulfate loading to groundwater	Implementability is complicated by scale of Sierrita operations and potential for fugitive dust	High	Rejected due to implementability and high cost
	Filtered Tailing	Reduce water discharge to STI using filter presses to reduce tailing water content to 20%	Effective; would reduce the amount of water discharged to STI and initiate earlier draindown and reduction in sulfate loading to groundwater	Implementability is complicated by material handling on STI, potential for fugitive dust, and need for concurrent reclamation	High	Rejected due to implementability and high cost
Seepage Source Control for Reclaim Pond	Extraction	Intercept seepage with infiltration gallery or caisson	Ineffective; would remove only a small fraction of tailing moisture	Implementable with current technology and equipment	Medium	Rejected due to poor effectiveness
		Intercept seepage with wicking system	Ineffective; would remove only a small fraction of tailing moisture	Implementable with current technology and equipment	Medium	Rejected due to poor effectiveness
	Reclaim Pond Containment	Limit reclaim pond seepage with low permeability liner	Moderately effective; would reduce seepage from reclaim pond, but would not reduce seepage from other portions of the STI	Implementable, but not recommended because liner gets buried as tailing deposition occurs causing restricted drainage and impoundment stability concerns	High	Rejected due to poor implementability
	Operational Controls	Control reclaim pond location to reduce seepage	Moderately effective; maintaining the pond location in the area with lowest permeability would reduce seepage, but would not reduce seepage from other portions of the STI	Implementable with current technology and equipment	Medium	Retain for alternative development
		Optimize reclaim pond pumping to increase solution recovery	Moderately effective; operating the reclaim pond pumps to maximize recovery from pond and reduce seepage, but would not reduce seepage from other portions of the STI	Implementable with current technology and equipment	Medium	Retain for alternative development
Containment	Minimize Infiltration After Closure and Enhance Drain	Soil cap at closure to limit future infiltration	Effective; a soil cap to limit infiltration can reduce future infiltration to the STI	Implementable at final reclamation with current technology and equipment	Medium	Retain for alternative development
		Stormwater controls at closure to limit future runon and infiltration	Effective; stormwater controls can reduce future infiltration by conveying stormwater away from the STI	Implementable at final reclamation with current technology and equipment	Medium	Retain for alternative development
In-Situ Tailing Treatment	In-Situ Stabilization	Inject or mix stabilization agent (reducing agent or carbon source) into tailing to reduce sulfate mobility	Uncertain effectiveness; not a proven technology and could mobilize other constituents	Not implementable due to size and depth of STI	Medium	Rejected due to uncertain effectiveness and poor implementability
	In-Situ Vitrification	Reduce sulfate mobility by vitrifying tailing with electric current	Uncertain effectiveness; not a proven technology at the scale of the STI	Not implementable due to size and depth of STI; requires massive amounts of electricity	High	Rejected due to uncertain effectiveness and poor implementability
	In-Situ Passivation of Reactive Minerals	Reduce sulfate mobility by injecting or mixing with sulfide passivation compound	Uncertain effectiveness; not a proven technology at the scale of the STI	Not implementable due to size and depth of the STI	Medium	Rejected due to uncertain effectiveness and poor implementability
Tailing Discharge Source Control	Product Development	Create marketable product (i.e., bricks) from tailing material	Effective	Not implementable; no local, commercial scale manufacturing facilities currently exist	Uncertain	Rejected due to poor implementability

Shading indicates process option retained for alternatives analysis

TABLE 1
Mitigation Actions, Control Technologies, and Process Options Evaluated for Alternative Development Mitigation Actions

Mitigation Response Action	Control Technology	Process Option	Effectiveness	Implementability	Cost	Evaluation
DOWNGRADIENT SOURCE CONTROL BY SEEPAGE CAPTURE (see HGC (2007b) for screening analysis)						
Groundwater Control	Groundwater Pumping	Vertical wells proximal to the interceptor wellfield	Potentially effective in short-term, potentially ineffective in long-term because well capacity will continue to decrease as saturated thickness decreases, resulting in diminished well yields and capture over time	Implementable on Sierrita property	High	Rejected because ineffective in long-term
		Vertical wells distal from the interceptor wellfield	Potentially effective in short- and long-term, wells east of the Sierrita STI where the aquifer is thicker and can sustain higher pumping rates from fewer wells to establish groundwater containment	Implementable pending permit and land access negotiation with ASLD or private parties	High	Retain for alternative development
		Horizontal wells	Ineffective for this application; most horizontal wells are shallow (< 100 feet deep), there are potential problems installing a horizontal well on an irregular bedrock surface in such a way as to maintain the saturated thickness for pumping	Not implementable due to technical infeasibility given site-specific conditions	High	Rejected because ineffective and not implementable
		Ranney (collector) wells	Ineffective for this application; Ranney wells and other types of collector wells are typically installed to depths of 150 feet or less	Not implementable due to technical infeasibility given site-specific conditions	High	Rejected because ineffective and not implementable
	Groundwater Barriers	Physical barriers	Ineffective for this application; physical barriers are difficult to install to depths greater that 150 feet	Not implementable due to technical infeasibility given site-specific conditions	High	Rejected because ineffective and not implementable
		Hydraulic barrier using injection wells	Potentially effective; a hydraulic barrier can be created by injecting low-sulfate water at the interceptor wellfield, but its effectiveness is uncertain due to complex O&M; requires pilot testing	Implementable on Sierrita property, but technology is associated with complex O&M	High	Rejected due to uncertain effectiveness and difficulty of implementation
		Hydraulic barrier using infiltration	Potentially effective; a hydraulic barrier can be created by infiltration ponds or infiltration gallery but would take a long time to reach steady state, is difficult to test and control, and may be influenced by perching	Infiltration gallery is potentially implementable on Sierrita land; Infiltration ponds may require access to ASLD land	Moderate	Rejected because option is potentially not as effective or controllable as a hydraulic barrier using injection wells
Water Treatment	In-Situ Treatment	Inject reagents for chemical precipitation or chemical or biological reduction of sulfate	Potential effectiveness is uncertain; site-specific pilot testing needed to evaluate effectiveness	Site-specific pilot testing needed to evaluate implementability; would require APP and UIC permits	High	Effectiveness and implementability uncertain; not considered further
	Ex-Situ Treatment	Water treatment by membrane process (reverse osmosis, nanofiltration, electrodialysis reversal)	Effective; reverse osmosis or nanofiltration identified as the most feasible treatment technologies. Treatment expensive and produces a brine waste although retained as option for water treatment if needed	Implementable	High	Retain for alternative development
		Blending	Effective; capable of meeting water quality standards and meeting the 250 mg/L sulfate limit	Implementable; requires source of water for blending	Medium	Retain for alternative development in the event post-mine life treatment is needed for water management
Water Management	Mine Use	Pump water to mine for use without treatment	Effective; dependant on water need in the mining operation; current projected mine life is through 2042	Implementable; currently in practice	Medium	Retain for alternative development
	In-Pit Storage	Water storage and evaporation in Sierrita pit	Effective; water storage can effectively manage mitigation water provided that the flow rate allows maintenance of hydraulic sink conditions	Implementable; would need to comply with applicable regulations	Medium	Retain for alternative development if mine use is infeasible
	Treatment for Use	Water treatment to meet standards appropriate for use (e.g., drinking water supply, release to aquifer, agricultural supply)	Effective; water treatment can effectively reduce sulfate concentrations to levels appropriate for potential uses	Implementable, but not preferred compared to mine use and in-pit storage due to significantly higher cost of treatment and conveyance; certain end uses may be limited by rights and permits in effect at the time	High	Retain for alternative development if mine use and in-pit storage are infeasible
SOURCE CONTROL BY NEW TAILING IMPOUNDMENT						
New Tailing Impoundment	Design and Construct New Impoundment		Effective; a new tailing impoundment would allow discontinuation of STI and thereby initiate drain down and reduce sulfate loading to groundwater while mine is operating	Implementable; requires Sierrita to obtain necessary property and design, permit, and build	High	Retain for alternative development
PLUME MANAGEMENT (see Appendix B for screening analysis)						
Institutional Actions	Groundwater Monitoring	Ongoing groundwater monitoring at monitor and drinking water supply wells	Potentially effective at determining the magnitude and extent of the plume	Implementable; may require installation of additional monitoring wells	Low	Retain for alternative development
Monitored Natural Attenuation	Sulfate Attenuation Through Mixing	Sulfate impacted groundwater mixes with dilute groundwater and recharge	Potentially effective depending on how sulfate concentrations naturally attenuate.	Implementable; may require installation of additional monitoring wells	Low	Retain for alternative development

Shading indicates process option retained for alternatives analysis

TABLE 1
Mitigation Actions, Control Technologies, and Process Options Evaluated for Alternative Development Mitigation Actions

Mitigation Response Action	Control Technology	Process Option	Effectiveness	Implementability	Cost	Evaluation
Groundwater Control	Groundwater Pumping	Vertical wells	Potentially effective; standard technology for plume management	Implementable; requires land access and right of way for wells and pipelines	Medium	Retain for alternative development
		Horizontal wells	Potentially effective, but some uncertainty regarding the extent of vertical capture for plume management	Implementable, but is a non-standard technology requiring specialized equipment, personnel, and well construction materials	High	Rejected because option is a non-standard technology that is more costly than vertical wells
	Groundwater Barriers	Physical barriers	Ineffective for this application; physical barriers are difficult to install to depths greater that 150 feet	Not implementable due to technical infeasibility given site-specific conditions	High	Rejected because option is ineffective and infeasible for plume management
		Hydraulic barrier using injection wells	Potentially effective; a hydraulic barrier can be created by injecting low-sulfate water, but effectiveness is uncertain due to complex O&M; requires pilot testing	Implementable, but technology is associated with a high level of O&M that can impact effectiveness	High	Rejected because effectiveness uncertain and because there's no apparent need for a barrier to enhance wellfield performance
		Hydraulic barrier using infiltration	Potentially effective; a hydraulic barrier can be created by infiltration ponds but would take a long time to reach steady state, is difficult to test and control, and may be influenced by perching.	Infiltration gallery is potentially implementable, but requires land for ponds	Medium	Rejected because option is not as effective as injection wells and there's no apparent need for a barrier to enhance wellfield performance
Water Treatment	In-Situ Treatment	Inject reagents for chemical precipitation or chemical or biological reduction of sulfate in the aquifer	Potential ineffective due to difficulty of attaining uniform treatment and potential well and aquifer clogging, site -specific testing needed to evaluate effectiveness	Site-specific pilot testing needed to evaluate implementability; would require APP and UIC permits	High	Effectiveness and implementability uncertain; not considered further
	Ex-Situ Treatment	Treatment by reverse osmosis	Effective; capable of meeting the 250 mg/L sulfate limit	Implementable; produces a brine concentration that requires management	High	Retain for alternative development in the event post-mine life treatment is needed for water management
		Blending	Effective; capable of meeting the 250 mg/L sulfate limit	Implementable; requires source of water for blending	Medium	Retain for alternative development in the event post-mine life treatment is needed for water management
Water Management	Mine Use	Pump water to mine for use without treatment	Effective; dependant on water need in the mining operation; current projected mine life is through 2042	Implementable; currently in practice	Medium	Retain for alternative development
	In-Pit Storage	Water storage and evaporation in Sierrita pit	Effective; water storage can effectively manage mitigation water provided that the flow rate allows maintenance of hydraulic sink conditions	Implementable; would need to comply with applicable regulations	Medium	Retain for alternative development if mine use is infeasible
	Treatment for Use	Water treatment to meet standards appropriate for use (e.g., drinking water supply, release to aquifer, agricultural supply)	Effective; water treatment can effectively reduce sulfate concentrations to levels appropriate for potential uses	Implementable, but not preferred compared to mine use and in-pit storage due to significantly higher cost of treatment and conveyance; certain end uses may be limited by rights and permits in effect at the time	High	Retain for alternative development if mine use and in-pit storage are infeasible
DRINKING WATER SUPPLY MITIGATION (see Appendix C for screening analysis)						
Alternative Water Supply	Well Modification to Eliminate Puming from Sulfate-Containing Zones		Ineffective; difficult to retrofit existing wells, high risk of damage to well	Implementable, but limited to sites with a low sulfate zone	Medium	Rejected due to poor effectiveness
	Well Replacement		Effective; well replacement may effectively provide a source of drinking water if there is low sulfate zone present beneath property	Implementable; requires well site and associated infrastructure	Medium	Retain for alternative development
	Connection to Alternative Water Supply		Effective; connection to an alternative water supply would provide drinking water that meets standards	Implementable; requires proximity to water supply	Medium	Retain for alternative development
	Recommission the Esperanza Wells		Effective, but best as a short term action due to proximity of Esperanza wells to sulfate plume	Implementable	Medium	Retain for alternative development
	Bottled Water		Effective; bottled water is a short term action for private wells or a small water system	Implementable	Low	Retain for alternative development

Shading indicates process option retained for alternatives analysis

TABLE 1
Mitigation Actions, Control Technologies, and Process Options Evaluated for Alternative Development Mitigation Actions

Mitigation Response Action	Control Technology	Process Option	Effectiveness	Implementability	Cost	Evaluation
Water Treatment	Point-of-Use Reverse Osmosis	Install reverse osmosis system for kitchen use only	Effective; point-of-use treatment can produce low volumes of water that meet standards for kitchen use	Implementable; point-of-use treatment systems are an existing and reliable technology	Low	Retain for alternative development
	Full-House Reverse Osmosis	Install reverse osmosis system for all household demands	Effective; household treatment can produce water that meets standards at point of entry to home	Implementable; household treatment systems are an existing and reliable technology	Medium	Retain for alternative development
	Ion Exchange	Install household ion exchange unit	Ineffective at achieving acceptable total dissolved solids and chloride levels	Implementable	Medium	Rejected because ineffective
	Well-head Membrane Treatment	Reverse osmosis treatment at wellhead	Effective; wellhead treatment can produce water that meets standards prior to the point of entry to system	Implementable; requires 3- to 12-month lead time	Medium	Retain for alternative development
		Nanofiltration treatment at wellhead	Effective; wellhead treatment can produce water that meets standards prior to the point of entry to system	Implementable; requires 12-month lead time	Medium	Retain for alternative development
		Electrodialysis treatment at wellhead	Effective; wellhead treatment can produce water that meets standards prior to the point of entry to system	Implementable; requires 24-month lead time	Medium	Retain for alternative development
Blending	Mix Impacted Well Water with Water from Other Sources to Meet Sulfate Action Level Prior to Distribution		Effective; blending can produce water that meets standards prior to the point of entry to system	Implementable; requires one or more sources of dilute water and mixing facility	Low	Retain for alternative development

Shading indicates process option retained for alternatives analysis

TABLE 2
Mitigation Alternatives

ALTERNATIVE		SOURCE CONTROL	PLUME MANAGMENT	DRINKING WATER SUPPLY MITIGATION
1	Source Control and Monitored Natural Attenuation	1. Base Case Source Control • Pump STI seepage at the IW and FFS wells until MNA can be implemented • Use mitigation water at mine during mine life • In-pit storage or water treatment for use after mine life • Install liner in Amargosa Pond and Duval Canal to eliminate stormwater discharges to STI • Control reclaim pond location and volume to reduce infiltration to STI • Install soil cover and surface water controls to reduce infiltration on closure of STI	1. Base Case Plume Management • Groundwater monitoring to evaluate mitigation effectiveness and quality of drinking water supplies	Mitigate any water supply impacted by sulfate from the STI per ARS 49-286. Depending on site-specific conditions, mitigation may consist of: • Well modification or replacement • Connection to alternative water supply • Bottled water • Point-of-use, full-house, or wellhead treatment • Blending
2	Source Control and Plume Stabilization	1. Base Case Source Control (see Alternative 1)	1. Base Case Plume Management (see Alternative 1) 2. Pump groundwater at the leading edge of the downgradient plume until MNA can be implemented 3. Use mitigation water at mine during mine life 4. Water treatment for use after mine life	Unnecessary if plume management is effective, but available as a contingency if needed (see Alternative 1)
3	Source Control Plume Stabilization, and Mass Removal	1. Base Case Source Control (see Alternative 1)	1. Base Case Plume Management (see Alternative 1) 2. Pump groundwater at the leading edge of the downgradient plume until MNA can be implemented 3. Pump groundwater at within the downgradient plume prior to end of mine life to reduce sulfate mass until MNA can be implemented 4. Use mitigation water at mine during mine life 5. Water treatment for use after mine life	Unnecessary if plume management is effective, but available as a contingency if needed (see Alternative 1)
4	New Tailing Impoundment, Source Control, and Plume Stabilization	1. Base Case Source Control (see Alternative 1) 2. Permit, design, and build a new tailing impoundment	1. Base Case Plume Management (see Alternative 1) 2. Pump groundwater at the leading edge of the downgradient plume until MNA can be implemented 3. Use mitigation water at mine during mine life 4. In-pit storage after mine life	Unnecessary if plume management is effective, but available as a contingency if needed (see Alternative 1)
5	New Tailing Impoundment, Source Control, Plume Stabilization, and Mass Removal	1. Base Case Source Control (see Alternative 1) 2. Permit, design, and build a new tailing impoundment	1. Base Case Plume Management (see Alternative 1) 2. Pump groundwater at the leading edge of the downgradient plume until MNA can be implemented 3. Pump groundwater at within the downgradient plume prior to end of mine life to reduce sulfate mass until MNA can be implemented 4. Use mitigation water at mine during mine life 5. In-pit storage after mine life	Unnecessary if plume management is effective, but available as a contingency if needed (see Alternative 1)

TABLE 3
Alternative 1 Pumping Specifications

Alternative 1 Well ID	Location		From year: / To year:		
			2010 / 2042	2043 / 2050	2051 / 2060
FFS Wellfield	**UTME**	**UTMN**	**Rate (gpm)**	**Rate (gpm)**	**Rate (gpm)**
FFS-1	498550	3527752	600	500	400
FFS-2	498880	3527300	600	550	400
FFS-3	498895	3526595	550	550	400
FFS-4	498910	3525935	500	500	400
FFS-5	498968	3525190	500	500	400
FFS-6	498760	3524659	400	400	400
Source Control Wellfield					
SC-1	497652	3523177	400	400	250
SC-2	497671	3522578	400	400	250
SC-3	497644	3522160	400	400	250
SC-4	497643	3521741	300	300	0
Interceptor Wellfield					
IW-1	496906	3521278	346	346	346
IW-2	497485	3521361	534	534	534
IW-3	497366	3521723	0	0	0
IW-3A	497366	3521723	572	572	572
IW-4	497372	3522466	230	230	230
IW-5	497370	3522815	115	115	115
IW-6A	497381	3523709	128	128	128
IW-7	496428	3521307	0	0	0
IW-8	497368	3522021	452	452	452
IW-9	497370	3522208	253	253	253
IW-10	497370	3523122	304	304	304
IW-11	497371	3523429	333	333	333
IW-12	497365	3523970	150	150	150
IW-13	497364	3524167	0	0	0
IW-14	497367	3524373	89	89	89
IW-15	497373	3524567	43	43	43
IW-16	497371	3524783	0	0	0
IW-17	497374	3525003	0	0	0
IW-18	497374	3525170	0	0	0
IW-19	497374	3525343	168	168	168
IW-20	497365	3525569	140	140	140
IW-21	497375	3525773	158	158	158
IW-22	497370	3523274	399	399	399
IW-23	497369	3522971	202	202	202
IW-24	497372	3522634	246	246	246

TABLE 3
Alternative 1 Pumping Specifications

Alternative 1 Well ID	Location				
		From year: / To year:	2010 / 2042	2043 / 2050	2051 / 2060
FFS Wellfield	**UTME**	**UTMN**	**Rate (gpm)**	**Rate (gpm)**	**Rate (gpm)**
Pumping Summary					
FFS Wellfield			3,150	3,000	2,400
Source Control Wellfield			1,500	1,500	750
Interceptor Wellfield			4,861	4,861	4,861
Mitigation Pumping Total			**9,511**	**9,361**	**8,011**
Canoa Wellfield			7,725	0	0
Pumping Total			**17,236**	**9,361**	**8,011**

Notes:

UTME = Universal Transverse Mercator Easting
UTMN = Universal Transverse Mercator Northing
ft bgs = feet below ground surface
gpm = gallons per minute

TABLE 4
Alternative 1 Cost Summary

Total Initial Capital	Annual O&M *(years 2010-2030)*	Annual O&M *(years 2031-2042)*	Annual O&M *(years 2043-2058)*	50 Year NPV [1]	Total Non-Discounted Cost to Year 2058
Cost in Millions					
$10.8	**$0.54**	**$0.54**	**$7.1**	**$37.1**	**$173**

Note:
[1] *NPV = Net Present Value calculated at a 7.8 percent discount rate minus a 2.4 percent escalation rate*

TABLE 5
Alternative 2 Pumping Specifications

Alternative 2 Well ID	Location		From year: / To year:	2010 / 2020	2021 / 2030	2031 / 2042	2043 / 2050	2051 / 2060

FFS Wellfield	UTME	UTMN	Rate (gpm)	Rate (gpm)	Rate (gpm)	Rate (gpm)	Rate (gpm)
FFS-1	498550	3527752	600	600	600	600	400
FFS-2	498880	3527300	550	550	550	550	400
FFS-3	498895	3526595	550	550	550	550	400
FFS-4	498910	3525935	500	500	500	500	400
FFS-5	498968	3525190	500	500	500	500	400
FFS-6	498760	3524659	400	400	400	400	400
Source Control Wellfield							
SC-1	497652	3523177	400	400	400	400	250
SC-2	497671	3522578	400	400	400	400	250
SC-3	497644	3522160	400	400	400	400	250
SC-4	497643	3521741	300	300	300	300	0
Plume Stabilization Wellfield							
PS-1	499030	3529240	600	600	450	450	450
PS-2	499189	3529336	600	600	400	200	200
PS-3	499440	3529317	600	500	500	500	500
PS-4	499010	3528715	500	500	500	350	350
Interceptor Wellfield							
IW-1	496906	3521278	346	346	346	346	346
IW-2	497485	3521361	534	534	534	534	534
IW-3	497366	3521723	0	0	0	0	0
IW-3A	497366	3521723	572	572	572	572	572
IW-4	497372	3522466	230	230	230	230	230
IW-5	497370	3522815	115	115	115	115	115
IW-6A	497381	3523709	128	128	128	128	128
IW-7	496428	3521307	0	0	0	0	0
IW-8	497368	3522021	452	452	452	452	452
IW-9	497370	3522208	253	253	253	253	253
IW-10	497370	3523122	304	304	304	304	304
IW-11	497371	3523429	333	333	333	333	333
IW-12	497365	3523970	150	150	150	150	150
IW-13	497364	3524167	0	0	0	0	0
IW-14	497367	3524373	89	89	89	89	89
IW-15	497373	3524567	43	43	43	43	43
IW-16	497371	3524783	0	0	0	0	0
IW-17	497374	3525003	0	0	0	0	0
IW-18	497374	3525170	0	0	0	0	0
IW-19	497374	3525343	168	168	168	168	168
IW-20	497365	3525569	140	140	140	140	140
IW-21	497375	3525773	158	158	158	158	158
IW-22	497370	3523274	399	399	399	399	399
IW-23	497369	3522971	202	202	202	202	202
IW-24	497372	3522634	246	246	246	246	246

TABLE 5
Alternative 2 Pumping Specifications

Alternative 2 Well ID	Location							
		From year:	2010	2021	2031	2043	2051
		To year:	2020	2030	2042	2050	2060
FFS Wellfield	**UTME**	**UTMN**	**Rate (gpm)**	**Rate (gpm)**	**Rate (gpm)**	**Rate (gpm)**	**Rate (gpm)**
Pumping Summary							
FFS Wellfield			3,100	3,100	3,100	3,100	2,400
Source Control Wellfield			1,500	1,500	1,500	1,500	750
Plume Stabilization Wellfield			2,300	2,200	1,850	1,500	1,500
Interceptor Wellfield			4,861	4,861	4,861	4,861	4,861
Mitigation Pumping Total			**11,761**	**11,661**	**11,311**	**10,961**	**9,511**
Canoa Wellfield			5,475	5,575	5,925	0	0
Pumping Total			**17,236**	**17,236**	**17,236**	**10,961**	**9,511**

Notes:
UTME = Universal Transverse Mercator Easting
UTMN = Universal Transverse Mercator Northing
ft bgs = feet below ground surface
gpm = gallons per minute

TABLE 6
Alternative 2 Cost Summary

Total Initial Capital	Annual O&M *(years 2010-2030)*	Annual O&M *(years 2031-2042)*	Annual O&M *(years 2043-2058)*	50 Year NPV [1]	Total Non-Discounted Cost to Year 2058
Cost in Millions					
$16.0	**$0.85**	**$0.85**	**$8.0**	**$49.1**	**$207**

Note:
[1] *NPV = Net Present Value calculated at a 7.8 percent discount rate minus a 2.4 percent escalation rate*

TABLE 7
Alternative 3 Pumping Specifications

Alternative 3 Well ID	Location		From year: 2010 To year: 2020	From year: 2021 To year: 2030	From year: 2031 To year: 2042	From year: 2043 To year: 2050	From year: 2051 To year: 2060
FFS Wellfield	**UTME**	**UTMN**	**Rate (gpm)**	**Rate (gpm)**	**Rate (gpm)**	**Rate (gpm)**	**Rate (gpm)**
FFS-1	498550	3527752	1000	1000	1000	500	450
FFS-2	498880	3527300	900	900	900	550	450
FFS-3	498895	3526595	850	850	850	550	400
FFS-4	498910	3525935	900	900	900	500	400
FFS-5	498968	3525190	900	900	900	500	400
FFS-6	498760	3524659	900	900	900	400	400
Source Control Wellfield							
SC-1	497652	3523177	400	400	400	400	250
SC-2	497671	3522578	400	400	400	400	250
SC-3	497644	3522160	400	400	400	400	250
SC-4	497643	3521741	400	400	300	300	0
Plume Stabilization Wellfield							
PS-1	499030	3529240	600	600	600	0	0
PS-2	499189	3529336	600	600	450	0	0
PS-3	499440	3529317	600	500	450	0	0
PS-4	499010	3528715	500	500	500	0	0
Mass Capture Wellfield							
MC-1	499370	3525643	750	750	600	0	0
MC-2	499460	3525190	750	750	0	0	0
Interceptor Wellfield							
IW-1	496906	3521278	346	346	346	346	346
IW-2	497485	3521361	534	534	534	534	534
IW-3	497366	3521723	0	0	0	0	0
IW-3A	497366	3521723	572	572	572	572	572
IW-4	497372	3522466	230	230	230	230	230
IW-5	497370	3522815	115	115	115	115	115
IW-6A	497381	3523709	128	128	128	128	128
IW-7	496428	3521307	0	0	0	0	0
IW-8	497368	3522021	452	452	452	452	452
IW-9	497370	3522208	253	253	253	253	253
IW-10	497370	3523122	304	304	304	304	304
IW-11	497371	3523429	333	333	333	333	333
IW-12	497365	3523970	150	150	150	150	150
IW-13	497364	3524167	0	0	0	0	0
IW-14	497367	3524373	89	89	89	89	89
IW-15	497373	3524567	43	43	43	43	43
IW-16	497371	3524783	0	0	0	0	0
IW-17	497374	3525003	0	0	0	0	0
IW-18	497374	3525170	0	0	0	0	0
IW-19	497374	3525343	168	168	168	168	168
IW-20	497365	3525569	140	140	140	140	140
IW-21	497375	3525773	158	158	158	158	158
IW-22	497370	3523274	399	399	399	399	399
IW-23	497369	3522971	202	202	202	202	202
IW-24	497372	3522634	246	246	246	246	246

TABLE 7
Alternative 3 Pumping Specifications

		From year:	2010	2021	2031	2043	2051
		To year:	2020	2030	2042	2050	2060
Alternative 3 Well ID	**Location**						
FFS Wellfield	**UTME**	**UTMN**	**Rate (gpm)**	**Rate (gpm)**	**Rate (gpm)**	**Rate (gpm)**	**Rate (gpm)**
Pumping Summary							
FFS Wellfield			5,450	5,450	5,450	3,000	2,500
Source Control Wellfield			1,600	1,600	1,500	1,500	750
Plume Stabilization Wellfield			2,300	2,200	2,000	0	0
Mass Capture			1,500	1,500	600	0	0
Interceptor Wellfield			4,861	4,861	4,861	4,861	4,861
Mitigation Pumping Total			**15,711**	**15,611**	**14,411**	**9,361**	**8,111**
Canoa Wellfield			1,525	1,625	2,825	0	0
Pumping Total			**17,236**	**17,236**	**17,236**	**9,361**	**8,111**

Notes:
UTME = Universal Transverse Mercator Easting
UTMN = Universal Transverse Mercator Northing
ft bgs = feet below ground surface
gpm = gallons per minute

TABLE 8
Alternative 3 Cost Summary

Total Initial Capital	Annual O&M *(years 2010-2030)*	Annual O&M *(years 2031-2042)*	Annual O&M *(years 2043-2058)*	50 Year NPV [1]	Total Non-Discounted Cost to Year 2058
Cost in Millions					
$20.6	$1.3	$1.1	$7.2	$58.0	$208

Note:
[1] NPV = Net Present Value calculated at a 7.8 percent discount rate minus a 2.4 percent escalation rate

TABLE 9
Alternative 4 Pumping Specifications

Alternative 4 Well ID	Location		From year: / To year:	2010 / 2020	2021 / 2023	2024 / 2030	2031 / 2035	3036 / 2042	2043 / 2060

FFS Wellfield	UTME	UTMN	Rate (gpm)	Rate (gpm)	Rate (gpm)	Rate (gpm)	Rate (gpm)	Rate (gpm)
FFS-1	498550	3527752	600	600	450	450	450	400
FFS-2	498880	3527300	550	550	450	450	450	300
FFS-3	498895	3526595	550	550	300	300	300	100
FFS-4	498910	3525935	500	350	350	250	250	100
FFS-5	498968	3525190	500	350	350	250	250	0
FFS-6	498760	3524659	400	400	350	300	300	0
Source Control Wellfield								
SC-1	497652	3523177	400	400	250	250	100	100
SC-2	497671	3522578	400	400	400	250	150	0
SC-3	497644	3522160	400	400	400	250	150	0
SC-4	497643	3521741	300	300	300	0	0	0
Plume Stabilization Wellfield								
PS-1	499030	3529240	600	500	500	500	450	400
PS-2	499189	3529336	600	500	500	450	450	0
PS-3	499440	3529317	600	600	600	600	600	650
PS-4	499010	3528715	500	500	500	500	500	350
Interceptor Wellfield								
IW-1	496906	3521278	346	346	346	346	259	104
IW-2	497485	3521361	534	534	534	534	400	0
IW-3	497366	3521723	0	0	0	0	0	0
IW-3A	497366	3521723	572	572	572	572	429	172
IW-4	497372	3522466	230	230	230	230	172	172
IW-5	497370	3522815	115	115	115	115	86	86
IW-6A	497381	3523709	128	128	128	128	96	38
IW-7	496428	3521307	0	0	0	0	0	0
IW-8	497368	3522021	452	452	452	452	339	135
IW-9	497370	3522208	253	253	253	253	190	190
IW-10	497370	3523122	304	304	304	304	228	91
IW-11	497371	3523429	333	333	333	333	250	100
IW-12	497365	3523970	150	150	150	150	113	45
IW-13	497364	3524167	0	0	0	0	0	0
IW-14	497367	3524373	89	89	89	89	67	27
IW-15	497373	3524567	43	43	43	43	33	13
IW-16	497371	3524783	0	0	0	0	0	0
IW-17	497374	3525003	0	0	0	0	0	0
IW-18	497374	3525170	0	0	0	0	0	0
IW-19	497374	3525343	168	168	168	168	126	50
IW-20	497365	3525569	140	140	140	140	105	42
IW-21	497375	3525773	158	158	158	158	118	47
IW-22	497370	3523274	399	399	399	399	299	120
IW-23	497369	3522971	202	202	202	202	152	152
IW-24	497372	3522634	246	246	246	246	184	74

TABLE 9
Alternative 4 Pumping Specifications

Alternative 4 Well ID	Location		From year: / To year:	2010 / 2020	2021 / 2023	2024 / 2030	2031 / 2035	3036 / 2042	2043 / 2060
FFS Wellfield	**UTME**	**UTMN**		**Rate (gpm)**	**Rate (gpm)**	**Rate (gpm)**	**Rate (gpm)**	**Rate (gpm)**	**Rate (gpm)**
Pumping Summary									
FFS Wellfield				3,100	2,800	2,250	2,000	2,000	900
Source Control Wellfield				1,500	1,500	1,350	750	400	100
Plume Stabilization Wellfield				2,300	2,100	2,100	2,050	2,000	1,400
Interceptor Wellfield				4,861	4,861	4,861	4,861	3,646	1,658
Mitigation Pumping Total				**11,761**	**11,261**	**10,561**	**9,661**	**8,046**	**4,058**
Canoa Wellfield				5,475	5,975	6,675	7,575	7,975	0
Pumping Total				**17,236**	**17,236**	**17,236**	**17,236**	**16,021**	**4,058**

Notes:
UTME = Universal Transverse Mercator Easting
UTMN = Universal Transverse Mercator Northing
ft bgs = feet below ground surface
gpm = gallons per minute

TABLE 10
Alternative 4 Cost Summary

Total Initial Capital	Annual O&M *(years 2010-2030)*	Annual O&M *(years 2031-2042)*	Annual O&M *(years 2043-2058)*	50 Year NPV [1]	Total Non-Discounted Cost to Year 2058
Cost in Millions					
$16.0	**$0.94**	**$0.64**	**$1.8**	**$32.4**	**$71.7**

Note:
[1] NPV = Net Present Value calculated at a 7.8 percent discount rate minus a 2.4 percent escalation rate

TABLE 11
Alternative 5 Pumping Specifications

Alternative 5 Well ID	Location		From year: 2010 To year: 2020	From year: 2021 To year: 2025	From year: 2026 To year: 2030	From year: 2031 To year: 3035	From year: 3036 To year: 2042	From year: 2043 To year: 2060
FFS Wellfield	**UTME**	**UTMN**	**Rate (gpm)**	**Rate (gpm)**	**Rate (gpm)**	**Rate (gpm)**	**Rate (gpm)**	**Rate (gpm)**
FFS-1	498550	3527752	1000	1000	1000	750	750	400
FFS-2	498880	3527300	900	900	900	900	900	300
FFS-3	498895	3526595	850	850	850	800	800	100
FFS-4	498910	3525935	900	900	900	800	800	100
FFS-5	498968	3525190	900	900	900	900	800	0
FFS-6	498760	3524659	900	900	750	750	600	0
Source Control Wellfield								
SC-1	497652	3523177	400	400	200	200	100	100
SC-2	497671	3522578	400	400	300	300	300	0
SC-3	497644	3522160	400	400	400	400	400	0
SC-4	497643	3521741	400	300	300	300	300	0
Plume Stabilization Wellfield								
PS-1	499030	3529240	600	600	600	600	600	0
PS-2	499189	3529336	600	450	450	300	300	0
PS-3	499440	3529317	600	450	450	300	300	0
PS-4	499010	3528715	500	500	500	500	500	0
Mass Capture Wellfield								
MC-1	499370	3525643	750	750	750	0	0	0
MC-2	499460	3525190	750	750	750	0	0	0
Interceptor Wellfield								
IW-1	496906	3521278	346	346	346	346	259	0
IW-2	497485	3521361	534	534	534	534	400	0
IW-3	497366	3521723	0	0	0	0	0	0
IW-3A	497366	3521723	572	572	572	572	429	172
IW-4	497372	3522466	230	230	230	230	172	172
IW-5	497370	3522815	115	115	115	115	86	86
IW-6A	497381	3523709	128	128	128	128	96	38
IW-7	496428	3521307	0	0	0	0	0	0
IW-8	497368	3522021	452	452	452	452	339	135
IW-9	497370	3522208	253	253	253	253	190	190
IW-10	497370	3523122	304	304	304	304	228	91
IW-11	497371	3523429	333	333	333	333	250	100
IW-12	497365	3523970	150	150	150	150	113	45
IW-13	497364	3524167	0	0	0	0	0	0
IW-14	497367	3524373	89	89	89	89	67	27
IW-15	497373	3524567	43	43	43	43	33	13
IW-16	497371	3524783	0	0	0	0	0	0
IW-17	497374	3525003	0	0	0	0	0	0
IW-18	497374	3525170	0	0	0	0	0	0
IW-19	497374	3525343	168	168	168	168	126	50
IW-20	497365	3525569	140	140	140	140	105	42
IW-21	497375	3525773	158	158	158	158	118	47
IW-22	497370	3523274	399	399	399	399	299	120
IW-23	497369	3522971	202	202	202	202	152	152
IW-24	497372	3522634	246	246	246	246	184	74

TABLE 11
Alternative 5 Pumping Specifications

Alternative 5 Well ID	Location							
		From year:	2010	2021	2026	2031	3036	2043
		To year:	2020	2025	2030	3035	2042	2060
FFS Wellfield	**UTME**	**UTMN**	**Rate (gpm)**	**Rate (gpm)**	**Rate (gpm)**	**Rate (gpm)**	**Rate (gpm)**	**Rate (gpm)**
Pumping Summary								
FFS Wellfield			5,450	5,450	5,300	4,900	4,650	900
Source Control Wellfield			1,600	1,500	1,200	1,200	1,100	100
Plume Stabilization Wellfield			2,300	2,000	2,000	1,700	1,700	0
Mass Capture			1,500	1,500	1,500	0	0	0
Interceptor Wellfield			4,861	4,861	4,861	4,861	3,646	1,555
Mitigation Pumping Total			**15,711**	**15,311**	**14,861**	**12,661**	**11,096**	**2,555**
Canoa Wellfield			1,525	1,925	2,375	4,575	4,925	0
Pumping Total			**17,236**	**17,236**	**17,236**	**17,236**	**16,021**	**2,555**

Notes:
UTME = Universal Transverse Mercator Easting
UTMN = Universal Transverse Mercator Northing
ft bgs = feet below ground surface
gpm = gallons per minute

TABLE 12
Alternative 5 Cost Summary

Total Initial Capital	Annual O&M *(years 2010-2030)*	Annual O&M *(years 2031-2042)*	Annual O&M *(years 2043-2058)*	50 Year NPV [1]	Total Non-Discounted Cost to Year 2058
Cost in Millions					
$20.6	**$1.4**	**$1.0**	**$1.2**	**$42.6**	**$81.4**

Note:
[1] *NPV = Net Present Value calculated at a 7.8 percent discount rate minus a 2.4 percent escalation rate*

TABLE 13
Comparison of Mitigation Alternatives

ALTERNATIVE		EFFECTIVENESS	IMPLEMENTABILITY	COST (millions)		
				Total Initial Capital	50-Year NPV	Total Non-Discounted Cost
1	Source Control and Monitored Natural Attenuation	• Meets mitigation objective, existing drinking water supply wells not predicted to be impacted in the 50-year simulation period • Source control contains seepage from STI; drain down starts at end of mine life • Plume expands into unimpacted aquifer and the plume extent increases over the 50-year simulation period • High long-term mitigation pumping rates, long duration and magnitude of source control, and low net sulfate mass removal compared to Alternatives 4 and 5 • Does not allow MNA of downgradient plume at end of mine life	• 18 to 30 months for full implementation • No significant technical or administrative implementability issues • Larger long-term water level declines than Alternatives 4 and 5	$10.8	$37.1	$173
2	Source Control and Plume Stabilization	• Meets mitigation objective; existing drinking water supply wells are not impacted because the plume does not expand • Source control contains seepage from STI; drain down starts at end of mine life • Plume does not expand into unimpacted aquifer and the plume extent unchanged over the 50-year simulation period • High long-term mitigation pumping rates, long duration and magnitude of source control, and low net sulfate mass removal compared to Alternatives 4 and 5 • Does not allow MNA of downgradient plume at end of mine life	• 24 to 36 months for implementation of pumping systems • No significant technical or administrative implementability issues • Larger long-term water level declines than Alternatives 4 and 5	$16.0	$49.1	$207
3	Source Control, Plume Stabilization, and Mass Removal	• Meets mitigation objective; existing drinking water supply wells are not impacted because the plume decreases in extent • Source control contains seepage from STI; drain down starts at end of mine life • Plume does not expand into unimpacted aquifer and the plume extent is reduced over the 50-year simulation period • High long-term mitigation pumping rates, long duration and magnitude of source control, and low net sulfate mass removal compared to Alternatives 4 and 5 • Allows MNA of downgradient plume at end of mine life	• 24 to 36 months for implementation of pumping systems • No significant technical or administrative implementability issues • Larger long-term water level declines than Alternatives 4 and 5	$20.6	$58.0	$208
4	New Tailing Impoundment, Source Control, and Plume Stabilization	• Meets mitigation objective; existing drinking water supply wells are not impacted because the plume does not expand • Source control contains seepage from STI and starts STI drain down before mine closure • Plume does not expand into unimpacted aquifer and the plume extent unchanged over the 50-year simulation period • Low long-term mitigation pumping rates, and shorter duration and magnitude of source control compared to Alternatives 1, 2, and 3 • Does not allow MNA of downgradient plume at end of mine life	• 24 to 36 months for implementation of pumping systems • 7 years for implementation of new tailing impoundment • No significant technical or administrative implementability issues, although successful land acquisition for new tailing impoundment is a critical to feasibility • Smaller long-term water level declines that Alternatives 1, 2, and 3	$16.0	$32.4	$71.7
5	New Tailing Impoundment, Source Control, Plume Stabilization, and Mass Removal	• Meets mitigation objective; existing drinking water supply wells are not impacted because the plume decreases in extent • Source control contains seepage from STI and starts STI drain down before mine closure • Plume does not expand into unimpacted aquifer and the plume extent is reduced over the 50-year simulation period • Low long-term mitigation pumping rates, shorter duration and magnitude of source control, and high net sulfate mass removal compared to Alternatives 1, 2, and 3; lower long-term mitigation pumping rates and higher net sulfate mass removal than Alternative 4 • Allows MNA of downgradient plume at end of mine life	• 24 to 36 months for implementation of pumping systems • 7 years for implementation of new tailing impoundment • No significant technical or administrative implementability issues, although successful land acquisition for new tailing impoundment is critical to feasibility • Smaller long-term water level declines than Alternatives 1, 2, 3, and 4	$20.6	$42.6	$81.4

TABLE 14
Predicted Water Level Changes at Selected Wells

WELL	ALTERNATIVE	WATER LEVEL CHANGE (feet)		
		YEAR		
		2020	2040	2060
ST-7	1	-10 to -15	-15 to -20	-25 to -30
	2	-15 to -20	-25 to -30	-35 to -40
	3	-25 to -30	-40 to -45	-30 to -35
	4	-15 to -20	-20 to -25	-15 to -20
	5	-25 to -30	-35 to -40	-10 to -15
CW-9	1	-10 to -15	-20 to -25	-30 to -35
	2	-20 to -25	-30 to -35	-40 to -45
	3	-30 to -35	-45 to -50	-35 to -40
	4	-20 to -25	-25 to -30	-20 to -25
	5	-30 to -35	-40 to -45	-15 to -20
CW-6	1	-10 to -15	-20 to -25	-40 to -45
	2	-15 to -20	-25 to -30	-45 to -50
	3	-30 to -35	-40 to -45	-45 to -50
	4	-15 to -20	-20 to -25	-15 to -20
	5	-30 to -35	-35 to -40	-15 to -20
CW-10	1	-5 to -10	-15 to -20	-45 to -50
	2	-5 to -10	-15 to -20	-45 to -50
	3	-15 to -20	-20 to -25	-45 to -50
	4	-5 to -10	-5 to -10	-15 to -20
	5	-15 to -20	-15 to -20	-10 to -15
GVDWID-1	1	-5 to -10	-15 to -20	-50 to -55
	2	-5 to -10	-10 to -15	-50 to -55
	3	-10 to -15	-15 to -20	-50 to -55
	4	-5 to -10	0 to -5	-15 to -20
	5	-10 to -15	-10 to -15	-10 to -15

Note:
Negative sign indicates water level decline

TABLE 15
Mitigation Alternatives Cost Summary

Alternative	Total Initial Capital	Annual O&M *(years 2010-2030)*	Annual O&M *(years 2031-2042)*	Annual O&M *(years 2043-2058)*	50 Year NPV [1]	Total Non-Discounted Cost to Year 2058
Cost in Millions						
1	$10.8	$0.54	$0.54	$7.1	$37.1	$173
2	$16.0	$0.85	$0.85	$8.0	$49.1	$207
3	$20.6	$1.3	$1.1	$7.2	$58.0	$208
4	$16.0	$0.94	$0.64	$1.8	$32.4	$71.7
5	$20.6	$1.4	$1.0	$1.2	$42.6	$81.4

Note:
[1] NPV = Net Present Value calculated at a 7.8 percent discount rate minus a 2.4 percent escalation rate