Groundwater Quality and Geochemistry

Introduction

The proposed mine involves potential impacts to groundwater quality in two groundwater basins. The mine water supply would be pumped from wells located on private land in the Santa Cruz Valley near the town of Sahuarita in the Upper Santa Cruz Sub-Basin of the Tucson Active Management Area. The mine pit and mine facilities are located in the Davidson Canyon drainage east of the Santa Rita Mountains. There are unlikely to be any water quality impacts in the Upper Santa Cruz Sub-Basin near the mine water supply pumping because no discharges of potential contaminants are associated with the pumping wells. However, the mine operations proposed in the Davidson Canyon/Cienega Basin have the potential to affect groundwater quality as a result of seepage from unlined mine waste rock and tailings facilities, potential leakage from heap leach processing facilities, and formation of a permanent pit lake following mine closure. The pit lake is described in this section because of its direct association with groundwater.

Changes from the Draft Environmental Impact Statement

Numerous comments were received concerning the predictions of groundwater quality and geochemical modeling disclosed in the DEIS. One of the most widespread comments, including comment by the EPA, questioned the prediction that precipitation would not infiltrate the waste rock or tailings facilities and cause seepage, which could potentially impact groundwater quality. In direct response to these concerns, the Coronado requested that additional modeling scenarios be conducted by Rosemont Copper for more conservative precipitation conditions. Rosemont Copper responded by conducting modeling under seven different reclamation scenarios—including a scenario in which ponding occurs on the surface of the waste rock and tailings facilities—and under four different climatic scenarios. The additional modeling reinforces earlier predictions that, under all scenarios, conditions are such that any precipitation infiltrating the waste rock or tailings would quickly evaporate, and no additional seepage would result. This more robust analysis is included in the FEIS (see the “Predicted Seepage Rates” part of this resource section).

Many technical concerns were raised over the analysis of predicted geochemistry in the pit lake. A series of specific questions was compiled by the Coronado from public comments, and these questions were investigated by the Coronado’s contracted geochemical experts. The results of this analysis are described in the FEIS (see the “Impacts from Mine Pit Lake” part of this resource section).

There was also a general concern that the geochemical sampling conducted was not adequately described in the DEIS and that the underlying types of samples, number of samples, and variety of geochemical tests conducted were not summarized. A summary of all geochemical sampling and tests conducted is now included in the FEIS (see the “Overview of Geochemical Tests Conducted by Rosemont Copper” part of this resource section).

One of the major concerns about the proposed mine operations as described in the DEIS, especially as expressed by the EPA, was the operation of the heap leach pad. Concerns were raised about the potential for release of pregnant leach solution and the lack of detail for how the heap leach would be managed during closure, especially treatment of any residual draindown. Since the publication of the DEIS, in response to agency concerns and as a result of logistical issues, the heap leach operation has been removed from the Barrel Alternative, which has been identified as the Forest Service preferred alternative. The oxide ore that otherwise would have been leached would now be processed through the sulfide flotation circuit or become waste rock.

However, the heap leach pad remains a part of the proposal for the other action alternatives. In order to address concerns, additional information was requested and received from Rosemont Copper about operation of the heap leach pad. Two additional pieces of information were received. First, the aquifer protection permit has been issued by the ADEQ; therefore, details of the liners, monitoring, and collection systems required for the heap leach and other process facilities are available and are better described in the FEIS (see the "Ability to Demonstrate Best Available Demonstrated Control Technology" part of this resource section). Second, details have been obtained for how Rosemont Copper would construct the heap leach treatment systems and how they would retain access to those systems for monitoring and sampling after enclosure of the heap leach pad in waste rock (see the "Predicted Seepage Rates" part of this resource section).

Concerns were raised that the sulfate plume in the Upper Santa Cruz Sub-Basin originating from the Sierrita mine was inadequately disclosed. The location of this plume and the planned control of the plume are now better described (see the "Impacts to Sierrita Sulfate Plume" part of this resource section).

Concerns were also raised about the apparent laboratory contamination observed in organic sampling from monitoring wells on the site. The Coronado requested a review of this information from their consulting geochemical experts, and this analysis has been added to the FEIS (see the "Organic Constituents" part of this resource section).

Another concern raised in public comments was the potential for technological enhancement of naturally occurring radioactive materials in the dry-stack tailings facility. The Coronado has undertaken additional investigations on this topic, and this analysis has been added to the FEIS (see the "Potential for Technologically Enhanced Naturally Occurring Radioactive Materials" part of this resource section).

Other concerns were raised in public comments about the levels of arsenic expected from seepage from the tailings facility. The Coronado has undertaken additional investigations to determine whether the geochemical modeling used is appropriate and acceptable. A further question is the appropriate standard with which to compare arsenic concentrations, as there is a discrepancy between the arsenic standard set by the EPA for drinking water and the standard set by the State of Arizona for protection of groundwater quality. This discrepancy has been further described in the FEIS (see the "Appropriate Standards for Comparison of Groundwater Quality" part of this resource section).

Additional mitigation measures have been incorporated into the document and assessed for effectiveness at reducing impacts (see "Mitigation Effectiveness" part of this resource section, as well as appendix B).

Monitoring has been incorporated into the mitigation and monitoring plan (see appendix B) in order to address uncertainty associated with geochemistry, acid rock drainage, and the potential for seepage from the waste rock facility (see the "Mitigation Effectiveness," "Monitoring Intended to Assess Seepage Predictions," and "Monitoring Intended to Assess Geochemical Predictions" parts of this resource section).

Issues, Cause and Effect Relationships of Concern

Mine operations involve several components that have the potential to affect groundwater. With certain geology and rock types, precipitation falling on waste rock and tailing facilities has the potential to leach metals from the rock, which could potentially infiltrate the aquifer and impact groundwater quality. Hazardous materials used at the mine could be released to the environment, which could cause contaminated runoff or directly infiltrate the aquifer. The mine pit lake, because of its contact with exposed rock formations, could develop hazardous water quality conditions, which could cause impacts to groundwater, birds, and wildlife.

One significant issue was identified with respect to groundwater quality. Issue 3C relates to groundwater quality in the Cienega Basin, which may be impacted by the mine operations. The issue, with specific factors and units of measure for determining environmental consequences, is listed below.

Issue 3C: Groundwater Quality

Construction and operation of the mine pit, waste rock, and leach facilities have the potential to exceed Arizona Aquifer Water Quality Standards. The mine pit could result in the creation of a permanent pit lake, which has the potential to concentrate dissolved metals and toxins and may lower pH levels. Likewise, disposal of waste material in surface facilities such as tailings, waste rock, and leaching operations could potentially contribute to degradation of the aquifer.

Issue 3C Factors for Alternative Comparison

1. Ability to meet Arizona Aquifer Water Quality Standards at points of compliance designated in the aquifer protection permit
2. Ability to demonstrate best available demonstrated control technology[1]

Other Effects Considered

Even though impacts to water quality in the Upper Santa Cruz Sub-Basin were not identified as a significant issue during the public scoping process, this resource section addresses the alternatives' impacts concerning the possible effect that pumping from the mine water supply well field would have on groundwater flow directions and gradients in the Upper Santa Cruz Sub-Basin. Primarily, this resource section addresses the potential for mine water supply pumping to cause migration of known areas of groundwater contamination, such as leaking underground storage tanks or the known sulfate plume from the Sierrita mine tailings. Of 54 known leaking underground storage tanks identified within the general area, all but two have been closed. The two open sites are located almost 10 miles southwest of Sahuarita (Arizona Department of Environmental Quality 2010). In general, groundwater contamination from most leaking underground storage tanks extends only a few hundred feet; therefore, further analysis of the effects on these leaking underground storage tanks was not conducted. However, potential impacts on the Sierrita sulfate plume from mine water supply pumping have been analyzed and are addressed in this section.

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[1] Use of best available demonstrated control technology is required by the aquifer protection permit. The purpose is to employ engineering controls, processes, operating methods, or other alternatives to reduce discharge of pollutants to the greatest degree achievable before they reach the aquifer.

Analysis Methodology, Assumptions, Uncertain and Unknown Information

Temporal Bounds of Analysis and Analysis Area

The temporal bounds of analysis near the mine site extends to 1,000 years after final reclamation and closure, in order to allow the bedrock aquifer impacted by the mine pit to come close to equilibrium. The temporal bounds of analysis near the mine water supply in the Santa Cruz Valley is 140 years after pumping ceases, in order to allow the cone of depression resulting from groundwater pumping to stabilize. The spatial area of analysis shown in figure 60 matches that for “Groundwater Quantity” and was selected to encompass all areas within which groundwater could be affected by either the mining water supply well field near Sahuarita or the mine and mine pit; the analysis area encompasses the areas included in the groundwater models conducted for the analysis.

The connected actions that are described in chapter 2 include the use of mechanized equipment to reroute an electrical transmission line within the project area; construct an electrical distribution line, water supply line, and associated maintenance road within the utility corridor; reroute the Arizona National Scenic Trail and construct ancillary facilities; and implement SR 83 highway maintenance improvements required by the ADOT encroachment permit. These activities have been considered in the description of impacts common to all action alternatives for the premining phase, when they would be constructed; and for the final reclamation and closure phase, when the water line and electrical distribution line would be removed.

Methodology for Impacts Analysis

The assessment factors include the ability to meet Arizona Aquifer Water Quality Standards at the points of compliance designated in the aquifer protection permit and the ability to demonstrate best available demonstrated control technology. Best available demonstrated control technology means the use of the most applicable and effective techniques available to prevent groundwater contamination.

In order to assess the ability to meet Arizona Aquifer Water Quality Standards, several specific parts of the mine operation were assessed. These include the following:

- Expected water quality of drainage from heap leach facilities;
- Expected water quality from seepage of precipitation through waste rock;
- Expected water quality from water seepage from tailings;
- Expected water quality in the mine pit lake;
- Potential for acid conditions in the mine pit lake; and
- Expected fate and transport of any contaminants reaching groundwater.

The methodology for determining impacts to groundwater quality involves both geochemical and groundwater predictive flow modeling to determine the likely effect on groundwater quality downgradient of the mine and in the pit lake predicted to form following mine closure. The geochemical predictive models account for potential sources from the waste rock, tailings, heap leach, and mine pit walls, as well as contributions from natural groundwater, surface runoff, and precipitation. Groundwater predictive flow models (Errol L. Montgomery and Associates Inc. 2009a, 2010; Montgomery and Associates Inc. 2010; Myers 2010; Tetra Tech 2010c) are discussed in the “Groundwater Quantity” section. Several additional technical reports consider the resulting

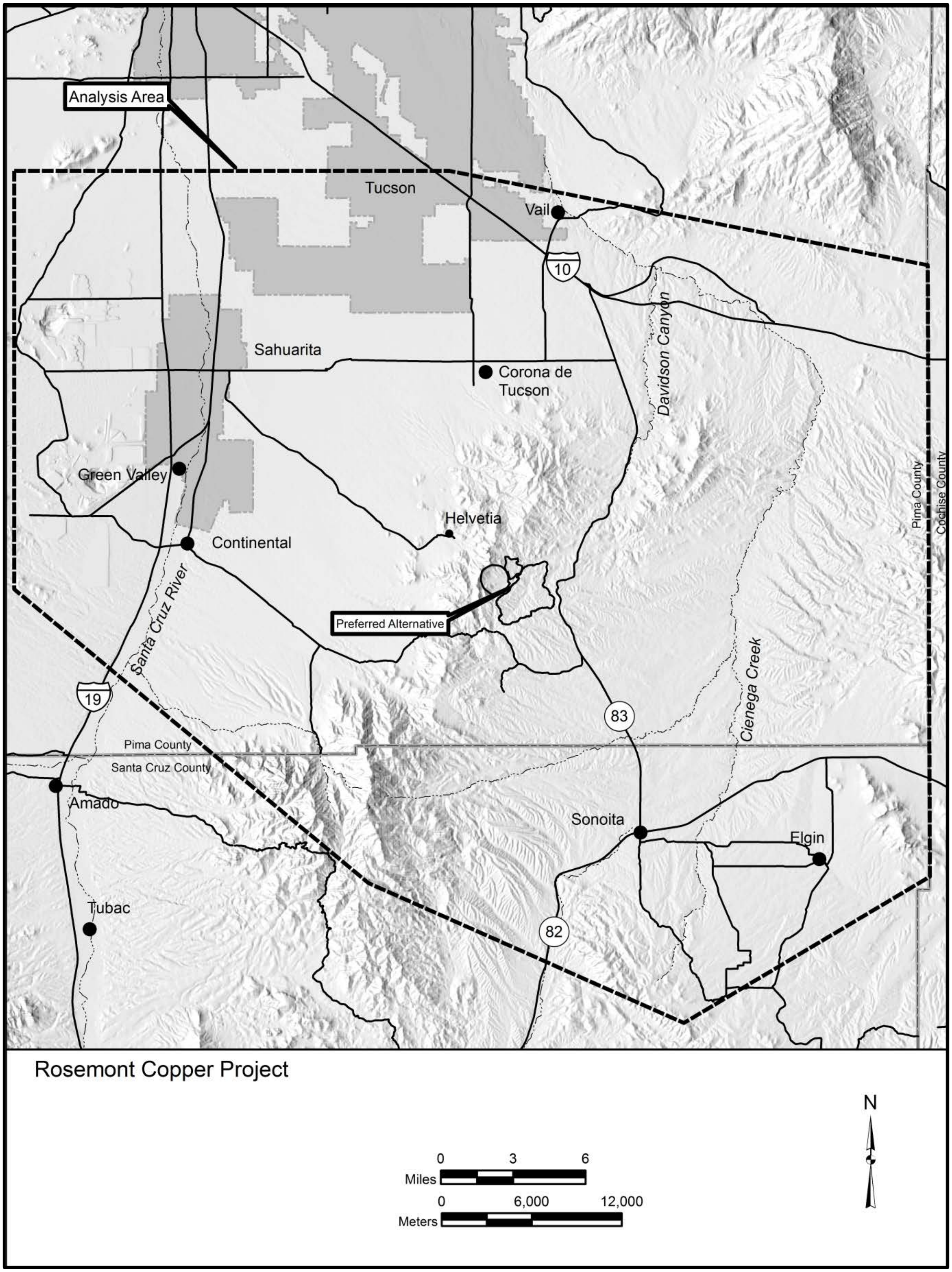

Figure 60. Analysis area for groundwater quality

geochemistry and potential fate and transport of contaminants. Seepage from waste rock, tailings, and heap leach facilities is described in “Infiltration, Seepage, Fate and Transport Modeling Report: Revision 2” (Tetra Tech 2010b), with additional documentation provided in “Rosemont Facility Fate and Transport Modeling Response to Comments: Technical Memorandum” (Hudson and Williamson 2011). Predictions of the geochemistry of the mine pit lake are described in “Geochemical Pit Lake Predictive Model: Revision 1” (Tetra Tech 2010a).

As with the groundwater flow models, these two predictive geochemical modeling reports have undergone peer review (Day and Hoag 2011; Sieber 2011; Sieber et al. 2010; Ugorets and Day 2010). Revised reports based on peer reviews have been completed. Following public comment on the DEIS, the Coronado also commissioned several reports to address various topics concerning geochemistry (Hoag et al. 2012a; Hoag et al. 2012b; Kline et al. 2012).

The impacts of discharge of runoff to surface waters from waste rock and tailings facilities are analyzed in the “Surface Water Quality” section of this FEIS.

Several public comments concerned the lack of analysis for specific chemical byproducts of mining operations that would be exposed to surface water or groundwater or would be present in seepage from the tailings facility. Most of the specific byproducts raised during public comment do not have specific aquifer water quality standards and therefore were not included in the analyses or modeling conducted. However, the lack of modeling does not change the ultimate fate of these compounds, if they were present. If these compounds did exist in tailings seepage they would not be discharged to the environment but would be contained by the capture zone of the mine pit lake. Geochemical modeling was not revised to attempt to incorporate these chemical byproducts.

However, one concern over chemical byproducts from blasting was analyzed further. The potential for nitrogen residue to be present from the use of ammonium nitrate explosives is well established, and nitrate, nitrite, and ammonia have regulatory standards that must be met for groundwater and surface water. This analysis relies on available literature, estimates of remnant nitrogen residue, and potential exposure pathways.

One other concern raised was analysis for radon. Ambient groundwater quality samples were not tested for radon. Levels of radon in groundwater do not have a numeric water quality standard and therefore were not addressed in this analysis.

Scientific Uncertainty and Professional Disagreement

As with groundwater flow modeling, the geochemical modeling process also involved peer review by independent experts (SRK Consulting), as well as comment and review from cooperating agencies. Most comments and questions related to the geochemical modeling efforts have been determined by the Coronado to have been adequately answered and the geochemical modeling techniques to be appropriate. However, one issue remains that is a source of scientific uncertainty and professional disagreement.

Rosemont Copper has conducted extensive geochemical analysis of the rock types encountered at the site that are representative of the ore body and waste rock. These samples are categorized by geological unit (i.e., Arkose, or Horquilla Limestone, Willow Canyon Formation). Within each geological unit or formation, however, there is a wide variety of difference in the minerals found, referred to as the mineralogy of the unit. Rosemont Copper has not conducted detailed mineralogical laboratory analysis of the samples collected. Questions arose as to whether this is appropriate and whether this mineralogical analysis is needed to support geochemical modeling.

The geochemical experts contracted by the Coronado determined that the analysis conducted is sufficient to support the modeling (Hoag et al. 2012a). Other specialists believe such mineralogical sampling is essential to understanding future geochemical impacts. The forest supervisor reviewed the available information and determined that the analysis conducted to date is sufficient to support the geochemical modeling relied upon in the FEIS.

Monitoring Intended to Assess Geochemical Predictions

While the geochemical analysis, specifically the potential for acid rock drainage, has been fully assessed and the found by the Coronado to be reasonable and valid, in consideration of public concerns regarding the uncertainty associated with geochemical modeling, existing waste rock characterization and interpreting the potential for acid rock drainage, three monitoring components have been incorporated into the mitigation and monitoring plan (see appendix B for full details). Two of these are required under the aquifer protection permit issued to Rosemont Copper:

- **Reduction of the potential for acid generation from tailings and waste rock.** Geochemical testing has indicated that there is adequate neutralization capacity in the overall waste rock composition to prevent potential acid generation. However, proper placement of the waste rock is necessary to allow this buffering capacity to be effective. This mitigation involves requirements for the segregation and encapsulation of potentially acid-generating waste rock with rock that has buffering capabilities in order to reduce the risk of potential acid generation. This is required under the aquifer protection permit issued to Rosemont Copper.
- **Groundwater quality and aquifer level monitoring required by the aquifer protection permit.** The aquifer protection permit requires the construction and operation of point-of-compliance monitoring wells and institutes groundwater quality monitoring and sampling protocols and reporting. These measures would ensure that water quality problems, if present, would be identified and monitored.

The Coronado has required two additional monitoring measures in order to ascertain that the reactivity of the waste rock pile is fully understood in order to ensure an adequate closure design is implemented, and to ensure that changes in groundwater quality are not occurring on Forest lands beyond the immediate facility.

- **Additional waste rock and tailings characterization.** During operations, additional waste rock characterization tests, above and beyond those required by the aquifer protection permit, would be required to be conducted on waste rock and tailings. This additional analysis includes requirements for humidity cell testing, whole rock chemistry, and mineralogical analysis in addition to the acid-base accounting and leachate testing already being conducted for the aquifer protection permit.
- **Additional water quality monitoring of springs and wells.** A suite of springs and wells, other than the point-of-compliance wells required to be monitored under the aquifer protection permit, would be monitored for water quality changes. These monitoring locations are situated beyond the perimeter fence of the mine and are intended to provide surveillance of any water quality changes that may be triggered by the changes in the hydrologic system. Specific springs and wells to be monitored are listed in appendix B.

Summary of Effects by Issue Factor by Alternative

Table 68 presents the summary comparison of impacts from each alternative.

Table 68. Summary of effects

Issue Factor	No Action	Proposed Action	Phased Tailings	Barrel	Barrel Trail	Scholefield-McCleary
Issue 3C.1: Ability to meet Arizona Aquifer Water Quality Standards at points of compliance designated in the aquifer protection permit	Concentrations of arsenic in some ambient groundwater samples exceed aquifer water quality standards	Modeled water quality for potential seepage from tailings and waste rock meets standards; modeled water quality from lined heap leach exceeds standards for cadmium, fluoride, nickel, and selenium but would not be discharged; treatment of heap leach with an engineered biological system meets standards; modeled water quality in mine pit lake exceeds the aquifer water quality standard for thallium and potentially ammonia, but the standard is not applicable to pit lakes.	Same as for proposed action	Same as for proposed action	Same as for proposed action	Same as for proposed action
Issue 3C.2: Ability to demonstrate best available demonstrated control technology	None	Best available demonstrated control technology has been accepted through the aquifer protection permit process and has been determined to be adequate.	Same as for proposed action	Same as for proposed action	Same as for proposed action	Same as for proposed action
Other Effects Considered						
Impact to Sierrita sulfate plume	None	Minor changes in gradient or groundwater levels as a result of mine supply pumping would occur in the vicinity of the Sierrita sulfate plume. Overall direction of flow, location of plume, and effectiveness of control are not expected to be affected.	Same as for proposed action	Same as for proposed action	Same as for proposed action	Same as for proposed action

Affected Environment

Relevant Laws, Regulations, Policies, and Plans

Table 69 lists the applicable laws, regulations, and policies related to the use, protection, and management of groundwater resources that would apply to the development and operation of the project. These laws, regulations, and policies, which will collectively be referred to in the following sections as "regulation(s)," are outlined in more detail in the following sections.

Table 69. Summary of the Federal, State, and local regulatory requirements applicable to the project with respect to groundwater quality

Law/Regulation	Regulates
Federal	
Safe Drinking Water Act	Water quality in public water supply systems; primacy delegated to Pima County
FSMs 2520, 2530, and 2880 and FS-881 Technical Guide	Watershed protection and management, water resource management, geological resources, and groundwater management
State	
Aquifer Protection Permit	Discharge of pollutants to surface or aquifer
State Water Quality Standards	Allowable water quality limits in surface waters and groundwater
Local	
Public Water System	New source approval and construction of public water system

Federal

Safe Drinking Water Act (Public Law 93-523)

As mandated by the Safe Drinking Water Act, passed in 1974, the EPA regulates contaminants of concern to domestic water supply. Contaminants of concern relevant to domestic water supply are defined as those that pose a public health threat or that alter the aesthetic acceptability of the water. The EPA regulates these types of contaminants through the development of national primary and secondary maximum contaminant levels for finished water.

In Arizona, the ADEQ administers the Safe Drinking Water Act (AAC R18-4), but the Pima County Department of Environmental Quality has the authority to review and approve new construction and new source approval for a public water system. The public drinking water system at the mine facility would require approval from Pima County Department of Environmental Quality prior to construction and operation.

State and Local

Aquifer Protection Permits (Arizona Revised Statutes 49-241)

Any discharge of a pollutant from a facility either directly to an aquifer or to the land surface or the vadose zone in such a manner that there is a reasonable probability that the pollutant would reach an aquifer requires issuance of an aquifer protection permit by the ADEQ. Unless the discharge is either specifically exempted by statute (ARS 49-250), or if the discharge is authorized under one of the General Aquifer Protection Permits issued by the ADEQ (AAC R18-9, Article 3), then the discharge requires issuance of an individual aquifer protection permit by the agency.

Temporary discharges associated with construction (hydrostatic line testing or well testing) would likely be covered under existing general aquifer protection permits. The coarse ore stockpile, temporary run-of-mine stockpile, and vehicle and equipment wash are covered under general aquifer protection permits as well. An individual aquifer protection permit is required for potential discharges at the mine associated with various process facilities. In addition, mine tailings and heap leach facilities are both considered to be discharging facilities requiring permits (ARS 49-241.B.6 and 49-241.B.7).

An individual aquifer protection permit was issued to Rosemont Copper by the ADEQ on April 3, 2012. The aquifer protection permit determined that the design of the following facilities was adequate to meet best available demonstrated control technologies: the dry-stack tailings facility (unlined), the process water temporary storage pond (lined), the primary settling basin (lined), the raffinate pond (lined), the heap leach pad (lined), the pregnant leach solution pond (lined), the stormwater pond (lined), the waste rock storage area (unlined), and the nonmunicipal solid waste landfill (lined).

State Water Quality Standards
(Arizona Administrative Code Title 18, Chapter 11)

State regulations dictate numeric water quality standards both for surface waters and for groundwater. Numeric Arizona Aquifer Water Quality Standards apply to all groundwater within the State. Numeric Surface Water Quality Standards are specific to the use of the water, as well as any special designations for surface waters, and there are varying standards for acute and chronic exposure. State regulations also identify a narrative water quality standard for groundwater. The narrative standard states that a discharge shall not cause or contribute to a violation of a water quality standard established for a navigable water of the State and that a discharge shall not cause a pollutant to be present in an aquifer that impairs existing or reasonably foreseeable future uses of water in an aquifer, or at a concentration which endangers human health.

From a regulatory standpoint, the mine pit lake is neither a navigable water subject to surface water standards nor a discharging facility subject to aquifer water quality standards. However, as a useful tool for disclosing and analyzing water quality impacts in the pit lake, both standards are compared with the pit lake water quality in this section.

Appropriate Standards for Comparison of Groundwater Quality

Beginning in 2001, the EPA set the maximum contaminant level for arsenic in drinking water systems at 0.010 milligram per liter. This authority derives from the Federal Safe Drinking Water Act, which is described above. When the Federal maximum contaminant level was lowered to 0.010 milligram per liter, public drinking water systems throughout the State of Arizona were faced with also meeting this standard. However, the authority under the Safe Drinking Water Act applies only to public drinking water systems and does not extend to regulation of groundwater quality in general.

Jurisdiction over general groundwater quality remains with the State of Arizona and is administered through the aquifer protection permit program as described above and through adherence to State aquifer water quality standards. Unlike the standard of 0.010 milligram per liter, which is applicable to public water systems, the Arizona Numeric Aquifer Water Quality Standard for arsenic remains at 0.050 milligram per liter. As such, the individual aquifer protection permit issued to Rosemont Copper uses the current aquifer standard of 0.050 milligram per liter.

There have been proposals to lower the Arizona Aquifer Water Quality Standard to 0.010 milligram per liter, as was acknowledged in the DEIS. However, at present, this action has not been approved by the State of Arizona, nor does the arsenic standard appear reasonably likely to decrease in the near future as there are no formal proposals to do so. The Coronado has considered public comments that arsenic concentrations associated with discharges to groundwater from the mine should be compared with the drinking water level of 0.010 milligram per liter but has determined that to do so would be inconsistent with applicable State laws and regulations, inconsistent with the issued aquifer protection permit, and contrary to the decisions of the pertinent permitting authority, which is the ADEQ. Therefore, in the FEIS, arsenic concentrations are compared with the Arizona Aquifer Water Quality Standard of 0.050 milligram per liter, as well as with background arsenic levels. As described above, in addition to the numeric aquifer water quality standard for arsenic, the State of Arizona narrative aquifer water quality standards prohibit a discharge that would cause a pollutant to be present in an aquifer that impairs existing or reasonably foreseeable future uses of water in an aquifer. All aquifers in Arizona are considered drinking water aquifers. Therefore, it is reasonable to assess whether predicted arsenic concentrations would impair future use of the aquifer for drinking water. This analysis has been conducted in the “Environmental Consequences” part of this resource section.

Forest Service Guidance

Forest Service guidance with respect to water resources is fully described in the “Groundwater Quantity” resource section in this chapter.

Existing Conditions

Extensive groundwater quality sampling has been conducted over the past few years throughout the project area, from existing springs, from wells drilled during the hydrogeologic investigation for the proposed project, and from existing wells in the area. Results of this sampling are presented in Errol L. Montgomery and Associates (2009b) and Rosemont Copper (2012b), with pertinent results included in the following description of conditions and summarized later in this resource section in tables 71 through 73.

Inorganic and Metal Constituents

Groundwater quality in the analysis area is considered acceptable for most uses. Total dissolved solids in groundwater samples collected from 39 wells and 12 springs ranged from 100 to 1,700 milligrams per liter, with a median concentration of 360 milligrams per liter. The field pH ranged from about 6.5 to 9.3, with a median of about 7.5, and the laboratory pH ranged from about 5.7 to 9.5, with a median of about 8.1. Nitrate, a commonly occurring contaminant, ranged from below detection limits to 8.4 milligrams per liter with a median of about 0.5 milligram per liter, below the Arizona Aquifer Water Quality Standard of 10 milligrams per liter. Fluoride, another naturally occurring contaminant, ranged from below detection limits to 3.6 milligrams per liter, with a median of about 0.7 milligram per liter, which is below the Arizona Aquifer Water Quality Standard of 4 milligrams per liter.

Metals with numeric Arizona Aquifer Water Quality Standards include antimony, arsenic, barium, beryllium, cadmium, chromium, cyanide, lead, mercury, nickel, selenium, and thallium. With the exception of arsenic, none of the groundwater samples exceeded Arizona Aquifer Water Quality Standards for these metals. Arsenic is a common naturally occurring metal contaminant in Arizona groundwater, and concentrations in project area groundwater samples ranged from below detection limits to 0.067 milligram per liter, which is above the Arizona Aquifer Water Quality Standard of 0.05 milligram per liter. For the most part, however, arsenic in the aquifer is below the arsenic standard. The median concentration of arsenic was 0.0032 milligram per liter, and of the 250 water samples analyzed for arsenic, only seven exceeded the arsenic standard of 0.05 milligram per liter, all of which were taken from the same Pima County well (D-16-17 31dcb). Based on these findings, no existing metal contamination of groundwater by past site use, including historic mining, is believed to exist in the analysis area.

Organic Constituents

Groundwater samples were collected from 38 wells and six springs and analyzed for volatile organic compounds and semivolatile organic compounds. There were 104 instances in which an organic compound was detected in a groundwater sample by the analytical laboratory. However, 48 of these instances were either the result of documented laboratory contamination or of suspected contamination of the sample because similar compounds were detected in quality control samples, such as the method blank or trip blank. Of the remaining instances, 39 were detected by the instrumentation but at methods below the limits considered practical for quantifying chemical constituents.

Only 17 instances were considered to accurately reflect possible contamination. These include eight instances where dimethyl ketone (also known as acetone), diethyl phthalate, or 2-butanone was measured; these are considered common laboratory contaminants, although they can also be present in the environment. Seven instances of toluene were measured in groundwater samples, ranging from 10 to 141 micrograms per liter. Two instances of benzoic acid were measured in groundwater samples, ranging from 65 to 70 micrograms per liter.

Toluene is an environmental contaminant commonly identified with contamination from gasoline or other fuels. Benzoic acid can be found alone in the environment but is also a potential breakdown product of toluene. The wells in which these constituents were found exhibit no pattern and are found across the entire project area. The Arizona Aquifer Water Quality Standard for toluene is 1,000 micrograms per liter, and there is no numeric standard for benzoic acid.

Public comment variously suggested that the detections described above reflected the presence of groundwater contamination in the aquifer, or that the discovery of laboratory contaminants invalidated the entire suite of sampling for organic constituents. The Coronado requested a review of this information by their contracted geochemical experts (Kline et al. 2012). This review determined that the number of detections for organic compounds was not unusual for a multi-year groundwater monitoring program such as that conducted by Rosemont Copper. Further, it was determined that the results of the remaining analyses, as well as the overall organics sampling program, were valid and that an extensive follow-up monitoring program was not necessary.

Radiochemical Constituents

Groundwater samples collected from 38 wells and six springs and were analyzed for gross alpha and gross beta activity, radium (radium-226 and radium-228), and uranium (total uranium, uranium-234, uranium-235, and uranium-238). Adjusted gross alpha activity exceeded the Arizona Aquifer Water Quality Standard of 15 picoCuries per liter in one sample from piezometer TTBH-08-08C and in one of three samples collected from drill hole P-899. Radium-226 and radium-228 also exceeded the Arizona Aquifer Water Quality Standard of 5 picoCuries per liter combined from piezometer TTBH-08-08C and drill hole P-899.

Adjusted gross alpha activity is a measure of the amount of radiation emitted by radioactive elements such as uranium or radium. Uranium and radium are both naturally occurring, particularly in bedrock aquifers. Radium and gross alpha activity are common naturally occurring contaminants in Arizona groundwater.

Overview of Geochemical Tests Conducted by Rosemont Copper

A great deal of public concern was raised regarding the types and number of geochemical tests conducted by Rosemont Copper and the need to more fully understand the sampling and test work that underlie the predictions of the geochemical modeling.

There are two general categories of geochemical tests undertaken by Rosemont Copper. One category of tests is primarily designed to determine the potential for acid rock drainage to occur. A second category of tests is designed to determine the chemical constituents and metals that would be expected to occur in water contacting waste rock or tailings. The types and number of tests are described here; the usage of these tests results to predict impacts is further detailed in the "Environmental Consequences" part of this resource section.

The potential for acid rock drainage is assessed through both short- and long-term tests. Static acid base accounting is the primary short-term test that was used. In these tests, the acid potential and neutralization potential of a rock sample are measured. The difference between neutralization potential and acid potential is called net neutralization potential; values of net neutralization potential greater than 20 represent minimal or no potential for acid rock drainage. The ratio of neutralization potential to acid potential is also a method of assessing the potential for acid rock drainage; a ratio greater than 3 is generally considered to represent minimal or no potential for acid rock drainage. A total of 226 static acid base accounting tests was conducted on 15 different rock types, as summarized in table 70.

Table 70. Number of geochemical tests conducted on Rosemont Copper waste rock samples

Rock Type	Tons of Material (thousands)	Percent of Material	Acid Base Accounting	Synthetic Precipitation Leaching Procedure	Meteoric Water Mobility Procedure	Humidity Cell Tests and Duration
Arkose	546,336	44.38	55	8	8	4 (35 weeks)
Tertiary	141,227	11.47	5	0	0	None tested
Abrigo	113,815	9.24	6	5	0	None tested
Horquilla	87,141	7.08	26	8	2	None tested
Glance	80,841	6.57	4	0	0	None tested
Andesite	49,118	3.99	38	4	6	7 (35 weeks)
Concha	34,107	2.77	6	1	1	None tested
Martin	32,304	2.62	7	4	0	None tested
Earp	29,577	2.40	14	6	0	2 (35 weeks)
Epitaph	27,150	2.21	16	6	0	1 (35 weeks)
Escabrosa	22,859	1.86	10	4	0	None tested
Bolsa	23,447	1.90	13	6	0	2 (25 weeks)
Colina	16,145	1.31	11	4	0	None tested
Quartz	13,047	1.06	9	2	1	None tested
Scherrer	8,542	0.69	0	0	0	None tested
Precambrian Granodiorite	4,203	0.34	0	0	0	None tested
Undefined	941	0.08	0	0	0	None tested

Rock Type	Tons of Material (thousands)	Percent of Material	Acid Base Accounting	Synthetic Precipitation Leaching Procedure	Meteoric Water Mobility Procedure	Humidity Cell Tests and Duration
Overburden	391	0.03	6	2	2	None tested
Total	**1,231,173**	**100**	**226**	**60**	**20**	**16**

Source: Rosemont Copper (2012a:75).

For those rocks that are suspected of having potential for acid rock drainage based on static testing, kinetic testing is often conducted, such as a humidity cell test. In this case, 16 humidity cell tests were conducted on five different rock types for which static testing suggested some acid-generating potential. Humidity cell testing is conducted over long periods of time in order to measure the rate at which acid production could occur. In these tests, waste rock is exposed to humidified oxygenated air and rinsed once a week, and the rinse solution is analyzed for acid-generating and chemical constituents. Most of the humidity cell tests were run for 35 weeks. Several public comments questioned whether the duration of the humidity cell tests was sufficient. The Coronado requested an opinion on this from geochemical specialists, and it was determined that as long as stable trends are apparent and the results are part of a larger strategy to characterize waste rock, it is acceptable to use kinetic testing as short as 20 weeks in duration (Hoag et al. 2012a).

In order to determine the likely chemical constituents that would be expected to dissolve from waste rock into stormwater or seepage, a different suite of tests is used. The synthetic precipitation leaching procedure is conducted by combining waste rock materials with water in a closed container, agitating the solution for 16 to 20 hours, and then analyzing the water for dissolved chemical constituents. Rosemont Copper conducted 60 synthetic precipitation leaching tests on 13 waste rock types. The meteoric water mobility procedure is similar but only allows one pass, or first flush, of water to occur. Rosemont Copper conducted 20 meteoric water mobility procedure tests on six waste rock types. In addition to these two procedures, the weekly results of the humidity cell tests can also be used to assess water quality changes over the long term.

A variety of comments have been made regarding the sufficiency of the type and number of geochemical tests conducted by Rosemont Copper. Following the public comment period, the Coronado requested opinions from geochemical specialists on a number of these issues:

- It was determined that the number, type, and distribution of samples were sufficient to adequately support the geochemical modeling conducted to date (Hoag et al. 2012a).
- It was determined that the nine samples used to represent the future tailings material were adequate in number and also were geologically representative of the future tailings material (Hoag et al. 2012a).
- Some comments suggested that Rosemont Copper be required to conduct formal, detailed mineralogical analysis of waste rock samples. While this type of analysis may be useful for providing realistic constraints on model assumptions, it was determined that the mineralogy of the deposit was well understood and that detailed work would likely not appreciably change the results or conclusions of the geochemical models (Hoag et al. 2012a). This issue remains a point of scientific uncertainty and professional disagreement, as previously discussed.
- The EPA raised the concern that the synthetic precipitation leaching procedure results may underrepresent concentrations in the geochemical models. This issue had been addressed

through the peer review process of the geochemical modeling and was reevaluated in light of public comments. It was determined that the synthetic precipitation leaching procedure data were indeed appropriate for use in the geochemical models (Hoag et al. 2012b).

Environmental Consequences

Direct and Indirect Effects of Each Alternative

No Action Alternative

Under the no action alternative, no impacts to groundwater quality beyond existing ambient concentrations would occur. Groundwater quality would continue to meet all existing numeric Arizona Aquifer Water Quality Standards, with the exception of arsenic. Over time, population is expected to increase in the area, increasing development and water use; however, these activities generally do not have the potential to affect groundwater quality.

Impacts Common to All Action Alternatives

All mine facilities potentially impacting groundwater quality are located near the mine pit, which has a location common to all alternatives. While the exact location of other facilities such as the waste rock, tailings, and heap leach pad may vary to some degree by alternative, the difference in location is not relevant to evaluating the general impact on groundwater quality; therefore, with one noted exception (the heap leach facility), the potential impact to groundwater quality from these facilities is considered common to all alternatives.

Impacts from Seepage from Tailings, Waste Rock, and Heap Leach Facilities

The specific individual mine activities and conditions that need to be considered with respect to groundwater quality are as follows:

- Expected water quality from water seepage from tailings;
- Expected water quality from seepage of precipitation through waste rock;
- Expected water quality of drainage from heap leach facilities (applicable to all action alternatives except the Barrel Alternative); and
- Fate and transport of any contaminants reaching the groundwater.

Predicted Seepage Rates

Overall, infiltration from precipitation over tailings, waste rock, or the heap leach facilities is expected to be negligible. Near-surface storage is expected to be such that based on infiltration modeling any precipitation that does not immediately run off would remain near the surface and then be lost to evaporation or transpiration by vegetation. The modeling techniques used to reach this conclusion were questioned during public comment, including by the EPA. In response, the Coronado requested that Rosemont Copper conduct more extensive and conservative infiltration modeling. Rosemont Copper conducted revised modeling and provided it to the Coronado (Tetra Tech 2012).

In response to the Coronado’s request for more extensive and conservative modeling, Rosemont Copper created additional variations of a series of model parameters in order to provide better assurance that infiltration of precipitation was not expected under real-world and extreme climatic conditions.

- With respect to climate, five different scenarios were analyzed: average climate conditions (which has a little bit of precipitation every day because of averaging), the 24-hour, 100-year storm event (which provides analysis of a short-duration and high-intensity event, such as observed during the Arizona monsoon season), a multi-day storm event (which provides analysis of a winter frontal storm that occurs over a longer period of time during cooler temperatures), 10 years of actual measured daily data, and 50 years of actual measured daily data.
- With respect to cover scenarios, four different scenarios were analyzed that included no reclamation cover, a mixed reclamation cover of sand and gravel, a 1-foot-thick reclamation soil cover, and a 3-foot-thick reclamation soil cover. (By design, a 1-foot-thick soil cover is expected to be used, as described in the "Soils and Revegetation" resource section.)
- Each of the four cover scenarios were analyzed with and without vegetation present.
- An additional scenario was run with ponding occurring on the benches of the facilities, which is a condition that would be expected for the Phased Tailings, Scholefield-McCleary, and Barrel Trail Alternatives but not for the proposed action and Barrel Alternative.

Similar to the results described in the DEIS, none of these scenarios resulted in infiltration of precipitation into the waste rock, tailings, or heap leach facilities. With the ponding scenarios, several of the climatic conditions (24-hour, 100-year and multi-day) did result in stormwater infiltrating past the surface layer of the waste rock facility, but the end result indicated that the infiltrated water is still eventually lost to evaporation.

As no water is incorporated into the waste rock, and as no precipitation infiltrates the facility even under extreme climatic and ponding conditions, no seepage is expected from the waste rock facility. Seepage from the tailings stack would develop as a result of the loss of the pore water present after filtration, as moisture content falls from 18 percent during stacking to a field capacity of 11 percent. Seepage from the tailings facility is estimated to rise to 8.4 gallons per minute over the active life of the mine. After final reclamation and closure, the seepage rate from the tailings facility would steadily decrease and is predicted to reach zero seepage approximately 500 years after closure. This seepage does not occur in a single spot but is spread over the entire area of the tailings facility. Public comments requested that this amount of seepage be given some perspective. During active mine life, 8.4 gallons per minute of seepage represents roughly 0.01 gallon per minute per acre of tailings facility, or slightly less than 14.5 gallons of seepage per acre per day from the entire tailings facility. Another way of visualizing the magnitude of seepage is to imagine the depth of seepage that would occur over the course of an entire year; in this case, a year's worth of seepage would accumulate to a depth of less than a quarter of an inch.

Seepage from the lined heap leach facility would be present and collected during the leaching process, which is expected to take approximately 6 years. Seepage would also be present and collected approximately 3 years after cessation of leaching, at which time the heap leach facility would be closed and encapsulated with waste rock. At the time of closure of the heap leach, seepage from the heap leach facility is estimated to be approximately 10 gallons per minute. Modeling indicates that heap leach seepage would decrease to 5 gallons per minute by 5 years after closure and to 1 gallon per minute by 45 years after closure and that seepage would cease approximately 115 years after closure (Tetra Tech 2010b). As previously mentioned, the heap leach facility is included in all action alternatives except the Barrel Alternative.

Some comments asked for a more thorough description of exactly how the heap leach pad would be closed and encapsulated in waste rock and still allow for monitoring and sampling of residual drainage. These details have since been provided by Rosemont Copper (Nelson 2012). After encapsulation, any residual drainage from the heap leach pad would flow from the heap leach collection system via pipe into a primary treatment basin, which would be located in the position of the former pregnant leach solution pond. The old liner for the pregnant leach solution pond would have been removed and replaced with a new liner system, and the treatment pond would have been filled with crushed limestone as well a mixed carbon source such as manure, straw, or wood chips; the exact contents of the primary and secondary treatment basin would be determined based on the sampling of the heap leach drainage. After passing through the primary treatment basin, treated drainage would flow via pipe to a secondary treatment basin in the location of the former stormwater pond; the existing stormwater pond liner would stay in place. The secondary treatment basin would likely be filled with crushed limestone. After treatment in the secondary basin, drainage would flow via pipe to a sump. The sump would be accessible to the surface of the waste rock by a 4- to 6-foot-diameter concrete riser pipe. This access would allow drainage to be monitored for quantity and sampled for treatment effectiveness. Drainage would discharge from the sump to the ground via an open port. If sampling indicates that treatment is ineffective, the sump is equipped with pump equipment to evacuate the drainage for further active treatment.

Encapsulation of a heap leach facility with waste rock is not typical with open-pit mines, as usually heap leach activities continue throughout the life of the mine. The nature of the ore at this location indicates that heap leach processing is only required for the initial 6 years of active mining. Waste rock encapsulation is expected to be beneficial for two reasons: prevention of infiltration of precipitation through the heap leach, and provision of large volumes of acid-neutralizing waste rock. Public comments raised concerns that the encapsulating waste rock would not be protective of the heap leach as was suggested in the DEIS. The Coronado conducted further investigation of this question and determined that while the waste rock encapsulation would help prevent infiltration of precipitation into the heap, it indeed would not be effective at neutralizing any drainage because of the very limited area of contact the drainage has with waste rock lying above and beside the heap (Hoag et al. 2012b). Therefore, the treatment systems described above are the sole method for neutralization of any heap leach drainage.

Monitoring Intended to Assess Seepage Predictions

While the Coronado has undertaken analysis that concludes it is unlikely that seepage would occur from the waste rock facility due to infiltration of precipitation, in consideration of the public concerns raised about this potential, a monitoring component has been incorporated into the mitigation and monitoring plan (see appendix B for full details):

- **Monitoring of waste rock for seepage.** Lysimeters or other collection equipment would be placed within the waste rock facility in order to monitor for the presence of seepage and allow for analysis of any leachate.

Expected Water Quality

This section describes the modeled water quality expected if seepage were to occur from the tailings, waste rock, and heap leach facilities. An overall discussion of the potential for acid rock drainage to occur, based on the numerous geochemical characterization tests conducted on materials from the site, is included in the “Surface Water Quality” resource section.

Tailings Facility — Geochemical models typically assume a starting liquid solution with a given concentration of various inorganic and metal constituents. Next, the movement of this starting solution through an unsaturated material such as waste rock or tailings is modeled. As the solution passes through the material, changes in geochemistry resulting from dissolution or precipitation of minerals are modeled, resulting in a final discharge or seepage solution.

The starting solution for the tailings seepage model was based on nine samples that were physically leached through simulated tailings in the laboratory. These samples were leached using standard leaching procedures typically conducted under laboratory conditions (the synthetic precipitation leaching procedure and the meteoric water mobility procedure). The starting solutions were then modeled as moving through the tailings facility. The expected seepage water quality for constituents with a numeric Arizona Aquifer Water Quality Standard is shown in table 71. The predicted water quality for seepage from tailings is not expected to exceed any numeric Arizona Aquifer Water Quality Standards (Hudson and Williamson 2011; Tetra Tech 2010b).

Table 71. Expected water quality from tailings facility

Constituent	Arizona Aquifer Water Quality Standard (milligrams per liter (mg/L))	Predicted Tailings Seepage (mg/L)	Ambient Groundwater Quality (mg/L)*
pH	No standard	5.87	8.1 (5.7 to 9.5)
Antimony	0.006	Not present	<0.0004 (<0.0004 to 0.0044)
Arsenic	0.05	Not present	0.0032 (<0.0005 to 0.067)
Barium	2	0.017	0.050 (<0.003 to 0.206)
Beryllium	0.004	Not present	<0.0001
Cadmium	0.005	Not present	<0.0001 (from not detectable to 0.001)
Chromium	0.1	Not present	<0.003 (<0.003 to 0.01)
Fluoride	4.0	2.37	0.7 (<0.1 to 3.6)
Lead	0.05	Not present	<0.0001 (<0.0001 to 0.0049)
Mercury	0.002	Not present	<0.0001 (<0.0001 to 0.0003)
Nickel	0.1	Not present	<0.005 (<0.005 to 0.03)
Nitrate and Nitrite (as N)	10	0.001	0.44 (<0.02 to 8.4)
Selenium	0.05	0.006	<0.0001 (<0.0001 to 0.0055)
Thallium	0.002	Not present	<0.0001 (<0.0001 to 0.0012)

Note:
Not present – constituent was either not detected in laboratory leached tailings solution and therefore was not modeled or was below laboratory detection limits in the modeled seepage.

* Median result from all well and spring samples, with range shown in parentheses. For samples without detections of contaminants above laboratory detection limits, the smallest detection limit is shown. If no range is shown, then all samples were below laboratory detection limits.

Waste Rock Facility — Under all modeled climatic conditions, seepage is not expected to occur from the waste rock facility. However, geochemical modeling was conducted to estimate seepage water quality if any infiltration were to occur (Hudson and Williamson 2011; Tetra Tech 2010b).

The starting solution for the waste rock modeling was based on 13 samples that were physically leached through simulated waste rock in the laboratory. Expected water quality from any waste rock seepage is shown in table 72 for those modeled constituents with numeric Arizona Aquifer Water Quality Standards. None of the constituents predicted in the waste rock seepage exceed current Arizona Aquifer Water Quality Standards.

Table 72. Expected water quality from waste rock seepage

Constituent	Arizona Aquifer Water Quality Standard (milligrams per liter (mg/L))	Predicted Waste Rock Seepage (mg/L)	Ambient Groundwater Quality (mg/L)*
pH	No standard	7.73	8.1 (5.7 to 9.5)
Antimony	0.006	Not present	<0.0004 (<0.0004 to 0.0044)
Arsenic	0.05	0.013	0.0032 (<0.0005 to 0.067)
Barium	2	0.013	0.050 (<0.003 to 0.206)
Beryllium	0.004	Not present	<0.0001
Cadmium	0.005	0.0004	<0.0001 (<0.0001 to 0.001)
Chromium	0.1	Not present	<0.003 (<0.003 to 0.01)
Fluoride	4.0	1.18	0.7 (<0.1 to 3.6)
Lead	0.05	0.003	<0.0001 (<0.0001 to 0.0049)
Mercury	0.002	Not present	<0.0001 (<0.0001 to 0.0003)
Nickel	0.1	Not present	<0.005 (<0.005 to 0.03)
Nitrate and Nitrite (as N)	10	0.018	0.44 (<0.02 to 8.4)
Selenium	0.05	0.036	<0.0001 (<0.0001 to 0.0055)
Thallium	0.002	Not present	<0.0001 (<0.0001 to 0.0012)

Note:

Not present – constituent was either not detected for the analysis of the waste rock samples and therefore was not modeled or was below laboratory detection limits in the modeled seepage.

* Median result from all well and spring samples, with range shown in parentheses. For samples without detections of contaminants above laboratory detection limits, the smallest detection limit is shown. If no range is shown, then all samples were below laboratory detection limits.

Heap Leach Facility (applies to all action alternatives except Barrel Alternative) — The starting solution for the heap leach facility seepage model was based on laboratory leach tests and was then modeled as moving through two rock types expected to be present in the heap (andesite and quartz monzonite porphyry).

As previously described, following closure and encapsulation of the heap leach facility, the collection system would remain in place and would use a passive treatment system in order to neutralize any remaining potential seepage. Monitoring of the treated drainage via a concrete riser pipe to the surface of the waste rock would be possible to ensure that treatment is effective.

Two passive treatment systems have been modeled to demonstrate conceptually that treatment of heap leach seepage would be adequate. Each treatment system would consist of two treatment basins. The engineered biological system would involve placement of carbon sources in the first basin to promote biological treatment, followed by placement of crushed limestone in the second basin to control alkalinity. The crushed limestone system would have crushed limestone in both basins. The engineered biological system may be modified based on sampling of actual heap leach drainage.

The expected seepage water quality, as well as the water quality using each of the passive treatment systems, is summarized in table 73, which shows those modeled constituents with numeric Arizona Aquifer Water Quality Standards (Hudson and Williamson 2011). Based on the modeling, seepage from the heap leach facility before and after passive treatment with crushed limestone would still exceed numeric Arizona Aquifer Water Quality Standards for cadmium, nickel, and selenium. However, the engineered biological system would reduce concentrations of all constituents below numeric Arizona Aquifer Water Quality Standards. As noted previously, the actual treatment system would be designed based on analysis of actual drainage from the heap leach. Also, the heap leach is not contained in the Barrel Alternative.

Table 73. Expected water quality from heap leach seepage

Constituent	Arizona Aquifer Water Quality Standard (milligrams per liter (mg/L))	Predicted Heap Leach Facility Seepage (mg/L)	Seepage through Engineered Biological System (mg/L)	Seepage through Crushed Limestone (mg/L)
pH	No standard	3.23	6.31	6.59
Antimony	0.006	Not present	Not present	Not present
Arsenic	0.05	0.003	0.003	0.002
Barium	2	0.013	0.013	0.011
Beryllium	0.004	Not present	Not present	Not present
Cadmium	0.005	**0.307**	0.002	**0.305**
Chromium	0.1	0.034	0.009	0.034
Fluoride	4.0	**5.23**	2.64	1.96
Lead	0.05	Not present	Not present	Not present
Mercury	0.002	Not present	Not present	Not present
Nickel	0.1	Not present	Not present	Not present
Nitrate and Nitrite (as N)	10	Not present	Not present	Not present
Selenium	0.05	**0.099**	Not present*	**0.099**
Thallium	0.002	Not present	Not present	Not present

Notes:

Boldfaced numbers indicate an exceedance of the aquifer water quality standard.

Not present = Constituent was either not detected for the analysis of the leached rock samples and therefore was not modeled or was below laboratory detection limits in the modeled seepage.

* Modeled seepage was reported but with an extremely low concentration (7.6×10^{-13} mg/L), effectively not present in the solution.

Comparison of Rosemont Deposit with Other Arizona Mines

In general, public comments (including those from the EPA) expressed concern that the geochemical modeling may be inaccurate, given real-world water quality issues that have arisen at other mines, especially porphyry copper deposits in Arizona. The Coronado requested that this issue be further investigated by the geochemical experts consulting with the Coronado and be further explored during an expert panel meeting with Federal cooperating agencies on May 3, 2012 (Garrett 2012b; Hoag et al. 2012b).

At first glance, the Rosemont deposit seems similar to other copper deposits in Arizona in that it is a porphyry copper deposit that contains sulfide mineralization in skarn derived from Paleozoic carbonate formations. However, nearly all porphyry copper deposits in Arizona and nearby States (Nevada and New Mexico) contain large amounts of mineralized intrusive igneous rock (from 30 to 100 percent by volume mined). In contrast, these materials in the Rosemont deposit account for only 6 percent of the total materials to be mined. As a whole, this results in a substantially larger ratio of carbonate rocks, which tend to neutralize acid, than is found in other similar deposits. In total, eight mines with similar porphyry copper deposits that contain skarn were researched, and 13 additional mines with porphyry copper deposits that do not contain skarn were researched. None of these mines were found to be a reasonable analog to the Rosemont deposit because of the large amount of carbonate rocks in the Rosemont deposit, compared with igneous intrusive rocks in the comparison deposits.

In itself, this comparison does not necessarily rule out the potential for water quality problems. The site-specific geochemical testing and modeling that have been completed as part of this analysis are the appropriate methods for determining that answer. However, the comparison does respond to the public perception that the potential for water quality problems at the Rosemont deposit is similar to the potential for water quality problems observed at other developed copper deposits in Arizona.

In addition to the dissimilarity of the Rosemont Copper deposit to other copper deposits, the results of the various geochemical tests to estimate the potential for acid rock drainage also indicate there is little potential for acid generation. Of the static tests conducted, only 5 percent of the rock samples (11 out of 226) indicated the potential for acid generation. Based on these results, 16 rock samples were selected for further kinetic testing. When the majority of these materials were subjected to long-term humidity cell testing, the leachate pH remained neutral, and the trends in sulfate, iron, and acidity provided no indication of sulfide oxidation. One rock type, Bolsa Quartzite, was shown to produce net acidity during humidity cell testing as a result of sulfide oxidation.

As a whole, the percentage of waste rock mined that is potentially acid generating is 10 percent, which is a mix of rock with likely acid-generating potential (2 percent) and with uncertain acid-generating potential (8 percent) (Williamson 2012). The remaining 90 percent is non-acid generating or acid neutralizing. As noted previously, guidance from the ADEQ indicates that any net neutralization potential greater than 20 indicates the waste rock can be generally considered non-acid generating. Calculated net neutralizing potential for waste rock mined per year ranges from 75 to more than 500, with a running annual average value of 225 for the projected life of the mine; thus, as a whole the waste can generally be considered non-acid generating.

Potential for Technologically Enhanced Naturally Occurring Radioactive Materials

Public comments raised the potential for the mining process to concentrate naturally occurring radioactive materials in the tailings. The Coronado requested further investigation of this issue from their contract geochemical experts (Kline et al. 2012). The investigation focused on the ranges of uranium typically found in crustal-type rocks, the general concentrations by rock type generally found in the Rosemont deposit, the results of radionuclide and whole rock geochemical analysis conducted by Rosemont Copper on rock samples, and the solubility of uranium at the pH ranges expected to be encountered in the tailings.

The most common source of radioactive materials is igneous intrusive and metamorphic basement rocks; as discussed above, compared with other deposits, these types of rocks are largely absent from the Rosemont deposit, although other types of rocks, including those present, typically also have lower levels of radioactivity. Geochemical analysis conducted by Rosemont Copper generally supported the finding that elevated levels of radioactive materials were not present. Mobility of any uranium present in the tailings was expected to be low, based on geochemical testing. Overall, the review found that the potential for technological enhancement of naturally occurring radioactive materials was adequately investigated and that the mineralized and unmineralized rocks present in the Rosemont deposit would not generate detectable concentrations of these materials.

Potential for Residue from Ammonium Nitrate Explosives

The potential for the presence of residue from the use of nitrogen-based explosives has been well documented in the literature (Ferguson and Leask 1988; Forsyth et al. n.d. [1995]; Morin and Hutt 2009; Pommen 1983; Revey 1996). The explosive reaction that occurs involving ammonium nitrate and fuel oil ideally generates only water, carbon dioxide gas, nitrogen gas, and heat. It is the rapid release and expansion of these gases that creates the explosive power of the mixture. However, the reaction is seldom completely efficient, and nitrogen can remain as a residue in waste rock and in the blast zone. Early literature analyzed explosive use in coal mines in Canada and suggested that 1 to 6 percent of the total nitrogen could remain as residue (Pommen 1983). The lower end of this range (1 percent) is typically associated with the dry use of ammonium nitrate, while the higher end of this range (6 percent) is typically associated with the use of a slurry form of ammonium nitrate. The slurry form of the explosive is usually used in wet environments; only dry use of ammonium nitrate fuel oil explosive is expected to be used by Rosemont Copper. Further studies of these same mines and additional mines clarified that the total nitrogen loss depended largely on the form of the explosive used and suggested that use of ammonium nitrate-fuel oil under dry conditions has significantly less residue, as little as 0.2 percent of the total nitrogen (Ferguson and Leask 1988). Therefore, for the purposes of this analysis, in order to calculate the potential nitrogen residue, the range of values associated with dry use of ammonium nitrate was used (0.2 to 1 percent).

Approximately 20,100 tons of ammonium nitrate would be used for blasting each year (see the “Hazardous Materials” resource section of chapter 3). By weight, ammonium nitrate is approximately 35 percent nitrogen. The total nitrogen being imported to the site in the form of ammonium nitrate is therefore approximately 14 million pounds per year. It can be estimated that 0.2 to 1 percent would remain as residue after blasting (based on dry use of ammonium nitrate), or approximately 28,000 to 140,000 pounds per year (or approximately 588,000 to 2.9 million pounds over the entire active mining phase). Residual phases of inorganic nitrogen can include ammonia, ammonium, nitrite, and nitrate, depending on the chemical and biological reactions that take place. Of these, ammonia is the most toxic to aquatic organisms, and the toxicity varies depending on both pH and temperature.

Although reactions can vary greatly due to site-specific conditions, previous studies have estimated that approximately 87 percent of nitrogen residue exists as nitrate, 11 percent exists as ammonia, and 2 percent exists as nitrite (Ferguson and Leask 1988).

The fate and transport of any nitrogen residue to groundwater or surface waters is of concern, as there are aquifer and surface water quality standards for nitrate, nitrite, and ammonia. There are two general areas in which nitrogen residue could be present within the mine site: within the pit, and within the waste rock facility. Within the pit itself, any residue transported by precipitation and infiltrating to groundwater would eventually end up in the pit lake that would form after closure. Blasting residue was not incorporated into the pit lake geochemical modeling (Tetra Tech 2010a). However, estimates suggest that if nitrogen residue were present in the pit, were to persist over the entire life of them mine, and were to persist and accumulate in the forming pit lake, concentrations of total nitrogen ranging from 6.7 to 33.3 mg/L could occur. This estimate assumes a range of explosive residue from 0.2 to 1 percent, assumes that approximately three percent of the total residue would remain in the pit rather than the waste rock facility, and that the pit lake would have a volume of about 1,000 acre-feet, which is expected to occur by about 20 years following mine closure (SWCA Environmental Consultants 2013).

The exposure pathway for this residue in the pit lake would be limited to birds or wildlife that could readily access the pit lake. As discussed elsewhere in this section, the surface water quality standards are not applicable to the pit lake from a regulatory perspective, but can be used to qualitatively assess potential impacts to exposed birds or wildlife. In this case, the most restrictive numeric surface water standards are for ammonia for warmwater aquatic and wildlife. Depending on temperature, the acute standard ranges from 6.95 to 8.4 mg/L, and the chronic standard ranges from 0.773 to 2.43 mg/L. Ammonia concentrations in the pit lake could range from 0.74 to 3.7 mg/L (SWCA Environmental Consultants 2013). Under these scenarios, estimates suggest that if chronic exposure occurred there could be negative impacts to wildlife and aquatic species due to ammonia levels in the pit lake.

An additional concern is nitrogen residue that would be entrained with the waste rock removed from the pit that would then be exposed to surface water runoff. Unlike residue remaining in the pit, any impacts from waste rock runoff could potentially leave the mine site and impact downstream waters. Stormwater would come into contact with only a small fraction of the waste rock. Most of the waste rock slopes would be covered by salvaged soil during reclamation, preventing stormwater from contact with residual nitrogen that might be entrained with the waste rock. Stormwater would likely only come into direct contact with waste rock in the conveyance channels along the benches, which represents a small percentage of the entire waste rock volume, with contact persisting for a relatively short amount of time. However, for erosion control some areas of the waste rock facility might have a final cover of waste rock, not salvaged soil, and exposure of stormwater to explosive residue could occur in these areas. Estimates suggest that concentrations of total nitrogen ranging from 1.4 to 7.2 mg/L could occur in runoff (SWCA Environmental Consultants 2013). This estimate assumes that approximately 5 percent of the waste rock represents surface or near-surface rock that could come into contact with stormwater runoff, and that contact could occur over the entire area of the waste rock facility.

There are no applicable surface water quality standards for nitrate, nitrite, or ammonia in the ephemeral washes immediately downstream. If infiltration of this runoff occurred, estimates suggest that numeric aquifer water quality standards for nitrate (10 mg/L) and nitrite (1 mg/L) would not be exceeded (SWCA Environmental Consultants 2013).

Further studies indicate that much of the loss of nitrogen is influenced by handling practices, more so than incomplete reactions, with as much as 5 to 15 percent loss experienced through spillage and improper handling (Forsyth et al. n.d. [1995]; Revey 1996). For these reasons it is desirable to have a robust explosives management program, as studies have found that rigorous explosives management programs were able to reduce ammonia concentrations by 50 percent (Revey 1996) (see the “Mitigation Effectiveness” part of this resource section).

Fate and Transport of Contaminants

Seepage from the tailings facility is expected to occur because of process water that is present during stacking, but geochemical modeling indicates that this seepage is not expected to exceed any numeric Arizona Aquifer Water Quality Standards. Seepage from the waste rock facility is not expected to occur, but in the event that it does, geochemical modeling indicates that it would not exceed any numeric Arizona Aquifer Water Quality Standards. Seepage from the heap leach facility in the proposed action, Phased Tailings, Barrel Trail, and Scholefield-McCleary Alternatives is expected to be treated after completion of active heap processing. Modeling indicates that untreated seepage would exceed numeric Arizona Aquifer Water Quality Standards; seepage treated with an engineered biological system would meet numeric Arizona Aquifer Water Quality Standards.

The fate of seepage reaching groundwater, if it occurs, is modeled using the three independent groundwater flow models that were conducted for the project area (Montgomery and Associates Inc. 2010; Myers 2008, 2010; Tetra Tech 2010c). All three models predict the presence of a cone of depression in the groundwater table around the mine pit as a result of active pumping of the mine pit during active mining and as a result of evaporation from the mine pit in perpetuity after mine closure. The cone of depression that occurs encompasses the area beneath the heap leach facility. By the end of active mining, groundwater levels beneath the heap leach facility are predicted to decrease by more than 100 feet (see the “Groundwater Quantity” resource section). While the liner and collection systems are designed to and fully expected to capture all seepage from the heap leach facility that exceeds numeric Arizona Aquifer Water Quality Standards, any seepage that inadvertently infiltrated to groundwater would move toward and be contained in the pit lake.

The cone of depression that results in groundwater flowing toward the pit lake would take time to develop during the mine life, and there is a possibility that heap leach seepage, if the containment system failed, could move laterally before reaching regional groundwater or migrate offsite before the cone of depression expanded to reach the heap leach facility. This scenario was modeled by analyzing particle tracks during the active mine life and after final reclamation and closure (Tetra Tech 2010c). Based on the modeling, with the exception of seepage from the northern portion of the dry-stack tailings facility, the movement of any potential infiltration is still toward the mine pit lake, even during active mining while the cone of depression is still developing.

During the active mine life, groundwater beneath the dry-stack tailings facility would continue to move northward and eastward, generally following the Davidson Canyon drainage and regional groundwater flow directions. As the mine pit lake develops and groundwater flow directions continue to change, seepage would begin to flow westward to the mine pit lake. However, as seepage from the dry-stack tailings facility is not expected to exceed any numeric Arizona Aquifer Water Quality Standard, there would be no water quality impacts from seepage flow away from the mine site during active mining operations.

Impacts from Mine Pit Lake

With respect to the mine pit lake, the following indicators were considered for the impacts analysis:

- Expected water quality in the mine pit lake; and
- Potential for acid conditions to form in mine pit lake.

The geochemistry of the mine pit lake that is predicted to develop after closure of the mine would not present a threat to groundwater regionally; as previously described, the pit is expected to capture regional groundwater and draw any contaminants toward it. However, the geochemistry of the mine pit lake is still potentially a hazard in and of itself. Impacts that would result from the geochemistry of the mine pit lake are analyzed in this section.

There are three general concerns with respect to the geochemistry of the pit lake: the potential for an acidic lake to form; geochemical reactions with the rock of the pit walls; and, since the pit represents a hydraulic sink, the potential for concentration of constituents due to evaporation of water from the pit. These parameters were evaluated in a geochemical and water balance model of the mine pit lake formation (Tetra Tech 2010a).

Predicted Lake Water Balance

The mine pit lake would be a dynamic system, gradually filling over a period of approximately 700 years. In that time, the lake elevation would increase by approximately 1,229 feet, rising from approximately 3,050 to 4,279 feet above mean sea level. The final pit volume would be approximately 95,975 acre-feet, with a surface area of approximately 213 acres (Tetra Tech 2010c).

Geochemical modeling (Tetra Tech 2010a) was based on a time frame of 200 years, at which time the pit lake stage would reach 3,962 feet above mean sea level (approximately 75 percent of its ultimate depth). The water balance of the lake at that time point is shown in table 74.

Table 74. Water balance of the mine pit lake 200 years after mine closure

Water Balance Component	Annual Volume (acre-feet)
Inflows	
Direct precipitation on lake surface	229.4
Runoff from mine pit walls	210.9
Groundwater inflow	139.7
Outflows	
Groundwater outflow	0
Evaporation	517.1
Increase in Mine Lake Volume	62.9

Predicted Geochemistry

Numerous public comments were received on the geochemical modeling used to predict water quality in the pit lake, primarily focused on the inputs, assumptions, and techniques used in the modeling. Prior to publication of the DEIS, the modeling itself had undergone a peer review process and was found to be acceptable. In response to six specific technical issues brought up during public comment, the Coronado conducted additional investigations (Hoag et al. 2012a). The review found that most of these concerns had been addressed in a reasonable manner or simply could not be addressed as suggested in the comments. However, the review found that two of these concerns had merit. These issues include: (1) accounting for chemical loading that could occur as precipitation percolates through fractures in the pit walls, and (2) the potential for stratification to occur. In both cases, however, it was concluded by the Coronado's consulting geochemical modeling experts that while changing the methods of modeling these conditions would have an effect on the results, it was unlikely to significantly change the modeling outcome.

The geochemical model considered the starting chemistry of the various sources of water entering the pit lake. The chemistry of the groundwater inflow was assumed to be similar to that of groundwater samples obtained throughout the area (Errol L. Montgomery and Associates Inc. 2009b). The chemistry of the precipitation was obtained from the nearest national Atmospheric Deposition Program station at Organ Pipe National Monument, approximately 200 miles west of the project area.

The chemistry of the runoff resulting from the interaction of precipitation with the rocks of the mine pit walls was based on a variety of tests, including acid base accounting tests, humidity cell tests, and laboratory leaching procedures. Only one rock type (Bolsa Quartzite) produced acid-forming conditions during humidity cell testing. The results of all three types of tests were considered when developing the input chemistry from runoff from mine pit walls.

Based on these inputs, four different geochemical modeling scenarios were conducted, as shown in table 75. Three of these scenarios represented a range (low, average, high) of possible geochemistry from interaction of water with the mine pit walls. The fourth scenario was designed to determine whether water interacting solely with Bolsa Quartzite, which is expected to be acidic, would be neutralized by the water in the mine pit lake. The results of all four modeling scenarios are shown in table 75. Numeric Arizona Aquifer Water Quality Standards are included in the table for comparison.

Table 75. Results of geochemical modeling for mine pit lake at 200 years

Constituent	Numeric Arizona Aquifer Water Quality Standards	Scenario 1: Low Geochemical Loading	Scenario 2: Average Geochemical Loading	Scenario 3: High Geochemical Loading	Scenario 4: Average Loading with Bolsa Quartzite
Aluminum	No standard	0.158	0.197	0.260	0.357
Antimony	0.006	0.003	0.003	0.003	0.003
Arsenic	0.05	0.004	0.005	Not present	0.003
Barium	2	Not present	Not present	0.009	Not present
Beryllium	0.004	0.001	0.001	0.001	0.001
Bicarbonate	No standard	37.3	36.2	37.0	36.0
Cadmium	0.005	0.002	0.002	0.002	0.002
Calcium	No standard	89.9	99.8	107.7	100.7
Chloride	No standard	9.9	11.1	12.5	11.1
Chromium	0.1	0.004	0.005	0.005	0.005
Copper	No standard	0.004	0.004	0.005	0.163
Fluoride	4.0	1.1	1.2	1.4	1.2
Iron	No standard	Not present	Not present	Not present	Not present
Lead	0.05	0.004	0.015	0.017	0.015
Magnesium	No standard	22.7	25.7	30.1	25.6
Manganese	No standard	0.229	0.255	0.243	0.254
Mercury	0.002	0.002	0.001	Not present	Not present

Constituent	Numeric Arizona Aquifer Water Quality Standards	Scenario 1: Low Geochemical Loading	Scenario 2: Average Geochemical Loading	Scenario 3: High Geochemical Loading	Scenario 4: Average Loading with Bolsa Quartzite
Molybdenum	No standard	0.137	0.150	0.192	0.154
Nickel	0.1	0.005	0.006	0.007	0.010
pH	No standard	8.1	8.0	8.0	8.0
Potassium	No standard	5.1	5.7	6.3	5.4
Selenium	0.05	0.013	0.014	0.016	0.014
Silver	No standard	0.004	0.004	0.005	0.004
Sodium	No standard	31.9	35.9	38.6	35.3
Sulfate	No standard	330.6	374.1	518.5	375.8
Thallium	0.002	**0.005**	**0.006**	**0.007**	**0.006**
Total Dissolved Solids		527	589	751	590
Uranium		0.005	0.006	0.006	0.006
Zinc		0.745	0.847	0.959	0.862

Notes:
All results are in milligrams per liter (mg/L).
Boldfaced numbers indicate an exceedance of the aquifer water quality standard.
Not present = Constituent was not modeled to be present at concentrations above three decimal places.

Potential for Acid Lake Formation — Based on the geochemical modeling, none of the modeled scenarios create acidic lake conditions.

Qualitative Comparison of Pit Lake with Aquifer Water Quality Standards — Under Arizona laws, the pit lake is not considered to be a facility discharging to groundwater; therefore, aquifer water quality standards are not applicable. However, these standards provide a point of comparison for the water quality in the pit lake. The geochemistry of the mine pit lake results from the contributing inflow water quality, the interaction with mine wall rock, and evaporation. Geochemical modeling indicates that thallium exceeds the numeric Arizona Aquifer Water Quality Standards under all four scenarios modeled. Thallium has not been observed at these levels in the background ambient groundwater samples collected in the project area and therefore is likely elevated due to contact with and reaction to the exposed rock.

Qualitative Comparison of Pit Lake with Surface Water Quality Standards — The mine pit lake is not a navigable water and is not regulated under surface water quality regulations. However, surface water quality standards are specific to wildlife use and are therefore useful solely as a tool for assessing the potential impacts to wildlife. The comparisons provided below are based on the acute and chronic surface water standards designated for warmwater aquatic species and wildlife. Note that some standards change as water hardness changes; a hardness of 355 milligrams per liter (as calcium carbonate [$CaCO_3$]) was used to calculate standards for comparison to pit lake water quality (Garrett 2012a). Surface water standards have been developed for both acute and chronic exposure. Wildlife groups that are most likely to be directly impacted by toxins potentially present in the mine pit lake include invertebrates (i.e., insects, etc.) and birds. Wildlife most likely to be indirectly impacted includes any animals that prey on insects or birds that have come in contact with the water in the mine pit lake. Acute exposure by avian species is the most likely scenario to occur, given the depth and isolation of the pit lake and general inaccessibility by wildlife. Chronic exposure is unlikely to occur directly, but chronic exposure could occur indirectly through predation on insects.

Geochemical modeling indicates that some surface water quality standards for acute exposure to warmwater aquatic species and wildlife could be exceeded:

- Copper exceeds the acute surface water standard for two scenarios. Copper has not been observed in background ambient groundwater concentrations at these levels.
- Zinc exceeds the acute surface water standard under all four scenarios. The concentrations modeled for the pit lake (0.745 to 0.959 milligram per liter) appear to be largely the result of the concentration of zinc naturally occurring in groundwater samples collected from near-pit wells (0.694 milligram per liter). The background concentration also exceeds the acute surface water standard for zinc.

Geochemical modeling also indicates that some surface water quality standards for chronic exposure to warmwater aquatic species and wildlife could be exceeded:

- Cadmium exceeds the chronic surface water standard under all four scenarios. Cadmium has not been observed in background ambient groundwater concentrations at these levels and therefore is likely elevated due to contact with and reaction to the exposed rock.
- Copper exceeds the chronic surface water standard under all four scenarios. Copper has not been observed in background ambient groundwater concentrations at these levels and therefore is likely elevated due to contact with and reaction to the exposed rock.
- Lead exceeds the chronic surface water standard for three scenarios. Lead has not been observed in background ambient groundwater concentrations at these levels and therefore is likely elevated due to contact with and reaction to the exposed rock.
- Mercury exceeds the chronic surface water standard for at least two scenarios. Mercury has not been observed in background ambient groundwater concentrations at these levels and therefore is likely elevated due to contact with and reaction to the exposed rock.
- Selenium exceeds the chronic surface water standard under all four scenarios.
  The concentrations modeled for the pit lake (0.013 to 0.016 milligram per liter) appear to be partially the result of the concentration of selenium occurring in groundwater samples collected from near-pit wells (0.00212 milligrams per liter), although the modeled concentrations are substantially higher. The background concentration also exceeds the chronic surface water standard for selenium.
- Zinc exceeds the chronic surface water standard under all four scenarios. As noted above, this appears to be largely the result of the concentration of zinc occurring naturally in groundwater samples collected from near-pit wells, which also exceeds the chronic surface water standard for zinc.

Potential impacts to biological resources based on these exceedances are analyzed in the “Biological Resources” resource section of this chapter.

Impacts to Sierrita Sulfate Plume

The Sierrita open-pit copper mine is located approximately 7 miles southwest of the Rosemont Copper Mine water supply wells. The Sierrita mine has been operational since the 1950s, and since the 1970s, it has used a slurry method to deposit tailings to the east of the open pit. Over time, seepage from the slurry tailings impoundment has infiltrated to groundwater and has migrated downgradient, resulting in a plume of groundwater impacted by high sulfate concentrations that extends northeast from the tailings facility. In 2006, Sierrita agreed to the ADEQ's request to conduct remedial actions concerning the plume, including pumping to halt migration of the plume and replacement of affected water sources.

The extent of the sulfate plume originating from the Sierrita mine tailings has not been fully characterized by Sierrita or ADEQ; however, Sierrita intends to conduct mitigation pumping to prevent further migration of this plume northward into the Upper Santa Cruz Sub-Basin. The mitigation pumping would be located approximately 5.5 miles south of the Rosemont Copper Mine water supply pumping and would extend an additional 5 miles southward from there (see figures 52 and 53 in the "Groundwater Quantity" resource section). Mitigation pumping is expected to commence in 2012 and extend through 2060, extracting about 23,000 acre-feet per year. By removing groundwater from the vicinity of the sulfate plume, the mitigation pumping will create a cone of depression in the groundwater table. The purpose of this is to control the movement of the sulfate plume and prevent any further migration. The mitigation pumping will be offset by reduced pumping by Sierrita elsewhere in the basin.

Any change in water levels, gradient, or flow direction has the potential to cause migration of existing areas of groundwater contamination. The location of the sulfate plume is beyond the expected range of significant drawdown from the Rosemont Copper Mine water supply wells. No change in flow direction is expected to occur in the aquifer near the Sierrita plume from the Rosemont Copper Mine water supply pumping; the change in gradient is from 8.2 feet per 1,000 feet without mine water supply pumping to 9.4 feet per 1,000 feet with water supply pumping (the change in water-level contours with and without the mine supply pumping is shown in the "Groundwater Quantity" resource section in figures 52 and 53). The approximate 15 percent increase in gradient resulting from the Rosemont Copper Mine water supply pumping could cause a change in the rate of movement of the Sierrita sulfate plume, but the overall direction of groundwater flow, location of the plume, and ability to control the plume are unlikely to be substantially affected.

Summary of Impact Assessment

The assessment factors identified during scoping include the ability to meet Arizona Aquifer Water Quality Standards and the ability to demonstrate best available demonstrated control technology.

Ability to Meet Arizona Aquifer Water Quality Standards

The ability to meet Arizona Aquifer Water Quality Standards is summarized as follows:

- Potential seepage from dry-stack tailings is expected to meet numeric Arizona Aquifer Water Quality Standards.
- Potential seepage from the waste rock facility is expected to meet numeric Arizona Aquifer Water Quality Standards.
- For the proposed action, Phased Tailings, Barrel Trail, and Scholefield-McCleary Alternatives, untreated seepage from the lined heap leach facility could exceed numeric Arizona Aquifer Water Quality Standards for cadmium, fluoride, nickel, and selenium; untreated heap leach drainage is not planned to be discharged to the environment. Modeling shows that seepage after treatment with an engineered biological system is expected to meet numeric Arizona Aquifer Water Quality Standards.

Narrative water quality standards must also be met. These standards indicate that a discharge shall not cause or contribute to a violation of a water quality standard established for a navigable water of the state and that a discharge shall not cause a pollutant to be present in an aquifer that impairs existing or reasonably foreseeable future uses of water in an aquifer, or in a concentration that endangers human health. None of the seepage expected from the tailings, or potentially occurring from the waste rock or heap leach, is expected to impact a navigable water, as these discharges would be captured by the mine pit lake.

Existing and reasonably future use of groundwater in the project area (Davidson Canyon watershed) is limited to domestic wells. There are not currently any public water systems (as defined by the Safe Drinking Water Act) that occur in the vicinity of the project (Arizona Corporation Commission 2012; U.S. Environmental Protection Agency 2012a, 2012b). None of the individual domestic wells that would occur within the area likely to be affected by tailings or waste rock seepage, as these discharges would be captured by the mine pit lake and do not exceed any water quality standards applicable to these individual wells that would preclude use for domestic purposes.

Ability to Demonstrate Best Available Demonstrated Control Technology

The ability to demonstrate best available demonstrated control technology at each of the facilities is a requirement of the aquifer protection permit issued by the ADEQ on April 3, 2012 (Arizona Department of Environmental Quality 2012) and is summarized as follows:

- Dry-stack tailings facility. The stability of the dry-stack tailings facility was evaluated under both static and seismic loading conditions, and the factors of safety meet those required by the ADEQ. Waste rock buttresses are built around the facility, and stormwater management has been designed to control stormwater and minimize the potential for erosion.
- Process water temporary storage pond. The process water temporary storage pond is actually divided into two cells (the process water pond and the temporary storage pond). The process water pond is double-lined, consisting of a bottom sodium bentonite geosynthetic clay liner overlaid by a 60-millimeter high-density polyethylene geomembrane liner, a leak collection and removal system, and a top 60-millimeter high-density polyethylene geomembrane liner. The temporary storage pond is single-lined, consisting of a sodium bentonite geosynthetic clay liner and a 60-millimeter geomembrane liner. The process water temporary storage pond operates with a 2-foot freeboard, and liners are secured in an engineered anchor trench. A slope stability analysis was found to be adequate under ADEQ standards. The temporary storage pond would be dry under normal operations, and impounded temporary or emergency storage water would be removed within 60 days.
- Primary settling basin. The primary settling basin receives non-filtered tailings on a short-term basis and stormwater. The primary settling basin is single-lined, consisting of a sodium bentonite geosynthetic clay liner and a 60-millimeter high-density polyethylene geomembrane liner, secured in an engineered anchor trench. The primary settling basin operates with a 2-foot freeboard. A slope stability analysis was found to be adequate under ADEQ standards. Impounded water in the primary settling basin would be removed within 60 days.
- Raffinate pond. The raffinate pond stores raffinate before it is pumped to the heap leach pad. The raffinate pond is double-lined, consisting of consisting of a bottom sodium bentonite geosynthetic clay liner overlain by a 60-millimeter linear low-density polyethylene geomembrane liner, a leak collection and removal system, and a top 80-millimeter high-density polyethylene geomembrane liner. The process water temporary storage pond operates

with a 3-foot freeboard, and liners are secured in an engineered anchor trench. A slope stability analysis was found to be adequate under ADEQ standards.

- Heap leach pad. The heap leach pad is single-lined, consisting of a sodium bentonite geosynthetic clay liner overlaid by a 60-millimeter linear low-density polyethylene geomembrane liner, above which is a minimum 3-foot layer of overliner drain fill (crushed rock). A network of collection piping within the overliner drain fill would collect and transport the pregnant leach solution. Liners are secured in an engineered anchor trench. A slope stability analysis was found to be adequate under ADEQ standards. Based on comments from the EPA, the Coronado also requested an independent review of the ability of the heap leach liner system to withstand the pressure generated by waste rock encapsulation (Hoag et al. 2012b). This analysis found that placement of the waste rock materials is within the design criteria for the heap leach facility.
- Pregnant leach solution pond. The pregnant leach solution pond stores solution collected from the heap leach pad. The pregnant leach solution pond is double-lined, consisting of a bottom sodium bentonite geosynthetic clay liner overlaid by a 60-millimeter linear low-density polyethylene geomembrane liner, a leak collection and removal system, and a top 80-millimeter high-density polyethylene geomembrane liner. The pregnant leach solution pond operates with a 3-foot freeboard, and liners are secured in an engineered anchor trench. A slope stability analysis was found to be adequate under ADEQ standards. The pregnant leach solution pond is designed to provide storage for 8 hours of operational flows plus 24 hours of draindown flows.
- Stormwater pond. The stormwater pond is located near the heap leach pad and pregnant leach solution pond and is designed to receive operational and stormwater overflow from the pregnant leach solution pond. The stormwater pond is single-lined, consisting of a sodium bentonite geosynthetic clay liner overlaid by a 80-millimeter high-density polyethylene geomembrane liner. The stormwater pond operates with a 3-foot freeboard, and liners are secured in an engineered anchor trench. A slope stability analysis was found to be adequate under ADEQ standards. Impounded water in the stormwater pond would be removed within 45 days.
- Waste rock facility. The stability of the waste rock facility was evaluated under both static and seismic loading conditions, and the factors of safety meet those required by the ADEQ. Stormwater management has been designed to control stormwater and minimize the potential for erosion. A materials testing program and waste rock segregation plan would be implemented to ensure that placement of potentially acid-generating waste rock is not on the outer slopes or other areas subject to contact with stormwater.
- Non-municipal solid waste landfill. The non-municipal solid waste landfill is permitted to receive such materials as clean fill, construction and demolition debris, landscape rubble and vegetative waste, rubbish, plastic, metal, and glass. It would not receive materials such as any waste generated offsite, any municipal solid waste, tires, batteries, septage, asbestos-containing material, or sewage sludge. The landfill is lined with a 24-inch recompacted clay layer and would be overlapped by a 24-inch-thick soil layer.

Certain aspects of the aquifer protection permit may change once the MPO is finalized. For instance, if the Barrel Alternative is implemented, the heap leach and underdrains would be at variance with the issued permit. The ADEQ has procedures for changes to the aquifer protection permit. Most importantly, for these changes to be approved requires demonstration that the best available demonstrated control technology remains in place for these facilities.

Proposed Action and Action Alternatives

The impacts described above apply to the proposed action and all action alternatives. There are no substantial differences in impacts that are unique to specific alternatives.

Cumulative Effects

This cumulative effects discussion addresses the cumulative impacts of the action alternatives and any applicable reasonably foreseeable actions as identified on the Coronado ID team's list of reasonably foreseeable future actions, provided in the introduction to chapter 3. The following reasonably foreseeable actions from that list were determined to contribute to a cumulative impact to groundwater quality and geochemistry:

- The Community Water Company of Green Valley is proposing delivery and recharge of groundwater with water from the Central Arizona Project in the Green Valley area.
- The Farmers Investment Company is proposing the extension of Central Arizona Project water into actively farmed pecan groves and activation of a groundwater savings facility near Sahuarita.
- Demand for groundwater in the Sahuarita area is expected to increase by 200 percent by the year 2030. Potential individual developments are proposed within the Sahuarita area, including development of the Farmers Investment Company property (known as Sahuarita Farms), the Rancho Sahuarita development, the Quail Creek development, and the Madera Highlands development.
- In late 2009, Freeport-McMoRan bought 8,900 acres of the long-closed Twin Buttes Mine site, near Sahuarita. Required permits for reopening the mine have not been issued to date, but it is reasonable to assume that this mine could be reopened at some point in the future.

The potential impacts associated with these activities are similar to those discussed in the "Groundwater Quantity" resource section in that they could change the water balance, groundwater levels, and groundwater flow directions within the Upper Santa Cruz Sub-Basin. In terms of groundwater quality, increased drawdown could potentially cause changes to the direction or rate of movement of the Sierrita sulfate plume.

Climate Change

Although climate change is likely to have an effect on the aquifer of the area and may reduce groundwater availability and increase depth to water, groundwater quality is generally good throughout the basin and does not vary with depth. Climate change is not expected to have an effect on the quality of groundwater resources.

Mitigation Effectiveness

Mitigation and Monitoring – Forest Service

- **Monitoring of waste rock for seepage.** Lysimeters or other collection equipment would be placed within the waste rock facility in order to monitor for the presence of seepage and allow for analysis of any leachate.
- **Location, design and operation of facilities and structures intended to route stormwater around the mine and into downstream drainages.** Various stormwater diversion channels and location of facilities have been designed and located in order to maintain flow

downstream as much as possible and avoid contact of stormwater with processing facilities and ore stockpiles.

- **Monitoring to determine impacts from pit dewatering on downstream sites in Barrel and Davidson Canyons.** Monitoring would be conducted of surface water, alluvial groundwater, and deeper groundwater at sites in Barrel and Davidson Canyons. Several locations have already been installed and are being actively monitored, whereas others will require access from landowners.
- **Hazardous materials containment and management.** In order to reduce potential human health and environmental risks, hazardous materials and substances will be managed and contained within facilities that are designed, constructed, and maintained to meet applicable laws and regulations. These facilities will include leak containment and recovery systems as required and adequate stormwater management and drainage systems to prevent contamination of outside containment areas. An explosives and blasting management procedure would be required to be implemented to ensure best management practices are applied.
- **Additional waste rock and tailings characterization.** During operations, additional waste rock characterization tests, above and beyond those required by the aquifer protection permit, would be required to be conducted on waste rock and tailings. This additional analysis includes requirements for humidity cell testing, whole rock chemistry, and mineralogical analysis in addition to the acid-base accounting and leachate testing already being conducted for the aquifer protection permit.
- **Additional water quality monitoring of springs and wells.** A suite of springs and wells, other than the point-of-compliance wells required to be monitored under the aquifer protection permit, would be monitored for water quality changes. These monitoring locations are situated beyond the perimeter fence of the mine and are intended to provide surveillance of any water quality changes that may be triggered by the changes in the hydrologic system. Specific springs and wells to be monitored are listed in appendix B.

Mitigation and Monitoring – Other Regulatory and Permitting Agencies

- **Design and location of the heap leach facility to reduce potential impacts to groundwater and surface water quality.** The heap leach facility has been designed and located to reduce the risk of potential contamination of groundwater from seepage. It is designed to collect all possible drainage and solution; is located on top of a stable rock location; the liner system is designed to meet requirements of the aquifer protection permit; and the facility would be encapsulated by waste rock at closure to protect from stormwater infiltration.
- **Reduction of the potential for acid generation from tailings and waste rock.** Geochemical testing has indicated that there is adequate neutralization capacity in the overall waste rock composition to prevent potential acid generation. However, proper placement of the waste rock is necessary to allow this buffering capacity to be effective. This mitigation involves requirements for the segregation and encapsulation of potentially acid-generating waste rock with rock that has buffering capabilities in order to reduce the risk of potential acid generation.
- **Equipment and methods to keep potentially contaminated water from being released into the environment.** This mitigation measure requires the use of lined ponds; retention of all contact stormwater for reuse as process water; and the installation of overflow alarms to

alert operators of a potential overflow situation. Much of these mitigation components are required under the aquifer protection permit or stormwater permit.

- **Control and recycling of process water.** This mitigation measure would result in overall reduction of fresh water use and avoidance of potentially contaminated discharges by containing all process water in lined facilities, to be recycled back into the process stream to offset fresh water use.
- **Processing and placement of tailings to reduce water content and overall footprint.** The use of dry-stack tailings instead of traditional slurry tailings would allow for a much smaller footprint for the tailings facility, minimizing soil disturbance.
- **Groundwater quality and aquifer level monitoring required by the aquifer protection permit.** The aquifer protection permit requires the construction and operation of point-of-compliance monitoring wells and institutes groundwater quality monitoring and sampling protocols and reporting. These measures would ensure that water quality problems, if present, would be identified and monitored.
- **Detention and testing of stormwater.** This mitigation measure requires detention and testing of stormwater quality from perimeter waste rock buttress areas for water quality testing prior to flowing downstream of the mine site. This also would allow a reduction of suspended sediment in stormwater flows before flowing downstream.

Conclusion of Mitigation Effectiveness

Use of dry-stack tailings would greatly reduce the potential for seepage to occur from the tailings facility, reducing it to a maximum of approximately 8 gallons per minute. While geochemical modeling predicts that tailings seepage would not exceed aquifer water quality standards, the reduction in seepage would further reduce any risk from tailings seepage.

Under the Arizona Aquifer Protection Permit program, all permitted facilities must use the best available demonstrated control technology to minimize or eliminate discharges. To do so, a mine has the option of selecting prescriptive control technologies or analyzing site-specific controls. Prescriptive control technologies are generally considered to be the more conservative and protective approach. Rosemont Copper chose to adopt prescriptive best available demonstrated control technologies in their permit application. Permitted facilities include the dry-stack tailings facility (unlined), the process water temporary storage pond (lined), the primary settling basin (lined), the raffinate pond (lined), the heap leach pad (lined), the pregnant leach solution pond (lined), the stormwater pond (lined), the waste rock facility (unlined), and the non-municipal solid waste landfill (lined). The heap leach facility is further designed to prevent potential discharge of contaminants for all alternatives except for the Barrel Alternative. The heap leach facility is designed and situated to collect all possible drainage and solution. It is on top of a stable rock location and would be encapsulated by waste rock to protect from stormwater infiltration up to the maximum reasoned storm event. Additional design features are intended to route stormwater around the mine, thus preventing contact with potential contaminants associated with plant site or ore piles, and detain stormwater for testing prior to release downstream. These design features would be effective at reducing the potential for impacts to groundwater quality at the mine site or in downstream shallow alluvial aquifers.

As a whole, the body of waste rock is expected to have little potential for acid rock drainage, as there are significant quantities of acid neutralizing rock and relatively little potentially acid-generating waste rock. However, proper placement of these two types of waste rock is necessary to take advantage of the acid neutralization potential. A waste rock segregation plan has been incorporated into the design of the facility and would be informed by continued monitoring and testing of waste rock for acid-generating potential as it is developed from the mine and placed into the waste rock facility. Proper implementation of the waste rock segregation plan would be effective at reducing the potential for impacts to groundwater quality.

Hazardous materials would be managed as required under various permits, including Mine Safety and Health Administration (MSHA) requirements and ADEQ requirements for storage and secondary containment that would be specified in the stormwater permit. Proper management of hazardous materials would be effective at reducing the potential for impacts to groundwater quality. In particular, proper blasting management procedures would be effective at reducing nitrogen residue that could accumulate in the forming pit lake or impact downstream surface water.

These mitigation measures are expected to be effective in avoiding or reducing impacts to groundwater quality. The effectiveness of the mitigation measures has been incorporated into the analysis and is described in more detail throughout this section.

In addition to the mitigation measures described above, which would effectively avoid, minimize, reduce, rectify, or compensate for impacts, a suite of monitoring measures is also proposed or required under permits. These measures generally would not be effective as mitigation, but rather would provide a means for monitoring potential changes to groundwater quality.