Chapter 3. Affected Environment and Environmental Consequences

Introduction

This chapter describes the existing natural and human environment that would potentially be affected by the proposed action and its alternatives ("Affected Environment") and presents the direct, indirect, and cumulative impacts of the proposed action and its alternatives ("Environmental Consequences"). This chapter is divided into three categories—Physical Environment, Biological Resources, and Social Environment—and the resources analyzed in this draft environmental impact statement (DEIS) are sorted accordingly into these three categories. Each resource section is divided into three subsections: "Introduction," "Affected Environment," and "Environmental Consequences."

For the purposes of this DEIS, the term "project area" refers to those areas that would be excluded from public access to accommodate mine activities and would include the open pit, waste rock storage area, tailings area, heap leach facility, plant site and ancillary facilities, fenced area around the mine, and mine primary and secondary access roads. Unless specifically noted, the term "project area" does not include the linear water and electricity utility corridors. The term "analysis area" is specific to each resource and is explicitly defined in each resource section. The analysis area includes all areas necessary to adequately assess impacts to resources and often includes areas beyond the project area, including utility corridors.

The introduction to each resource section begins by identifying the temporal bounds of analysis and the spatial area of analysis, which are specific to each resource. The introduction then restates the relevant issues and cause and effect relationships of concern for the resources, which were identified during the scoping process (listed in chapter 1). The identified issue or cause and effect relationship of concern directs the analysis to appropriately define and describe the affected environment, anticipated impacts to the affected environment, and appropriate unit(s) of measure for carrying out the analysis (e.g., acres, miles, cubic tons). Several resources in this chapter were not identified during the scoping process as having an issue or cause and effect relationship of concern; however, these resources are included in the analysis because of their importance in aiding the analysis of other resources and their specific resource significance (e.g., "Geology, Minerals, and Paleontology"). The resource section introduction then outlines the analysis methodology, assumptions, and uncertain or unknown information.

The "Affected Environment" part of each resource section begins by identifying the relevant laws, regulations, and policies that guide management of the resource. The existing conditions for the resource are then described qualitatively and/or quantitatively, depending on the analysis requirements identified by the "Issues, Cause and Effects Relationships of Concern" statement. The existing conditions descriptions for a resource may be divided into subcategories, depending on the complexity of the resource (e.g., subcategories for socioeconomics include employment, income levels, and quality of life, among others). Effects from past and present actions that may have a cumulative impact on resources are included in the "Affected Environment" part of each resource section as baseline conditions. Past actions are analyzed to determine whether the affected environment has already been impacted and to what extent. For example, the impacts of historic mining activities within the project area are discussed in the "Affected Environment" part of the "Geology, Minerals, and Paleontology" resource section, among others. Present actions are analyzed to determine which activities are currently causing impacts in the affected environment that may be compounded by impacts from the action alternatives. For example, current traffic activity along State Route 83 is identified as the baseline traffic level, which is described in the "Affected Environment"

discussion in the "Transportation/Access" resource section. With this baseline level identified, the impacts that the addition of mine related traffic would have on State Route 83 are then presented in the environmental consequences section.

The "Environmental Consequences" part of each resource section follows the detailed description of the existing conditions for each resource. Impacts to the resource are analyzed for each alternative; however, in order to reduce redundancy, the section begins by describing the impacts to the resource that are common to all action alternatives. The action alternatives consist of the proposed action and the Phased Tailings, Barrel, Barrel Trail, and Scholefield-McCleary Alternatives. After the impacts common to all alternatives are disclosed, alternative-specific impacts are analyzed qualitatively and/or quantitatively, in accordance with the "Issues, Cause and Effects Relationships of Concern" statement and the units of measure. Mitigation measures identified in chapter 2 are then analyzed for each alternative for the measures' effectiveness in avoiding or minimizing the alternative's impact to the resource.

After mitigation effectiveness is discussed, the cumulative impacts of the action alternatives are addressed. The Council on Environmental Quality regulations for implementing the National Environmental Policy Act define a cumulative impact as "the impact on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable actions regardless of what agency (federal or nonfederal) or person undertakes such other actions. Cumulative impacts can result from individually minor but collectively significant actions taking place over a period of time" (40 Code of Federal Regulations 1508.7). As stated above, past and present actions are addressed in the "Affected Environment" part of each resource section in chapter 3. Reasonably foreseeable actions are analyzed in the "Cumulative Effects" part of each resource section in chapter 3. Reasonably foreseeable actions are actions that are likely to occur in the future and would not be considered speculative. For example, pavement preservation activities are planned to occur on State Route 83 between Sonoita and milepost 43. This activity is analyzed in the cumulative effects part of the "Transportation/Access" section, among others. In order to determine which future activities are likely to occur, the Coronado National Forest (the Coronado) interdisciplinary team (ID team) convened to create a list of reasonably foreseeable actions with input from all resource specialists. The list includes these actions:

- Beaver reintroductions at Cienega Creek by the Arizona Game and Fish Department and the Bureau of Land Management
- Delivery and recharge of groundwater with water from the Central Arizona Project in the Green Valley area by the Community Company of Green Valley
- Pima County Conservation Plan activities may include acquisition of archaeological and historical sites and traditional use sites for conservation and heritage education purposes, tours, monitoring, and other uses of sites by County staff and others
- Designation of the Santa Rita Mountains as a traditional cultural place
- Continued maintenance of forest roads and private roads in support of permitted Rosemont Copper Company (Rosemont Copper) grazing operations
- Pavement preservation activities on State Route 83 between Sonoita and milepost 43 by the Arizona Department of Transportation
- Sahuarita Road Phase II from La Villita Road to Country Club Road (roadway widening and drainage improvement project)
- Stakaer Parsons concrete batch plant and aggregate operations

- Decommissioning of Forest Roads 4032 and 505
- Extension of Central Arizona Project water into Farmers Investment Company actively farmed pecan groves and activation of groundwater storage facility
- Closure of approximately 35 abandoned mines in the Santa Rita Mountains
- Anticipated increase in demand for groundwater in the Sahuarita area by 200 percent in year 2030
- Expansion of limestone quarries in the Davidson Canyon drainage system north and northeast of the Santa Rita Mountains
- Continued precious metal exploration throughout southeastern Arizona

Specific projects included by the ID team typically need to have a level of documentation describing the type and location of proposed activities, such as a permit application submitted to a Federal, State, or local agency. Projects without this level of documentation are considered speculative and are not considered "reasonably foreseeable." Some projects in the area were not included as reasonably foreseeable actions in part because this level of detail was not met. This includes the future mining by Rosemont Copper of other mineral deposits in the area, specifically the Peach-Elgin, Copper World, and Broadtop deposits. Currently, no proposals for development of these projects have been submitted to the Coronado or other land management agency.

The resource section ends with a description of the anticipated irretrievable and irreversible commitment of the resource (in other words, irreversible and irretrievable impacts) that would result from implementation of the action alternatives. Irreversible impacts are those impacts that would result in changes to the environment that cannot be reversed, reclaimed, or repaired. An example of an irreversible impact would be the removal of groundwater from a poorly recharged aquifer. Once groundwater reserves are removed, they cannot be replaced or reclaimed. Irretrievable impacts are those impacts that result in the temporary loss or degradation of the resource value until reclamation is successfully completed. An example of an irretrievable impact would be mine related noise impacts that would no longer exist after mine operations have ended.

Geology, Minerals, and Paleontology

Introduction

This section presents the geology, minerals, and paleontology resources that could be encountered within the project area. The objective of the analysis is to evaluate the potential impacts on these resources that would result from the construction or operation of the proposed action or its alternatives.

Issues, Cause and Effect Relationships of Concern

Even though impacts on geology, minerals, and paleontology were not identified as major issues during the public scoping process, the following section addresses the alternatives' impacts on these resources in order to provide a full impact analysis, as well as to provide background information that is used in the analysis of impacts to other resources such as groundwater. Other aspects of the project that are analyzed in this section include the following:

- Amount of rock and sediment removed (tons)
- Potential loss of paleontological resources (sensitive acres disturbed)
- Qualitative assessment of geotechnical and seismic stability of pit

Qualitative Assessment of Potential for Disturbance of Cave Resources

Other matters that were considered in this analysis but not analyzed in detail include the following:

- Subsidence. The potential for subsidence to occur is linked primarily to groundwater withdrawal. For this reason, this issue is analyzed in detail in the "Groundwater Quantity" section of this document.
- Loss of locatable mineral resources due to burial by waste rock and tailings.
- Legal authority for locatable minerals operations on National Forest System land relative to ownership and validity of mining claims.

Impact to locatable mineral resources, such as restriction of access to minerals owing to burial by waste materials, could potentially be a loss to Rosemont Copper, who has laid claim to all such bedrock minerals within the project footprint and the surrounding area. However, development of potential ore deposits on most of the claims has not occurred, and no proposal to further explore or recover the potential resources has been made.

Regulatory authority to conduct locatable minerals operations on National Forest System lands is found in Code of Federal Regulations 228 Subpart A, allowing for activities that are reasonably incidental to mining, whether or not the operator has active mining claims in the area, and including processing and disposal of mineral materials.

Analysis Methodology, Assumptions, Uncertain and Unknown Information

The analysis area for geology, minerals, and paleontology coincides with the project area (see figure 1). Available data from published and unpublished literature, government reports from sources, including the Arizona Department of Water Resources and U.S. Geological Survey, and available geotechnical studies were used as baseline data for this analysis.

Occurrences of paleontological resources are closely tied to the geological units that contain them. The probability of finding paleontological resources can be broadly predicted from the geological units present at or near the surface. Therefore, geological mapping can be used to assess the potential for the occurrence of paleontological resources. For this analysis, geological mapping by Johnson and Ferguson (2007), Ferguson et al. (2009), and Ferguson (2009) was consulted to identify the geological units that occur within the project area. Numerous scientific publications were consulted to provide baseline geological and paleontological data. A museum records search of previously recorded paleontological localities in the project vicinity was performed by the Arizona Museum of Natural History for the purposes of determining whether there are any known fossil localities within or near the project area. The paleontological sensitivity of each geological unit within the project area was evaluated using the Potential Fossil Yield Classification system (Bureau of Land Management 2007b). The Potential Fossil Yield Classification system was originally developed by the Forest Service's Paleontology Center of Excellence and the Region 2 Paleontology Initiative in 1996. Modifications have been made by the Bureau of Land Management in subsequent years.
The Potential Fossil Yield Classification version used for this analysis was recently approved as policy by the Bureau of Land Management and is widely recognized and used by Federal agencies. Fieldwork is currently ongoing in support of this analysis.

Summary of Effects by Issue Measures by Alternative

Table 9 presents the summary comparison of impacts from each alternative.

Table 9. Summary of effects

Issue Category	No Action	Proposed Action	Phased Tailings	Barrel	Barrel Trail	Scholefield-McCleary
Other Effects Considered						
Amount of rock and sediment removed (tons)	None	1.8 billion	1.8 billion	1.8 billion	1.8 billion	1.8 billion
Potential loss of paleontological resources (sensitive acres disturbed)	None	3,782	3,759	4,409	4,409	3,592
Potential for disturbance of cave resources	None	No cave resources have been identified in project area; however, potential may exist. If present, cave resources could be impacted.	Same as proposed action	Same as proposed action	Same as proposed action	Same as proposed action
Geotechnical and seismic stability of pit	Not applicable	Failure is unlikely because of the design criteria for expected seismic activity.	Same as proposed action	Same as proposed action	Same as proposed action	Same as proposed action

Affected Environment

Relevant Laws, Regulations, Policies, and Plans

Metals and other locatable mineral resources on U.S. Forest Service (Forest Service) lands are managed in accordance with the Mining and Minerals Policy Act of 1970, which states that the Federal Government should “foster and encourage private enterprise in the development of economically sound and stable industries, and in the orderly and economic development of domestic resources to help assure satisfaction of industrial, security, and environmental needs.” Administration of locatable mineral resources on National Forest System lands follows direction in regulations at 36 Code of Federal Regulations 228 Subpart A. The regulations describe what information is required for a proposal to explore for, develop, and recover locatable minerals; how impacts to resources from a proposed operation will be scoped, assessed, and mitigated; and how reclamation will be bonded and completed during the operation at the conclusion of activity. The regulations apply to locatable minerals activity, whether or not the operator has active or valid mining claims.

Mining Laws

Forest Service direction for management of locatable minerals also follows the Multiple-Use Mining Act of 1955 and the General Mining Law of 1872, as amended. The Multiple-Use Mining Act of 1955 removed common varieties of minerals, such as sand and gravel, clay, building stone, and cinders, from the category of locatable minerals and provided for multiple uses of the lands and surface resources on mining claims.

The General Mining Law of 1872 (mining law) (30 United States Code 22–54) authorizes citizens to stake or "locate" mining claims on Federal lands. The mining law consists of five basic elements: discovery of a valuable mineral, location of mining claims, recordation of claims, maintenance (performance of annual requirements on claims), and patenting of a claim, with possible transfer of the surface estate to the claimant. Conditions and requirements for these elements are detailed in Bureau of Land Management regulations (43 Code of Federal Regulations Chapter 2).

Mineral Discovery

There is no Federal statutory definition of what constitutes a valuable mineral deposit, but several judicial and administrative rulings or declarations on the subject have been made.

The Prudent Man Rule was first defined in Castle *v*. Womble, 19 Land Decision 455 (1894), in which the Secretary of the Interior held that "where minerals have been found and the evidence is of such a character that a person of ordinary prudence would be justified in the further expenditure of his labor and means, with a reasonable prospect of success, in developing a valuable mine, the requirements of the statute have been met." This definition was approved by the U.S. Supreme Court in 1905.
The marketability test is supplemental to the prudent man rule and considers deposit economics and market entry. The claimant is required to show a reasonable prospect of making a profit from the sale of minerals from a claim or a group of contiguous claims. Meeting the above "discovery" requirements is the key test for determining whether a mining claim is valid for mineral patent applications, or whether there are valid existing rights in the event of a segregation or withdrawal of the lands from the mining law.

Claim Location

Mining claims may be located only by citizens of the United States, persons who have declared an intention to become citizens, and corporations organized under any State law. Mining claims may only be located on Federal lands open to mineral entry under the mining laws and only for mineral commodities considered to be locatable. Locatable minerals include metallic minerals, certain unusual nonmetallic minerals, and minerals that are of an uncommon variety, with unique or special properties. The mining law grants to the successful claimant (one who has a discovery of a valuable mineral deposit), an equitable title to the minerals so discovered, a fully protected property right under the Constitution. Under the mining law, the public lands are free and open to exploration, acquisition, and purchase. The mining claimant may enter the land and locate mining claims to cover the ground of interest for minerals or for mineral processing and recovery, and waste disposal. Claims may be located prior to a discovery if the ground is of interest, and as long as the claimant actively holds and works the ground, seeking a discovery, they are protected by the doctrine of *pedis possessio.* This judicial doctrine protects the claimant against rival claimants having no better right to the land and allows them peaceful adverse possession of the land pending discovery. There are four main types of mining claims: lode, placer, tunnel, and mill site. Lode claims are located on indurated bedrock, whereas placer claims are located on loosely consolidated materials, such as mineral-bearing sands and gravels, or on layered bedrock. Tunnel claims are linear in nature and resemble a right-of-way, intended to allow for access to ore bodies held under other mining claims. Mill site claims are located for processing of minerals and for disposal of waste. The actual location of a mining claim involves posting a notice of location at the discovery point and erecting corner posts, or monuments, on the ground to ensure that the claim boundaries are readily identifiable.

Claim Recordation and Maintenance

Since enactment of the Federal Land Policy and Management Act, notices of claim location must be filed with the Bureau of Land Management state office, as well as with the appropriate county recorder. This requirement has allowed the Bureau of Land Management to know the number, type, and current status of mining claims located on Federal lands.

Claimants having a legal interest in 10 or fewer mining claims nationwide and who also meet certain other requirements have the option to perform assessment work and file evidence of the assessment work with the Bureau of Land Management. All other claimants must pay an annual maintenance fee per claim or site.

Claim Patent Requirements

It is not necessary to have a patent in order to remove minerals from a mining claim. In fact, it is not even necessary to have a mining claim at all to explore for or process and recover locatable minerals from Forest Service lands if the land is open to mineral entry. However, a patent in most cases gives the claim owner title to the surface estate in addition to his or her rights to the locatable minerals. In order to obtain patent, the claimant must have performed at least $500 worth of development work per claim; must have had a mineral survey and plat prepared at the claimant's expense; must show that he or she holds possessory rights by chain of title documents; must publish a notice for potential adverse claimants to assert his or her claims; and must demonstrate discovery of a valuable mineral deposit within the meaning of the mining law. Demonstrating discovery typically involves extensive mineral exploration and feasibility analysis of the mineral resources.

Surface Management Regulations

Regardless of the rights inherent in patented or unpatented claims, mine operators must comply with Federal surface management regulations. Until the 1960s, there were no Federal or State statutes or regulations governing hardrock mining. This began to change, however, with the enactment of Federal statutes, including the Wilderness Act, National Environmental Policy Act, Clean Water Act, Clean Air Act, and Endangered Species Act. These statutes did not target hardrock mining, but mine operations were subject to their provisions. State environmental protection laws, including some mining-specific laws, also began to emerge during this period.

Surface use regulations at 36 Code of Federal Regulations 228 Subpart A, governing mining operations on lands managed by the Forest Service, were promulgated in 1974. Additionally, operators are required to comply with all other Federal, State, and local laws and regulations and in the State of Arizona, must file a reclamation plan with the State mine inspector's office for mining activities on associated private lands

Paleontological Resource Laws

Fossils are classified as nonrenewable scientific resources and are protected by various laws, ordinances, regulations, and standards across the country. Professional standards for the assessment and mitigation of adverse impacts on paleontological resources have been established by the Society of Vertebrate Paleontology (1995; 1996). Federal protections for scientifically significant paleontological resources apply to projects if any construction or other related project impacts occur on federally owned or managed lands, involve the crossing of state lines, or are federally funded. Federal protections apply to scientifically significant paleontological resources on federally owned or

administered lands within the project area. Pertinent Federal laws, ordinances, regulations, and standards are summarized in the following sections.

Paleontological Resources Preservation Act

In March 2009, the Paleontological Resources Preservation Act was enacted as a result of the passage of the Omnibus Public Lands Management Act of 2009, Public Law 111-011, Title VI, Subtitle D, "Paleontological Resources Preservation." Under the Paleontological Resources Preservation Act, fossils from Federal lands are Federal property that must be preserved and protected using scientific principles and expertise. The Paleontological Resources Preservation Act provides the following:

- Uniform definitions for "paleontological resources" and "casual collecting"
- Uniform minimum requirements for paleontological resource-use permit issuance (terms, conditions, and qualifications of applicants)
- Uniform criminal and civil penalties for illegal sale and transport, theft, and vandalism of fossils from Federal lands
- Uniform requirements for curation of Federal fossils in approved repositories

The Paleontological Resources Preservation Act applies only to lands administered by the U.S. Department of the Interior (except tribal lands) and the National Forest System. Implementing regulations for this legislation are currently under development.

Federal Land Policy and Management Act

The Federal Land Policy and Management Act of 1976 (43 United States Code 1712(c), 1732(b)); Federal Land Policy and Management Act of 1962 (30 United States Code 611, Subpart 3631.0, et seq.), Federal Register 47(159), 1982, does not refer specifically to fossils. However, "significant fossils" are understood and recognized in policy as scientific resources. Permits that authorize the collection of significant fossils for scientific purposes are issued under the authority of the Federal Land Policy and Management Act.

American Antiquities Act of 1906 (6 United States Code 431–433)

The act establishes a penalty for disturbing or excavating any historic or prehistoric ruin or monument or object of antiquity on Federal lands as a maximum fine of $500 or 90 days in jail. The American Antiquities Act is pertinent to paleontological resources because "objects of antiquity" include fossils.

National Historic Preservation Act of 1966

The act (Public Law 89 665; 16 United States Code 470 et seq.) provides for the survey, recovery, and preservation of significant paleontological data when such data may be destroyed or lost as a result of a Federal, federally licensed, or federally funded project.

Title 43 Code of Federal Regulations

Under 43 Code of Federal Regulations 8365.1–5, the collection of scientific resources, including vertebrate fossils, is prohibited without a permit. Except where prohibited, individuals are also authorized to collect some invertebrate and plant fossils for their personal use. The use of fossils found on Federal lands for commercial purposes is also prohibited.

Coronado National Forest Land and Resource Management Plan

Under the management direction of the "Coronado National Forest Land and Resource Management Plan," as amended (forest plan) (U.S. Forest Service 1986:9), the following goal is set forth: "Preserve and protect caves for their unique environmental, biological, geological, hydrological, archaeological, paleontological, cultural and recreational values." No other mention of paleontological resources is identified in the forest plan.

Management direction is similarly limited with respect to mineral resources, as follows:

- To the extent possible, avoid construction of roads across sensitive soils and scenic lands. Prohibit the construction of roads across mountain meadows.
- Mining and leasing activities will be allowed within the framework of applicable laws and regulations, including environmental laws and regulations designed to mitigate the impacts of mining activities. Emphasis should be on gaining cooperation and control through the use of operating plans and bonds for rehabilitation to protect and restore surface resources.

Existing Conditions

Physiography

Arizona is divided into three geographic provinces, a division that is based on distinct geological and geographic characteristics. The three provinces were first reported by (Fenneman 1931:274, 326, 328, 381) and were more recently described by Titley and Zürcher (2008:275–276). The provinces are the Colorado Plateau, Transition Zone, and Basin and Range. The transitions between these provinces typically are gradational, both physiographically and geologically, although the transition from the Colorado Plateau of northern Arizona to the Transition Zone of central Arizona is a relatively pronounced change from high plateaus of relatively flat-lying Paleozoic through Cenozoic strata and volcanic flows to abrupt mountains and valleys of Proterozoic and younger rocks. The Transition Zone of central Arizona gradationally changes to the mountains and valleys of the Basin and Range of central, southern, and western Arizona, a region that contains sedimentary, igneous, and metamorphic rocks ranging in age from Proterozoic through Cenozoic.

The Basin and Range province of southern Arizona has been further divided into the Mexican Highlands and Sonoran Desert subprovinces. The Mexican Highlands area comprises southeastern Arizona and southwestern New Mexico. The topography there is characterized by average elevations and physiographic relief that are greater than those of the Sonoran Desert subprovince to the west (Hayes 1969:35). The Sonoran Desert subprovince is distinguished by extensive, largely undissected valleys separated by intermittent mountain ranges that cover less than one-fourth of the region (Hayes 1969:35, 36, 43, 440).

The project area is in the eastern part of the Sonoran Desert subprovince (Arizona Geological Society 2007:26), near the boundary with the Mexican Highlands. The project area is approximately 30 miles southeast of Tucson (Arizona Geological Society 2007:11) on the eastern slope of the Santa Rita Mountains, a range that separates the Cienega Basin to the east from the Santa Cruz Basin to the west. Elevations in the project area range from 4,600 feet to nearly 6,300 feet above mean sea level. Slope angles vary from less than 3 percent in drainage bottoms to more than 100 percent on the rock faces of some mountain fronts.

The proposed mining operation is located in the upper reaches of the Barrel Canyon drainage, which drains to the northeast. The main tributaries to Barrel Canyon are McCleary and Wasp Canyons.

Barrel Canyon drains approximately 4 miles northeastward to Davidson Canyon, which drains approximately 13 miles north-northeastward to Cienega Creek. Cienega Creek, in turn, is one of two main drainages in the Cienega Basin. These drainages flow intermittently.

Regional Geology

The oldest, or "basement," rocks in Arizona are Proterozoic in age. These units are overlain by thick sequences (as much as 1.2 to 2.4 miles) of Paleozoic-, Mesozoic-, and Cenozoic-age (Phanerozoic) sedimentary and volcanic rocks. Titley (1995:7) describes the regional Phanerozoic cover as "consisting of Paleozoic [continental] platform strata and a variable thickness of Mesozoic clastic and volcanic rocks." The Paleozoic-Mesozoic transition was a period of uplift and erosion. Mesozoic igneous stocks intruded into the Proterozoic through Mesozoic-age formations. Cenozoic dikes and volcanic rocks crosscut older formations throughout Arizona.

Three important periods of tectonic activity affected the modern landscape of southern Arizona, including the Rosemont area, as follows: (1) the Laramide Orogeny (mountain-building event), approximately 80 million to 45 million years ago; (2) the mid-Tertiary Orogeny, approximately 25 million to 16 million years ago; and (3) the Basin and Range Orogeny, which lasted until about 5 million years ago (Armstrong and Ward 1991)13.209 to 13.210). The Laramide Orogeny was a time of regional volcanic and intrusive activity, with complex folding and thrust faulting. Large, disseminated copper deposits in central and southern Arizona were emplaced with the intrusion of granitic rocks during the Laramide Orogeny. Tertiary extension of the crust produced high-angle faulting that characterized the Basin and Range orogenic phase. The crustal extension was accompanied by volcanism. The steeply dipping, mountain range bounding faults formed the valleys and mountains of the Basin and Range province seen today. Although major tectonic activity ceased in this region about 5 million years ago (Menges and Pearthree 1989:675), deposition and erosion of landforms, as well as limited earthquake and fault activity, continue to the present time. The largest magnitude earthquake of Quaternary age in the region occurred along the 32-mile-long Santa Rita fault, located on the western flank of the Santa Rita Mountains. This earthquake was estimated by the Arizona Geological Survey (Pearthree and Calvo 1987:1) to have been of magnitude 6.4 to 7.3 and to have occurred between 60,000 and 100,000 years ago. In southeastern Arizona, late Quaternary faults such as the Santa Rita fault are reported by Pearthree and Calvo (1987:1) to have extremely long repeat intervals between displacement events and reactivation of faulting after a period of inactivity.

Mineralization episodes are spatially and temporally diverse across Arizona. Titley and Zürcher (2008:275) consider the following mineralizing episodes to be the most important: Paleoproterozoic (approximately 2,500 to 1,600 million years ago), Jurassic (201 to 145 million years ago), late Cretaceous to early Tertiary (Laramide, approximately 80 to 45 million years ago), and middle to late Tertiary. Laramide porphyry deposits in the region extend from Bagdad and Mineral Park in northwestern Arizona southeastward to Cananea in Sonora, Mexico. This regional cluster of deposits is part of the larger, extensive belt of porphyry copper deposits that is traced through the Cordillera of North and South America. The Rosemont deposit is one of more than 35 significant porphyry copper deposits formed in southeastern Arizona and adjacent areas during Laramide time.

Rosemont Claim History

The core of the project area consists of 132 patented lode claims totaling 1,968 acres. Surrounding the patented lode claims is a contiguous group of 850 unpatented lode mining claims totaling approximately 12,000 acres. Rosemont Copper also owns 911 acres of private fee land in the area.

Most of the unpatented claims were staked on Federal land now administered by the Coronado, but a limited number of claims in the northwestern portion of the property are on Federal land administered by the Bureau of Land Management.

The first patented Rosemont claims date from 1898 and predate Arizona Statehood and the designation of the Coronado National Forest by the U.S. Congress. The most recent claims were patented in the 1990s. All private land and unpatented mining claims described above are owned and/or controlled by Augusta Resource Corporation (Augusta Resource).

Rosemont Deposit Geology

The Rosemont deposit is located in the Helvetia and Rosemont mining districts in the northern Santa Rita Mountains. Adjacent mining districts include the Empire, Greaterville, Old Baldy, and Pima districts. Farther south, in the Patagonia Mountains, are the Harshaw and Patagonia districts. The first significant study of mineral deposits and geology of the region is by Schrader (1915:78). That investigation is a detailed analysis of the presence of gold, silver, copper, lead, zinc, tungsten, and molybdenum in fissure veins and replacement or contact-metamorphic deposits and contains a detailed geological map of the area. Starting in the 1950s, work in the area began to describe larger, disseminated deposits such as the Rosemont ore deposit through an extensive drilling program. The Rosemont ore deposit was identified as a major porphyry copper deposit in 1963. Drilling continued sporadically over the next four decades, culminating in the most recent drilling programs, conducted by Augusta Resource from 2005 through 2008 (Rose 2008:26-27).

A geological map showing the rock formations of the project area is shown in figure 20. Figure 21 depicts an east-west geological cross section, showing the surface and subsurface rock formations in the area of the proposed open pit and dry-stack tailings. The geology of the Rosemont area is described at regional and local scales by Schrader (1915:44), Drewes (1971:C1; 1972a:4–6; 1972b: 1–2), Hardy (1997:44–71), Ferguson et al. (2001:6–29), Johnson and Ferguson (2007), Ferguson (2009), and Ferguson et al. (2009). Geological mapping for the area is ongoing and is constantly being revised. Not all units discussed in this section are represented on figures 20 and 21. In particular, several units important to paleontological investigations and discussed later in this section were not mapped at the scale shown in figures 20 and 21.

The Rosemont area contains a sequence of Proterozoic intrusive rocks overlain by Paleozoic carbonate rocks, quartz sandstone, siltstone, Mesozoic sedimentary and igneous rocks, and Cenozoic basin-fill formations and igneous rocks. The bedrock units are crosscut by andesite dikes and quartz monzonite dikes and stocks; mafic lava flows are found in selected basin-fill units. The stratigraphic sequence that hosts the Rosemont deposit includes, from oldest to youngest, the Bolsa Quartzite and Abrigo Limestone (both of Cambrian age); Devonian Martin Formation; Mississippian Escabrosa Limestone; Pennsylvanian Horquilla Limestone; Earp Formation (Pennsylvanian to Permian age); Colina Limestone, Epitaph Formation, and Scherrer Formation (all of Permian age); Upper Jurassic-Lower Cretaceous Glance Conglomerate; and Lower Cretaceous Willow Canyon Formation.

The Horquilla Limestone is the most significant host rock, accounting for almost half of the sulfide mineralization. Significant mineralization also occurs in the Earp Formation and Colina Limestone, and minor mineralization occurs in the other Paleozoic units. The Mesozoic host rocks are the Willow Canyon Formation and the Glance Conglomerate, which are predominantly arkosic siltstone, sandstone, and conglomerate. The Willow Canyon Formation also includes mafic or andesitic flows, which host minor mineralization.

Mesozoic sedimentary rocks consist of continental and shallow marine conglomerate, sandstone, and siltstone units that overlie the older units. Some volcanic (andesitic) rocks are interbedded with the Mesozoic sedimentary sequence. A Lower Cretaceous andesite flow ranging in width from a few tens of feet to several hundred feet wide overlies siltstone of the Lower Cretaceous Willow Canyon Formation. Shale and laminated mudstone of the Lower Cretaceous Apache Canyon Formation and Upper Cretaceous Mt. Fagan Rhyolite and Rhyolite megabreccia (ash-flow tuff) overlie the Willow Canyon Formation.

Cenozoic rock units include consolidated and unconsolidated (loose) conglomerate, colluvium, talus debris, and alluvium. Conglomerates are composed of clay- to boulder-sized grains eroded from older rocks that are at the surface nearby at the time at which the conglomerate is deposited. The Gila Conglomerate ranges in age from Pliocene to Miocene (Johnson and Ferguson 2007), and the thickness varies locally. This unit contains a wide range of clasts, ranging from granite rocks, quartzite, carbonate, argillite, and rhyolite. The matrix contains calcite and is notably alkaline, similar to contemporary soils in the adjacent basins.

Igneous rocks in the Santa Rita Mountains are of Proterozoic, Jurassic, and late Cretaceous/ early Tertiary (Laramide Orogeny) age. Proterozoic granitic rocks are on the crest of the Santa Rita Mountains and down the western slope in the Rosemont-Helvetia area. Mapped rock types include granite, quartz diorite, quartz monzonite, and associated aplite. Small, Laramide intrusions (stocks) of quartz monzonite and quartz latite occur in the project area, and larger stocks of similar composition occur to the north at Broadtop Butte and west in the Helvetia area.

Descriptions of the principal units found in the Rosemont deposit area and the approximate thicknesses of the units are presented below and are based on information compiled by Johnson and Ferguson (2007) and on descriptions of Rosemont drill core (Arizona Geological Society 2007: 39–41).

Proterozoic Era

Quartz monzonite (Early or Middle Proterozoic, unmeasured thickness) Medium-grained, quartz monzonite granite with 15 to 20 percent altered dark minerals (Johnson and Ferguson 2007).

Paleozoic Era

Cambrian Period

Bolsa Quartzite (Cambrian, 260–570 feet): Light gray, medium- to fine-grained, thick- to medium-bedded, quartzose sandstone that forms cliffs and ledges. The lower part is cross stratified, commonly coarse grained, and locally feldspathic, with composition apparently ranging from quartz arenite to subarkosic arenite. Pebbly to granular beds occur near the base of the unit, which unconformably overlies granitic basement. The upper part of the Bolsa Quartzite is medium gray, fine-grained, and commonly bioturbated with *Planolites* and *skolithos* ichnofossils (traces of ocean-bottom burrows) and includes as much as 30 percent siltstone and shale near the gradational contact with the overlying Abrigo Formation.

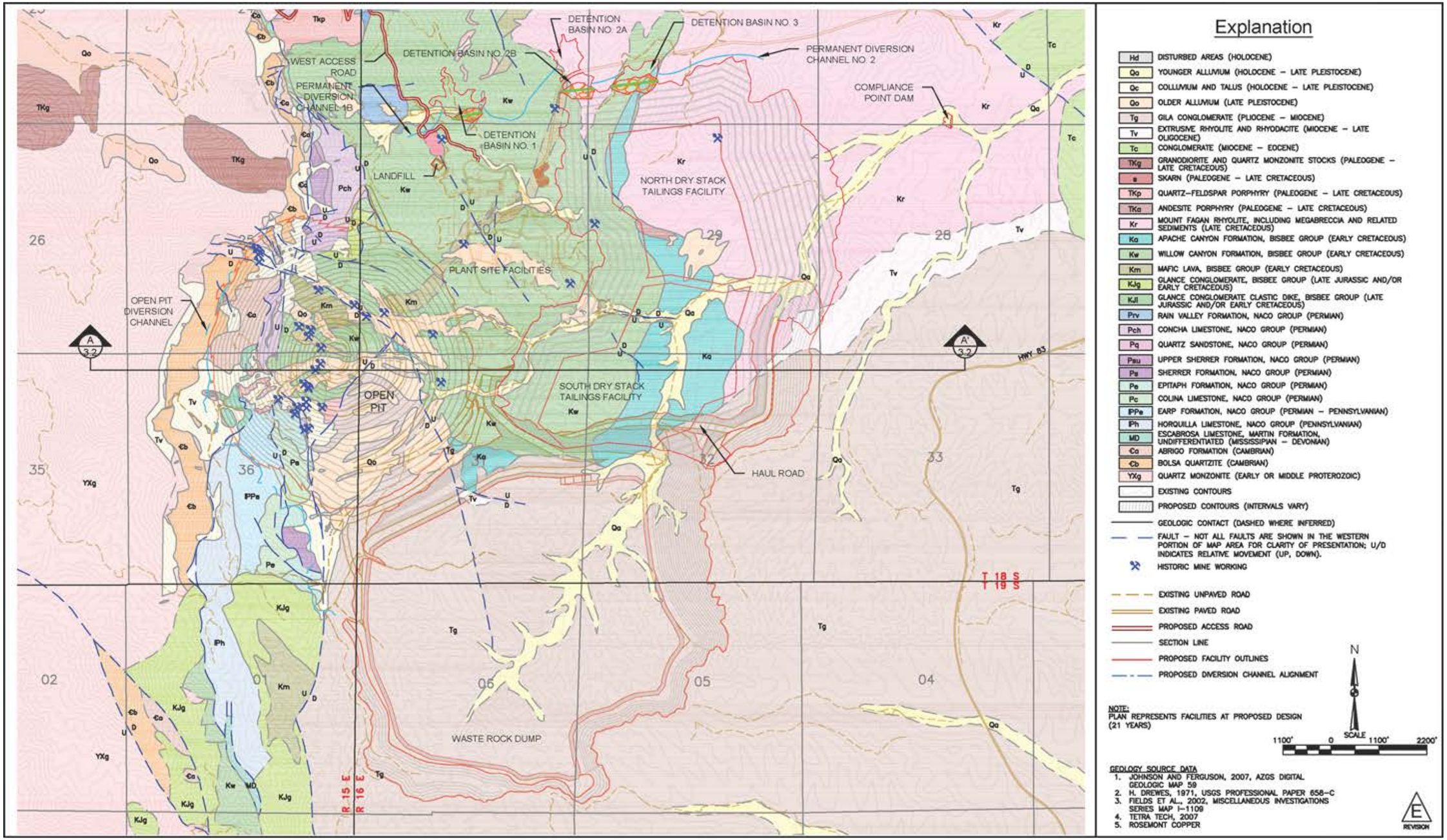


Figure 20. General geology of the project area. Adapted from Tetra Tech (2007a), Johnson and Ferguson (2007), and Drewes (1972a)

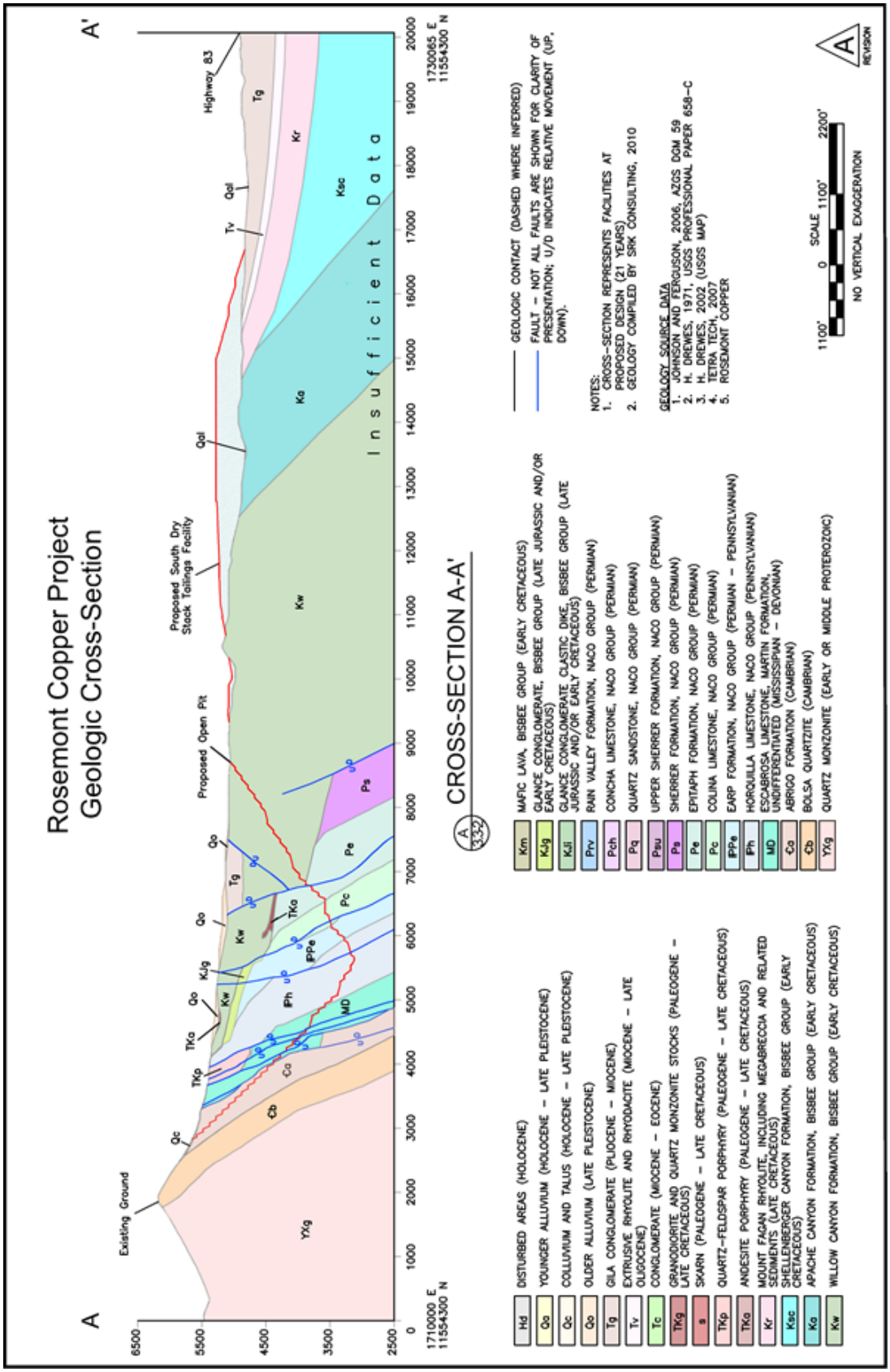


Figure 21. Geological cross section of the project area. Adapted from Tetra Tech (2007a), Johnson and Ferguson (2007), and Drewes (1972a)

Abrigo Formation (Cambrian, 330–660 feet): Thin- to medium-bedded limestone with laminae. The lower part contains intercalated fine-grained, parallel-laminated to ripple-laminated, fine-grained sandstone, siltstone, silty mudstone, and shale. Locally, the unit has partly been metamorphosed to light pinkish gray to greenish yellow, calc-silicate hornfels that form resistant outcrops with recessive, thin beds, lenses, and laminations.

Mississippian Period

Escabrosa Limestone–Martin Formation undifferentiated (Mississippian–Devonian, 230–560 feet): Light gray, medium- to thick-bedded, amalgamated, massive, locally cherty, recrystallized limestone. Massive dolostone or dolomitic limestone locally is present in the lower section. Although an unconformity is present between the Martin Formation and the Escabrosa Limestone, these units are not preserved well enough in this area to distinguish between them.

Pennsylvanian Period

Horquilla Limestone (Pennsylvanian, 660–980 feet): Light gray, thin- to thick-bedded, cherty limestone with interbeds of dark gray to green silty mudstone and shale that becomes more abundant higher in the section.**Permian Period**

Earp Formation (Permian–Pennsylvanian, 490–660 feet): A mixed siliciclastic-carbonate consisting of light, reddish brown to light green, thin- to medium-bedded, planar-laminated siltstone, silty mudstone, and very fine-grained sandstone that is intercalated with light gray to pinkish gray, thick-bedded, micritic limestone and skeletal wackestone. The siliciclastic components commonly are metamorphosed to light green or orange-pink hornfels.

Colina Limestone (Permian, 165–540 feet): A light gray to white, medium- to thick-bedded, amalgamated, commonly dolomitic, micritic carbonate and skeletal wackestone.

Epitaph Formation (Permian, 820–1,280 feet): A mixed siliciclastic-carbonate unit. The siliciclastic units are purple to reddish, thin- to medium-bedded siltstone and silty mudstone, and a fine-grained, laminated sandstone. These units commonly are metamorphosed to light, orange-pink or greenish hornfels. The carbonate units are light gray to pink, micritic carbonates.

Scherrer Formation (Permian, 1,080–1,610 feet): Generally light gray to pink, fine-grained, massive, quartzose sandstone with rare laminations. The upper portion locally is differentiated as a transitional interval consisting of cream-colored, medium-bedded, dolomicrite with poorly preserved siltstone and argillaceous carbonate rocks.

Concha Limestone (Permian, 660–820 feet): Light to medium gray, medium- to thick-bedded, massive to planar-laminated, amalgamated, cherty limestone. Chert nodules characteristically are wispy and poorly formed. Locally dolomitic, the limestone mostly is micritic but includes skeletal wackestone and possible packstone, which locally contain spiculite beds and brachiopod fragments.

Rain Valley Formation (Permian, 330 feet): Gray, medium- to thick-bedded limestone, intercalated with subordinate thin-bedded to laminated, locally ripple-laminated, fine-grained

sandstone and siltstone. The unit is generally present in the Santa Rita Mountains but is not found locally.

Mesozoic Era

Triassic–Jurassic Periods

Gardner Canyon Formation (Triassic–Jurassic, 0–400 feet): The Gardner Canyon Formation includes a diverse range of mudstone, sandstone, conglomerate, and limestone strata, with minor ash-flow tuff units (Ferguson 2009; Ferguson et al. 2001:27). The units are predominantly reddish, with minor amounts of green mudstone.

Cretaceous Period

Glance Conglomerate (Upper Jurassic and/or Lower Cretaceous, 0–980 feet): Massive- to very thick-bedded, clast-supported conglomerate containing pebbles, cobbles, and local boulders that reflect the composition of underlying Proterozoic through Permian rocks. The basal contact is an angular unconformity. Within the Rosemont area, the Glance is a clast-supported limestone conglomerate recrystallized to fine- to medium-grained marble.

Willow Canyon Formation (Lower Cretaceous, 7,200 feet):
A succession of medium- to coarse-grained, feldspathic sandstone (typically arkosic arenite) and argillaceous sandstone with some vuggy, silty mudstone. A distinctive interval of volcaniclastic pebble-cobble conglomerate is present near the middle of the unit, below a sequence of mafic lava flows. The conglomerate contains as much as 70 percent mafic and intermediate-composition, porphyritic, igneous clasts, including clasts of chert and quartzose sandstone. Sandstone throughout the formation is cross stratified to plane-bedded, typically medium to thick bedded. Weak to moderate propylitic alteration has been identified in the Willow Canyon Formation in the Rosemont area.

Apache Canyon Formation (Lower Cretaceous, 1,000–2,000 feet): Arkosic sandstone, mudstone, limestone, and rare pebbly sandstone. The Apache Canyon is dominated by mudstone and arkosic-lithic sandstone. It is distinguished by its signature lithology: dark, typically laminated, nonfossiliferous, fetid, micritic limestone. The limestone, making up as much as 50 percent of the formation, occurs in thin- to medium-bedded, rarely thick-bedded sequences of amalgamated laminated to thin-laminated black limestone interleaved with dark mudstone and shale. Rare, thin- to medium-bedded massive recrystallized limestone is also present. Sandstone occurs in thin- to thick-bedded units that display bed-scale cross-stratification, but also, and more commonly, graded beds, either massive or plane-bedded stratified. Ripple-laminated sequences are common in individual thin beds and laminae, and as gradational tops to the graded beds. The mudstone, which dominates the formation, occurs in sets that range up to 35 feet thick. The mudstone is also mostly shale or claystone with sparse thin-bedded to laminated siltstone.

Shellenburger Formation, upper part (Lower Cretaceous, 1,500 feet): Arkosic sandstone, mudstone, and rare pebbly sandstone. Sandstone is thin- to thick-bedded, typically massive or weakly plane-bedded or cross-stratified and argillaceous, arkosic. Sandstone also occurs in fairly thick, ripple-laminated beds. Mudstone, making up slightly more than one-half of the formation, is almost exclusively dark olive green. The unit includes a distinctive type of massive, fine- to medium-grained, spotted argillaceous sandstone. The spots, making up as

much as 30 percent, are diffuse, evenly spaced, and range in size from 0.5 to 2 millimeters. The lower part includes locally abundant, irregular carbonate nodules that weather out of mudstone units. Mudstone is mostly silty, with relatively sparse pure shale or claystone intervals.

Shellenburger Formation, lower part (Lower Cretaceous, 1,000 feet): Arkosic sandstone and mudstone capped by the Mural limestone. The limestone, less than 20 feet thick, is a distinctive oyster packstone that defines the top of this unit. Sandstone is fine- to medium-grained, arkosic to lithic, and argillaceous. The sandstone is medium-bedded with diffuse, low-angle cross-strata. Mudstone intervals include abundant siltstone, and pure shale or claystone is rare.

Turney Ranch Formation (Lower Cretaceous, 3,280 feet): Alternating layers of sandstone and mudstone that range from 16 to 160 feet thick and typically are reddish in color (Ferguson 2009; Ferguson et al. 2001:11). The sandstone commonly is cross stratified, and the sandstone units generally are fractured (Ferguson et al. 2009:27).

Andesite lava (Upper Cretaceous, 0-800 feet): Andesite lava containing less than 15 percent phenocrysts (<3 millimeters) of plagioclase and lesser altered mafics (probably olivine and pyroxene).

Fort Crittenden Formation (Upper Cretaceous, 0–1,000 feet thick): Pebble-cobble-sparse boulder conglomerate, pebbly sandstone, and lesser siltstone and mudstone. Clasts are mostly derived from the underlying Bisbee Group but also locally include abundant volcanic. Mudstone-rich parts of the formation have recently yielded dinosaur fossils in the Cienega basin near an ash layer that has recently yielded a U-Pb zircon date of 69 million years (Ferguson 2011).

Mount Fagan Rhyolite (Upper Cretaceous, at least 5,000 feet): Rhyolite ash-flow tuff containing 20 to 35 percent phenocrysts (1 to 4 millimeters) of K-feldspar, plagioclase, quartz, and biotite. The unit is typically strongly welded, but is also poorly welded in many areas, particularly in the vicinity of megabreccia blocks and megabreccia avalanche breccias contained within it. Two U-Pb zircon ages of 73 million years have been obtained recently from the rhyolite just northeast of the Rosemont area (Ferguson 2011).

Mount Fagan Rhyolite megabreccia (Upper Cretaceous): Blocks and avalance breccia blocks contained within the Mount Fagan Rhyolite. Blocks, ranging in size from 1 to 1,000 meters, consist mostly of fractured blocks of the Bisbee Group, Fort Crittenden Formation, and andesite lava. Some blocks have been confused for intact stratigraphic sections of Tertiary conglomerate, but contact relationships show this to be incorrect (Ferguson 2009). Blocks of Fort Crittenden Formation conglomerate within the Mount Fagan Rhyolite east of State Route 83 in the Empire Mountains, and in the 73-million-year old Cat Mountain Rhyolite of the Tucson Mountains (which is probably correlative to the Mount Fagan Rhyolite), have both yielded Upper Cretaceous *hadrosaur* skeletons.

Cenozoic Era

Tertiary Period (including units spanning Late Cretaceous–Early Tertiary age)

Andesite porphyry (Paleogene–Upper Cretaceous, unmeasured thickness): Strongly altered, fragmental, fine-grained plagioclase porphyritic andesite or intrusive porphyry. Elliptical outcrops are located along the margin of the Mount Fagan caldera.

Quartz-feldspar porphyry (Paleogene–Upper Cretaceous, unmeasured thickness): Light gray to pink felsic porphyry dikes and stocks containing 8 to 15 percent phenocrysts of quartz, and as much as 25 percent feldspar and 1 to 2 percent biotite.

Skarn (Paleogene–Upper Cretaceous, >655 feet): Metasomatic alteration (influx of hydrothermal solutions rich in silica, aluminum, iron, and magnesium) and replacement of carbonate units, producing calc-silicate rocks and hornfels in association with sulfide and oxide copper mineralization. Skarn contains gangue minerals characterized by intense iron-oxide and local clay alteration; synonymous with the term tactite.

Gila Conglomerate (Pliocene?–Miocene, >655 feet): Light brown, medium- to thick-bedded, conglomerate, pebbly sandstone, and sandstone with a calcareous matrix. The clasts are subangular to rounded, and consist of granitic rocks, quartzite, limestone, argillite, and rhyolite ash-flow tuff. The abundance of clasts varies, depending on the composition of nearby upslope areas.

Quaternary Period

Older Alluvium (Late Pleistocene, 13–40 feet): Weakly consolidated gravel terraces consisting of medium- to thick-bedded, sandy, pebble-cobble gravel with rare boulders, derived from upslope or upstream units. Granitoid clasts are absent in the upper Pleistocene terrace gravels, so this is an important diagnostic characteristic of the Gila Conglomerate. The deposits are generally incised between 13 and 40 feet, locally forming cliffs and ledges as much as 10 feet high.

Colluvium and Talus (Holocene–Late Pleistocene, variable, unmeasured thickness): Unconsolidated deposits and debris consisting of subangular to angular pebbles, cobbles, and boulders derived from upslope units.

Younger Alluvium (Holocene–Late Pleistocene, 0–10 feet): Alluvium deposited in streams and washes that are actively being incised, generally less than 10 feet deep, locally vegetated.

Folding and faulting occurred in several intervals of geological time. Most host rocks at Rosemont dip steeply (approximately 55 to 65 degrees) to the east. The principal faults in the area include the nearly horizontal Flat fault and the younger north-striking Backbone fault system. The Flat fault places mostly Mesozoic sedimentary rocks over the older Paleozoic units. The postmineral Backbone fault system defines the western boundary of the ore deposit and separates the mineralized, Paleozoic limestone units on the east from the Proterozoic granodiorite and lower Paleozoic quartzite on the west. No evidence exists in the deposit area of recent fault activity that cross cuts Quaternary or Holocene talus, colluvium, alluvial fan or terrace gravels; these alluvial formations typically mask the underlying, older fault contacts where faults are present (Ferguson et al. 2009).

The Rosemont deposit primarily is a garnet-diopside skarn (of the type that formed in Paleozoic sedimentary rocks of Cambrian, Devonian, Mississippian, Pennsylvanian, and Permian age elsewhere in Arizona and the western United States. The deposit formed in response to emplacement of quartz latite to quartz monzonite stocks approximately 56 million years ago during the Laramide Orogeny. Marble was formed from the more pure carbonate rock types, while the more siliceous, silty rocks were altered to hornfels.

The Flat fault separates the upper, weakly mineralized oxide zone from the underlying, strongly mineralized, sulfide zone. Oxidized and supergene copper mineralization above the Flat fault appear to be well developed in the Mesozoic-age andesitic rocks (Huss 2009:27-28).

Mineralization from the Laramide Orogeny is typically associated with intrusions of granite-like rocks, although it also occurs less frequently in adjacent, older sedimentary rocks. Unlike most other porphyry copper deposits in the area, the Rosemont mineralization occurred primarily in metamorphosed limestone (skarn) and other sedimentary rocks rather than in a granitic or related intrusive rock. Most of the oxide mineralization occurs in the Mesozoic sedimentary and volcanic rocks.

Paleontology

Paleontological resources, or fossils, are the remains, imprints, or traces of once-living organisms preserved in rocks and sediments. These include mineralized, partially mineralized, or unmineralized bones and teeth, soft tissues, shells, wood, leaf impressions, footprints, burrows, and microscopic remains. The project area contains geological units (formations and members thereof) that are known in other areas of Southern Arizona to contain scientifically significant paleontological resources.

Fossil bearing sedimentary rocks in southeastern Arizona contain an array of various ages and types of vertebrate, invertebrate, and plant fossils. Mesozoic rock units near the project area have yielded marine invertebrates, as well as dinosaurs and other terrestrial vertebrates. Fossils have also been identified in Neogene surficial sedimentary deposits such as the Gila Conglomerate, and unnamed Pliocene and Pleistocene lacustrine and alluvial deposits close to the project area.

The sedimentary bedrock geological formations and overlying surficial sedimentary deposits that occur within the perimeter fence of the project area are listed in table 10. It should be noted that the geological data analyzed were derived from published mapping by Johnson and Ferguson (2007), Ferguson et al. (2009), and Ferguson (2009). The paleontological sensitivity of each geological unit within the project area was ranked according to the Potential Fossil Yield Classification (Bureau of Land Management 2007b). The Potential Fossil Yield Classification designations were assigned by the authors of the “Paleontological Resource Survey Report” (available in the project record), based on the results of the literature and records reviews and subsequent field survey. These classifications were concurred with by the Forest Service.

Table 10. Summarized geology, age, potential paleontological content, and paleontological sensitivity of the project area using the Potential Fossil Yield Classification system

Geological Unit	Map Symbol	Age	Typical Fossils	Potential Fossil Yield Classification
Disturbed areas	d	Holocene	No in situ fossils in deposits of Holocene age	Class 2 (Low)
Younger surficial sedimentary deposits	Qy2, Qa, Qtc, Qyc	Holocene	No in situ fossils in deposits of Holocene age	Class 2 (Low)
Older surficial sedimentary deposits	Qoa, Qi3, Qi2	Late Pleistocene–Holocene	Vertebrates, invertebrates, and plants	Class 3a (Moderate)
Gila Conglomerate	Tc	Pliocene–Miocene	Mammals, freshwater invertebrates, microfossils, petrified wood	Class 3b (Unknown)
Megabreccia, Mesobreccia	Krz, Kra	Late Cretaceous	Hadrosaur found in Empire Mountains in megabreccia block of Fort Crittenden Formation	Class 3b (Unknown)
Fort Crittenden Formation	Kfc	Late Cretaceous	Dinosaurs, fish, amphibians, reptiles	Class 3a (Moderate)
Bisbee Group				
Turney Ranch Formation	Kt	Late Cretaceous	Dinosaurs, turtles, fish, invertebrates, plants	Class 3a (Moderate)
Apache Canyon Formation	Ka	Early Cretaceous	Possible terrestrial vertebrates in some facies	Class 3b (Unknown)
Shellenberger Canyon Formation	Ks	Lower Cretaceous	Dinosaurs, turtles, reptiles, fish, invertebrates, crocodilians, petrified wood	Class 3a (Moderate)
Willow Canyon Formation	Kw	Lower Cretaceous	None reported	Class 2 (Low)
Glance Conglomerate	Kjg	Upper Jurassic or Lower Cretaceous	Sparse marine invertebrates in limestone clasts	Class 3a (Moderate)
Gardner Canyon Formation		Late Triassic–Early Jurassic	Poorly preserved plants; crocodilians, tritylodont (mammal-like reptile)	Class 3a (Moderate)
Naco Group				
Rain Valley Formation	Pr	Permian	Locally common marine invertebrates	Class 3a (Moderate)
Concha Limestone	Pch	Permian	Locally common marine invertebrates	Class 3a (Moderate)
Scherrer Formation		Permian	Sparse marine invertebrates	Class 3a (Moderate)
Epitaph Formation	Pe	Permian	Marine invertebrates	Class 3a (Moderate)
Colina Limestone	Pc	Pennsylvanian	Sparse marine invertebrates	Class 3a (Moderate)
Earp Formation	PPe	Pennsylvanian–Permian	Diverse marine invertebrates	Class 3a (Moderate)
Horquilla Limestone		Pennsylvanian	Chaetitid corals locally abundant	Class 3a (Moderate)
Escabrosa Limestone	MDu	Mississippian	Marine invertebrates and uncommon vertebrates	Class 3a (Moderate)

Geological Unit	Map Symbol	Age	Typical Fossils	Potential Fossil Yield Classification
Martin Formation	Dm	Devonian	Marine vertebrates (mostly placoderms), conodonts, diverse invertebrates	Class 3a (Moderate)
Abrigo Formation	Ca	Late Cambrian	None reported	Class 1 (Very low)
Bolsa Quartzite	Cb	Cambrian	Ichnofossils (*Planolites*)	Class 2 (Low)

Previously recorded fossil localities occur approximately 3 miles away in the Gardner Canyon Formation and approximately 1 mile away in the Shellenberger Canyon Formation.
The Shellenberger Canyon Formation has yielded fossil remains from dinosaur, crocodile, and turtle, as well as bivalves. A fossil locality in the Fort Crittenden Formation in the southeastern Santa Rita Mountains has also produced dinosaurs, crocodiles, a few different types of turtles, and invertebrates. At least one Late Pleistocene fossil locality has also been reported within a few miles of the project area. That site has produced camel, mastodon, horse, bison, and other mammals (Huckell 1980; U.S. Forest Service 2011b). Numerous invertebrate fossil localities have been found in the Escabrosa Limestone, Epitaph Formation, Scherrer Formation, Concha Limestone, and Rain Valley Formation within the project area and to the north, northwest, and southwest. No significant fossil localities were discovered within the proposed perimeter fence boundary during the paleontological resources field surveys conducted in March 2011.

Waste and Ore Classification

Waste rock is typically defined as rock material overlying an ore deposit or within a mine plan that is below the cutoff grade required for economic extraction and processing. The waste rock is removed to access the ore materials and requires disposal in an overburden pile or waste rock disposal facility. Cutoff grades may decrease or increase throughout the mine life owing to fluctuations in capital and operating costs, processing recovery effectiveness and efficiencies, commodity prices, or other reasons. The “NI 43-101 Technical Report for the Rosemont Copper Project, Updated Feasibility Study” (Huss 2009:5) reports that sulfide waste material at Rosemont falls below a grade of 0.20 percent total copper. Oxide waste is reported to be material with a grade below 0.10 percent total copper.

The percentages of rock types forming potential waste materials at Rosemont are tabulated in Tetra Tech (2007b:Table 3.1). The percentage of waste relative to ore has decreased in recent years, as additional mineralized material has been delineated through drilling, geological mapping, and other mineral exploration and development activities. More than one-half of the waste materials consist of weathered (oxidized) and fresh (unoxidized) arkose and other oxidized units in the Willow Canyon Formation. Andesite and various Paleozoic formations constitute the remaining waste rock materials.

Ore is defined as the portion of a mineral deposit that can be economically extracted and processed for the metals of interest it contains. The Rosemont ore deposit contains copper, molybdenum, silver, and gold mineralization primarily in Paleozoic limestone units that were metamorphosed to skarn by intrusion of the Laramide quartz monzonite porphyry stocks. Extensive drilling has identified mineralization to a depth of at least 2,000 feet below the surface (Huss 2009:27). The degree (concentration) of mineralization diminishes to the south; it appears to extend northward amid complex faulting and eastward beneath an increasingly thick Mesozoic cover, as observed in drill cores.

The copper sulfide-bearing materials in potentially economic concentrations consist primarily of Horquilla Limestone (50 percent), Colina Limestone (40 percent), quartz monzonite porphyry (5 percent), and the Earp Formation (5 percent) (Vector Arizona 2006:Table 2). The sulfide ore will be processed through milling, flotation, and concentration processes, with metal-bearing concentrates being shipped off-site for smelting, and the residual material being disposed of as dry-stack tailings. The copper oxide bearing host rocks in potentially economic concentrations consist primarily of Willow Canyon arkose (50 percent), quartz monzonite porphyry (15 percent), and quartz latite porphyry and andesite (35 percent). The copper oxide ore will be processed by extraction with dilute sulfuric acid on a heap leach facility and recovered in a solvent extraction and electrowinning plant that will produce nearly pure (99 percent or more) copper cathodes.

Mineralization occurs primarily in the form of copper sulfide minerals—principally copper sulfides like chalcopyrite, chalcocite, and bornite—and also molybdenite, which is a molybdenum sulfide mineral. These minerals occur as veinlets and disseminations in the Paleozoic, garnet-diopside skarn, and associated marble and hornfels. The sulfide minerals are accompanied by quartz, amphibole, serpentine, and chlorite alteration. Silver is minor but economically important. Silver mineralization is associated with the primary copper mineralization in the Paleozoic rocks. Trace amounts of gold are anticipated to be recovered; however, anticipated recovery rates are not expected to be significant.

Copper oxide mineralization results from weathering of the primary copper sulfide minerals. The oxide mineralization occurs in the upper part of the ore deposit. Copper oxide mineralization primarily includes copper-bearing limonite, chrysocolla, tenorite, malachite, and azurite. Minor amounts of enriched chalcocite and associated native copper mineralization are found in and beneath the oxide mineralization.

Mineral Exploration and Mining History

Southeastern Arizona is a major copper-producing area. A roughly triangular area from northeast of Phoenix, east to Safford, and south to Bisbee contains a number of active and closed porphyry copper mines that have operated (or had operated, if closed) since the early 1900s. Ten mines are currently active in this area: the Quadra Carlota operation; the Freeport-McMoRan Miami, Safford, Morenci, and Sierrita operations; the BHP Billiton Miami and Pinto Valley operations; and the ASARCO Ray, Silver Bell, and Mission operations. The ASARCO Mission Mine is approximately 20 miles west of Rosemont and shares common geology and mineralization characteristics.

Mineral exploration in the Santa Rita Mountains dates from the mid-1800s. By 1880, small underground mines and smelters had been established in the area. The Helvetia and Rosemont mining districts, located on the west and east flanks, respectively, of the northern Santa Rita Mountains, were established in 1880. By the time most production had ceased in 1951, the area had produced approximately 227,300 tons of ore containing 17.3 million pounds of copper, 1.1 million pounds of zinc, and 181,000 ounces of silver. The locations of known historic mine workings in relation to the proposed Rosemont facilities are illustrated in figure 20.

Although most production ceased in 1951, the Narragansett Mine, a mine with copper, silver, zinc, lead, gold mineralization, continued to operate until 1961. It produced more than 90,000 tons of ore materials averaging more than 4 percent copper and 0.5 ounce of silver per ton (Mindat 2010a). Mineral exploration continued in the northern Santa Rita Mountains to the present, with most exploration targeting much larger, more disseminated ore deposits than those that were mined historically.

Banner Mining Company, which had acquired most of the claims in the area by the late 1950s, drilled the discovery hole into the Rosemont deposit. Anaconda Mining Company acquired the property in 1963 and carried out an extensive exploration program that identified Rosemont as a major porphyry copper deposit. In 1973, Anaconda joined with AMAX, forming the ANAMAX partnership. The partnership lasted until 1986, when Anaconda was dissolved, at which time the Rosemont and Peach-Elgin properties were sold to a real estate company. ASARCO purchased the property in 1988, began engineering studies on the Rosemont property and drilled 12 diamond drill holes. In 2004, ASARCO sold the entire property to real estate interests. In 2005, Augusta Resource acquired the Rosemont property, continued delineation of the Rosemont deposit through sampling and drilling, and in 2007 submitted a preliminary mine plan of operations (MPO) (WestLand Resources Inc. 2007a) to the Forest Service.

Other Mining Activity

There is no significant metal mining in the immediate vicinity of the proposed project or in the Cienega Basin to the east of the Santa Rita Mountains. Major metal mining activity, primarily copper and molybdenum, with lesser amounts of gold and silver, has occurred since the mid-1950s approximately 20 miles northwest of the project site in the Santa Cruz Basin. Three major porphyry copper/molybdenum operations are located on the east side of the Sierrita Mountains (on the west side of the Santa Cruz Basin), near the communities of Green Valley and Sahuarita. These include the Sierrita and Mission mines, which are active, and the currently closed Twin Buttes Mine. The San Xavier Mine, a smaller operation associated with the Mission Mine, is inactive. Exploration of other metal prospects occurs in the area when market conditions provide incentives.

The area also has produced limestone for industrial purposes, including high-grade calcium carbonate suitable for cement manufacturing and pharmaceutical use. The Imerys limestone quarry, located on the Coronado National Forest on the northwest side of the Santa Rita Mountains, is an active open-pit mine that occupies about 22 acres. Limestone mined from the quarry (calcium carbonate) is used for landscaping, calcium supplements, paper filler and coating, paint and drywall filler, and various other products. The operation produces more than 217,000 tons of material per year. Mineralization has been reported as “contact metamorphism deposit of the Escabrosa Limestone altered to marble” (Mindat 2010b).

A new operation that will expand an existing limestone quarry has been proposed approximately 6 miles northeast of the Rosemont Copper Mine in the Davidson Canyon drainage. A second quarry is proposed on the east side of Davidson Wash. The quarry expansion and new quarry by CalPortland Cement are under review by Federal and State agencies.

The Andrada Marble Quarry (W.R. Henderson Arizona Properties) is located in Vail and is an active marble quarry currently operating on private land. The operator has a pending MPO filed with the Bureau of Land Management to mine Federal minerals on adjacent State Trust lands.

Geotechnical

Site Geotechnical Environment

The project area is generally characterized by two surficial conditions: (1) bedrock at or near the surface with a thin mantle of soil (except where it is thicker in drainage bottoms); and (2) bedrock covered with Cenozoic alluvial deposit, including the Gila Conglomerate (Tetra Tech 2009c). The bedrock is faulted and fractured, but there are no known active faults crossing the site. Rosemont

Copper has completed site-wide geotechnical investigations (Tetra Tech 2007a), the findings of which would be incorporated into the design of the project infrastructure.

Earthquakes (Seismicity)

Historic earthquake activity in Arizona has been documented by DuBois et al. (1982), while Quaternary faulting in the state has been mapped and reported by workers such as Menges and Pearthree (1983:18–33; 1989:649, 659, 666–669, 672–675), Pearthree and Calvo (1987:97–99, 107–114), and Pearthree et al. (1983:1–8, 12–30, 37–52).

The most notable seismic event felt in Arizona occurred in 1887 in Bavispe, Mexico, approximately 110 miles southeast of the project site. Ground shaking was felt as far north as Albuquerque, New Mexico. Structural damage from the earthquake was recorded in the Tucson area, including damage to the courtyard wall at the San Xavier Mission, southwest of town. The U.S. Geological Survey estimated the magnitude of this earthquake at 7.4 (Stover and Coffman 1993:62). The largest earthquake to occur within Arizona in historic times happened on July 21, 1959, along the Arizona-Utah border. The U.S. Geological Survey reported the magnitude of that earthquake as 5.6.
The magnitude of the earthquake that formed the Quaternary-age Santa Rita fault on the western flanks of the Santa Rita Mountains is estimated to have been between 6.4 and 7.3 (Pearthree and Calvo 1987:1). The maximum earthquake recorded by the U.S. Geological Survey in the immediate project area was magnitude 4.5.

Although no earthquake in recorded history has caused deaths or injuries in Arizona, potentially active faults in the Basin and Range province and the Transition Zone can occasionally generate significant earthquakes of moderate intensity, with a possibility of serious damage over a wide area. Tetra Tech (2007a) completed a regional seismological assessment for the project, and the results indicate that five faults within an approximately 60-mile radius of the project site were active in historic times and that an additional 22 faults within a 125-mile target radius have been active in historic times. All of the potentially active faults in the Phoenix and Tucson areas have low slip rates and long intervals between ruptures and have had little historic activity. Because of this, the Arizona Geological Survey places these areas in the low to moderate hazard category.

Arizona Department of Environmental Quality (2004) regulations require the development of two seismic design values for incorporation in mine facility design. Seismic design values are expressed as peak ground acceleration at the site relative to the earth's gravity.

- Maximum Probable Earthquake – Earthquake with an 80 percent probability of not being exceeded in 100 years or the largest historical earthquake, whichever is greater. This design value is to be used for structures with a relatively short design life (e.g., 10 years) and minimum potential threat to human life or environment. At the project area, these facilities include the heap leach pads, non-jurisdictional ponds, and other short-lived facilities.
- Maximum Credible Earthquake – The maximum earthquake that appears possible under the presently known tectonic framework. This design value is to be used where human life is potentially threatened. This value will be used in the design of the waste rock storage area and the dry-stack tailings facility.

Tetra Tech (2007a) completed a regional seismological assessment, resulting in the following findings relative to the project area:

- The peak ground acceleration for a maximum probable earthquake for an earthquake with an 80 percent probability of not being exceeded in 100 years is 0.045 g (where g is the acceleration due to gravity equaling 32 feet per second squared).
- The peak ground acceleration for a maximum probable earthquake for the largest historical earthquake (Bavispe, Mexico, 1887) is 0.036 g. Therefore, the maximum probable earthquake seismic design value for the project area is a peak ground acceleration of 0.045 g, which is the greater of the two values.
- The peak ground acceleration for the maximum credible earthquake for the Santa Rita fault zone located 6.9 miles from the project site is 0.328 g. This fault zone is Quaternary in age and has a length of 32.3 miles. The value of 0.328 g was therefore selected as the relevant maximum credible earthquake seismic design value for the project area.

Subsidence

Land subsidence is the lowering of the land surface resulting from changes that take place underground. The most common causes of land subsidence from human activity are pumping groundwater, oil, and gas from underground reservoirs and collapse of an underground mine. A common cause of subsidence from natural causes is dissolution of limestone by groundwater, which results in sinkholes, caves, and other karst features. Assessment of geological hazards in the project area indicates little risk of subsidence from historic mining operations or karst features (Tetra Tech 2007b:16). Land subsidence associated with groundwater withdrawal is described in the "Groundwater Quantity" section.

Other Geological Resources

Caves

Moderately extensive cave systems are common in southern Arizona, particularly in the Paleozoic limestone formations that occur in the region. Two caves of commercial and scientific importance are Kartchner Caverns State Park near Benson and Colossal Cave Mountain Park near Tucson. Kartchner Caverns is a wet cave and a developed state park that is located within the limestone hills at the base of the Whetstone Mountains (Hill 1999). The park is approximately 23 miles due east of the project area.

Colossal Cave, located in a privately owned park, is a dry cave in the Rincon Mountains approximately 17 miles north-northeast of the project area. This cave formed in a structurally complex block of deformed limestone—notably the Escabrosa Limestone (Peachey 2000).

Two caves, Cave of the Bells and Onyx Cave, both wet caves, are in the eastern slopes of the Santa Rita Mountains. Cave of the Bells is in Sawmill Canyon, approximately 7 miles south of the project area. The cave is about 0.25 mile long. It has many passages and 60-foot-tall vertical passageways that are developed in a complex stratigraphic sequence of Permian carbonate units, including the Colina Limestone, Epitaph Formation, and Concha Limestone. Onyx Cave is approximately 8 miles south of the Rosemont site. Onyx Cave is about 0.5 mile long, with a series of passageways and rooms that intersect primarily the Permian Rain Valley Formation and possibly the Colina Limestone.

No known caves are located within the immediate project area. Rosemont Copper has stated that no indication of caves or open spaces was found in the project drill cores and that the calc-silication that occurred during the hydrothermal mineralization event significantly changed the original limestone rock composition, making them unlikely hosts for subsequent cave formation (Cornoyer 2011).

However, caves have been found in the historic underground mines of the Bisbee/Warren mining district in southeastern Arizona. Caves were not encountered during drilling activities; however, the Coronado has not determined that drilling density would necessarily have been adequate to identify cave resources. The proposed activities will impact Paleozoic limestone units, and the potential for caves or karst features cannot be ruled out based on existing information. Furthermore, surface surveying in the project area has yielded float that appears to be cave or possibly spring deposits. Springs in limestone are an indicator of potential karst (cave) geology.

Environmental Consequences

Direct and Indirect Effects of Each Alternative

No Action Alternative

Under the no action alternative, no new impacts on geology, minerals, or paleontological resources would occur.

Impacts Common to All Action Alternatives

All impacts to geology and mineral resources are the same for all action alternatives, other than those described for specific alternatives later in this section.

Impacts to geology and mineral resources are associated with the excavation and relocation of geological materials from the mine pit and are related to mineral processing and mine waste disposal. In addition, there is a potential land subsidence impact related to the mine water supply withdrawal in the Santa Cruz Valley. All impacts are common to all action alternatives.

The mining operation would excavate and relocate approximately 1.8 billion tons of geological material, of which approximately 1.3 billion tons would be waste rock and 0.5 billion tons would be ore. The Arizona Department of Water Resources is monitoring land subsidence associated with groundwater withdrawal in the Santa Cruz Valley. Subsidence is discussed in detail in the “Groundwater Quantity” section of this document.

Slippage or ground movement may occur inside the Rosemont open pit on individual benches or portions of benches and will vary over time during pit expansion; this type of subsidence is typically limited to the confines of the pit. The potential for slippage and the intensity of the potential slippage depend on the type and competency of the rock remaining in the pit walls after excavation, the angle or slope of intersecting fault structures, and the location above natural or human-made voids. Slope stability management will be addressed by the pit slope and catch-bench designs, dewatering programs to depressurize the pit walls, and routine monitoring programs. Based on a slope stability analysis by (Pratt et al. 2007:1–2), depressurization by dewatering will be required primarily in the east wall (Willow Canyon Formation), the south wall (Gila conglomerate), and the northwest wall (Bolsa Quartzite). Seismic hazards are considered low to moderate; because of project design criteria, seismic impacts to operations are not expected.

Based on existing information, the potential to impact cave resources or karst features cannot be ruled out. Cave resources, if present, would be impacted by the project. All potential impacts to geology and mineral resources are considered direct impacts.

Paleontology

For this project, the entire area within the perimeter fence for the proposed action and each alternative was analyzed for potential effects on paleontological resources. A paleontological field survey was conducted by Forest Service and SWCA Environmental Consultants paleontologists of the areas with exposures of paleontologically sensitive geological units (Potential Fossil Yield Classification Classes 3 through 5), as determined by desktop analysis. The results of the field survey were used to further refine the paleontological resource sensitivity of geological units specific to the project area.
The results of this refinement showed that no geological units within the project area are considered to have a Potential Fossil Yield Classification ranking of Class 4 (high) or Class 5 (very high) sensitivity. Therefore, conditional paleontological surface clearance is recommended; monitoring ahead of ground disturbance would be required in some areas to prevent impact to significant fossils in geological units that still have a moderate (Class 3b) potential for significant fossils, such as the Gila Conglomerate and Cretaceous volcanics. For the impacts analysis of subsurface impacts to paleontological resources, the total number of possible disturbance acres within geological units by Potential Fossil Yield Classification was calculated for each alternative. These calculations were used to estimate indirect and direct effects on paleontological resources as a result of project related surface-disturbing activities. Table 11 summarizes these calculations for each of the action alternatives.

Table 11. Summary of proposed surface disturbance in acres for each alternative by Potential Fossil Yield Classification ranking

Potential Fossil Yield Classification Ranking	No Action	Proposed Action	Phased Tailings	Barrel	Barrel Trail	Scholefield-McCleary
Class 1 (Very low)	NA	1,838.4	1,752.5	1797.0	1,797.0	2,951.2
Class 2 (Low)	NA	561.7	561.7	604.8	604.8	633.6
Class 3a (Moderate)	NA	666.0	666.0	673.8	673.8	685.8
Class 3b (Unknown)	NA	3,115.7	3,092.9	3,735.2	3,735.2	2,905.8
Class 4 (High)	NA	0	0	0	0	0
Class 5 (Very High)	NA	0	0	0	0	0
Subtotal Classes 3–5	*NA*	*3,781.7*	*3,758.9*	*4,409.0*	*4,409.0*	*3,591.6*
Total Acres	**NA**	**6,181.8**	**6,073.0**	**6,810.8**	**6,810.8**	**7,176.4**

Note: NA = Not available.

Proposed Action

Under the proposed action, a maximum total of 6,182 acres within the project area as defined for this analysis (see assumptions) are proposed for disturbance. Of these, 3,782 acres have moderate or unknown paleontological sensitivity (see table 11). Of all the alternatives, the proposed action has the third highest potential for disturbance of paleontologically sensitive acreage and potential adverse effects on scientifically significant paleontological resources.

Phased Tailings Alternative

Under the Phased Tailings Alternative, a maximum total of 6,073 acres within the project area as defined for this analysis (see assumptions) are proposed for disturbance. Of these, 3,759 acres have moderate or unknown paleontological sensitivity (see table 11). Of all the alternatives, the Phased Tailings Alternative has the third lowest potential for disturbance of paleontologically sensitive acreage and potential adverse effects on scientifically significant paleontological resources.

Barrel Alternative

Under the Barrel Alternative, a maximum total of 6,811 acres within the project area as defined for this analysis (see assumptions) are proposed for disturbance. Of these, 4,409 acres have moderate or unknown paleontological sensitivity (see table 11). Of all the alternatives, the Barrel Alternative has the highest potential (along with the Barrel Trail Alternative) for disturbance of paleontologically sensitive acreage and potential adverse effects on scientifically significant paleontological resources.

Barrel Trail Alternative

Under the Barrel Trail Alternative, a maximum total of 6,811 acres within the project area as defined for this analysis (see assumptions) are proposed for disturbance. Of these, 4,409 acres have moderate or unknown paleontological sensitivity (see table 11). Of all the alternatives, the Barrel Trail Alternative has the highest potential (along with the Barrel Alternative) for disturbance of paleontologically sensitive acreage and potential adverse effects on scientifically significant paleontological resources.

Scholefield-McCleary Alternative

Under the Scholefield-McCleary Alternative, a maximum total of 7,176 acres within the project area as defined for this analysis (see assumptions) are proposed for disturbance. Of these, 3,592 acres have moderate or unknown paleontological sensitivity (see table 11). Of all the alternatives, the Scholefield-McCleary Alternative has the lowest potential for disturbance of paleontologically sensitive acreage and potential adverse effects on scientifically significant paleontological resources.

Cumulative Effects

The Council on Environmental Quality defines a cumulative impact as “the impact on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable actions regardless of what agency (federal or nonfederal) or person undertakes such other actions” (40 Code of Federal Regulations 1508.7). As outlined in the chapter 3 introduction, cumulative impacts of past and present actions are identified and analyzed in the “Affected Environment” part of each resource section, including for “Geology, Minerals, and Paleontology.” 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 chapter 3 introduction.
The following reasonably foreseeable actions from that list were determined to contribute to a cumulative impact to paleontological resources:

- Potential expansion of limestone quarry in the Davidson Canyon drainage system northeast of the Santa Rita Mountains
- Expansion of the Andrada limestone quarry
- Ongoing base and precious metal exploration, depending on market, throughout southeastern Arizona

These activities would be expected to cause some disturbance to potential paleontologically significant geological formations within the area, as well as geological units with potential for cave formation.

Mitigation Effectiveness

Two mitigation measures are proposed that would affect paleontological and cave resources.

Upon indication or discovery of a cave, sinkhole, underground drainage into a solution cavern or similar karst features, Rosemont Copper would suspend work at that site and contact the designated Forest Service representative to investigate the discovery before work is reinitiated. The designated Forest Service representative would promptly coordinate the investigation with appropriate agency resource specialists. Any natural void in rock that is large enough for a human to enter constitutes a cave. Any collapse feature in or over carbonate rock constitutes a sinkhole.

In order to mitigate potential impacts to significant paleontological resources, monitoring by a Forest Service approved paleontologist would occur ahead of ground disturbance in formations with a moderate potential for scientifically significant paleontological resources. Upon discovery of such resources, Rosemont Copper would suspend work at that site and the site would be investigated by the appropriate personnel before work resumes. The designated Forest Service representative would promptly coordinate the investigation with appropriate Forest Service or other specialists.

Irretrievable and Irreversible Commitment of Resources

Irretrievable and irreversible commitment of geological and mineral resources will occur with the excavation and relocation of approximately 1.8 billion tons of ore and waste rock, with the recovery of approximately 4.6 billion pounds of copper, 100 million pounds of molybdenum, and 70 million ounces of silver.

A commitment of resources is considered to be irretrievable when project impacts limit the future use or productivity of a nonrenewable resource over a limited amount of time, e.g., structures built on top of paleontologically sensitive geological units. A commitment of resources is considered to be irreversible when project impacts cause a nonrenewable resource to be permanently lost, e.g., destruction of significant fossils and loss of associated scientific data. With the implementation of proper mitigation measures, the project is not likely to result in the irreversible commitment of paleontological resources. An irretrievable commitment of paleontological resources may occur should structures be situated on top of paleontologically sensitive geological units. Such a commitment would be considered temporary if the building structures are subsequently removed when the project ends. It would also be beneficial, as it would prevent natural erosion of potentially sensitive geological units.

Soils

Introduction

This section discusses soils and soil productivity in the project area and in the analysis area. Soil consists of the mineral and organic matter on the surface that supports vegetation and stores moisture. Soils are defined by their specific physical, chemical, and biological characteristics. Soil productivity is the ability of a given soil to support plant growth under natural conditions.

Issues, Cause and Effect Relationships of Concern

One significant issue was identified during scoping concerning soils and soil productivity. Mine activities that disturb the soil and remove vegetation can cause erosion, loss of the ability of soil to sustain vegetation, and the movement of sediment into surface waters.

Issue 1: Impact on Land Stability and Soil Productivity

Ground disturbance from clearing vegetation, grading, and stockpiling soils may accelerate erosion and reduce soil productivity. The tailings and waste rock piles may be unstable over time, and reclamation may not adequately result in a stable, revegetated landscape. The geochemical composition of tailings and waste rock piles may not support native vegetation. Soils are nonrenewable resources. Loss of the soil resource may result in an irretrievable loss of soil productivity, physical structure, and ecological function across the proposed mine site and across downgradient lands if the mining area acts as a barrier to sourcing and supporting natural downslope transportation of geological material, water, and nutrients through alluvial, eolian, and fluvial processes.

Issue 1 Factors for Alternative Comparison

- Qualitative assessment of long-term stability of tailings and waste piles
- Character of risks to stability through time, including expected results of reclamation
- Area and quantitative level of disturbance leading to lost soil productivity (acres)
- Qualitative assessment of the potential for revegetation of tailings and waste rock piles
- Qualitative evaluation of alteration of soil productivity and soil development
- Sediment delivery to Davidson Canyon, Cienega Creek, or other streams and washes, compared with background sediment loading (tons per year)

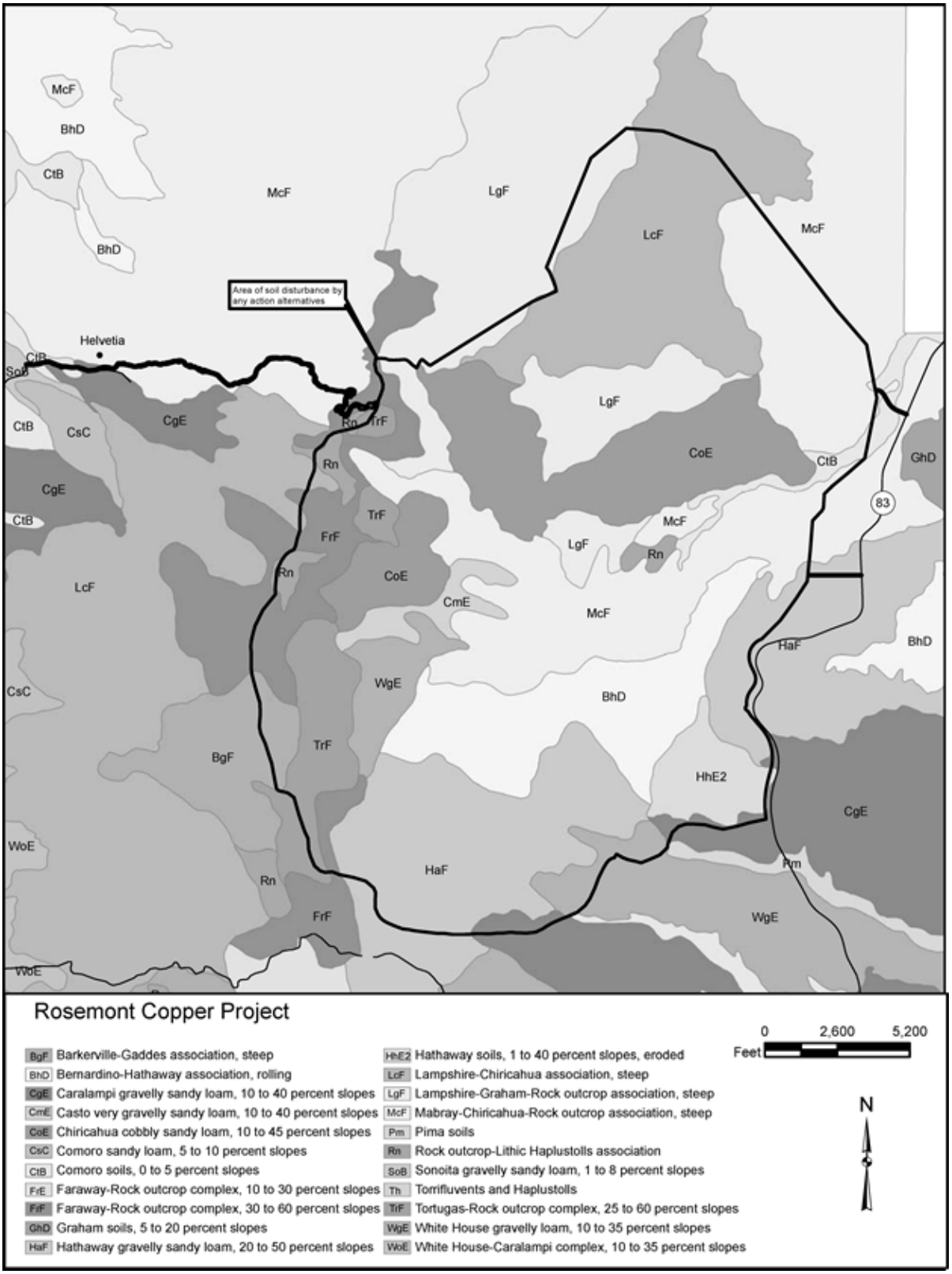
Analysis Methodology, Assumptions, Uncertain and Unknown Information

Temporally, any potential impacts to soils would occur from initial construction of mine facilities through reclamation and closure. However, soil is a nonrenewable resource, and the loss of soils from the project area is permanent. Therefore, the temporal bounds of analysis for soils is the period that encompasses construction, operation, reclamation, and closure, as well as postclosure activities.

The analysis area for soils encompasses the project area (i.e., mine process facilities, fuel storage tanks, processing fluid pipelines, tailings, and waste rock facilities) and access roads. The analysis area for soils is depicted in figure 22. Utility corridors were not considered in the analysis area. Unlike soil disturbance on the mine site, which is concentrated on an individual watershed and stream channel (Barrel Canyon), linear utility disturbance will result in small impacts to multiple stream channels and watersheds. In addition, during the greatest disturbance (during construction), best management practices will be in place to control soil loss. Best management practices include both structural controls to prevent soil from leaving the site during storm events (i.e., silt fences, straw bales), management controls to prevent soil loss in the first place (i.e., limiting disturbance footprints), and stabilizing measures following disturbance (i.e., reseeding). Therefore, impacts on soils and soil productivity from linear utilities were considered to be negligible.

Soils of the Coronado National Forest were identified using the National Resources Conservation Service (2010b) Web Soil Survey. In addition, site-specific soil profile surveys were conducted by Tetra Tech in March 2007 to assess the potential for soils to support reclamation and revegetation (Tetra Tech 2007e).

Qualitative assessments of long-term stability for waste rock and the character of risks to stability through time are based on stability analysis by Tetra Tech (2010f); for tailings, the qualitative assessments are based on stability analysis by AMEC Earth and Environmental (AMEC Earth and Environmental Inc. 2009b).



Rosemont Copper Project

0 2,600 5,200
Feet

N

BgF	Barkerville-Gaddes association, steep	HhE2	Hathaway soils, 1 to 40 percent slopes, eroded
BhD	Bernardino-Hathaway association, rolling	LcF	Lampshire-Chiricahua association, steep
CgE	Caralampi gravelly sandy loam, 10 to 40 percent slopes	LgF	Lampshire-Graham-Rock outcrop association, steep
CmE	Casto very gravelly sandy loam, 10 to 40 percent slopes	McF	Mabray-Chiricahua-Rock outcrop association, steep
CoE	Chiricahua cobbly sandy loam, 10 to 45 percent slopes	Pm	Pima soils
CsC	Comoro sandy loam, 5 to 10 percent slopes	Rn	Rock outcrop-Lithic Haplustolls association
CtB	Comoro soils, 0 to 5 percent slopes	SoB	Sonoita gravelly sandy loam, 1 to 8 percent slopes
FrE	Faraway-Rock outcrop complex, 10 to 30 percent slopes	Th	Torrifluvents and Haplustolls
FrF	Faraway-Rock outcrop complex, 30 to 60 percent slopes	TrF	Tortugas-Rock outcrop complex, 25 to 60 percent slopes
GhD	Graham soils, 5 to 20 percent slopes	WgE	White House gravelly loam, 10 to 35 percent slopes
HaF	Hathaway gravelly sandy loam, 20 to 50 percent slopes	WoE	White House-Caralampi complex, 10 to 35 percent slopes

Figure 22. Analysis area for soils

Expected results of reclamation and the qualitative assessment of the potential for revegetation of tailings and waste rock piles are based on general ecosystem survey plant community descriptions (Shaw et al. 1991), more current rangeland monitoring by the Coronado (Biedenbender 2010a, 2010b; Lockwood 2010), and preliminary results from completed greenhouse research and ongoing onsite field research conducted by the University of Arizona (Fehmi 2007; Fehmi et al. 2008).

Area and quantitative level of disturbance leading to lost soil productivity is measured by the footprint of surface-disturbing mine activities.

Qualitative evaluation of alteration of soil productivity and soil development is analyzed by assessing the expected results of reclamation and potential for erosion.

Sediment delivery to Davidson Canyon and Cienega Creek from the watershed as a whole under each alternative was estimated by Zeller (2010a; 2010b); sediment volume was converted to tonnage using a bulk density of 1.5 grams per cubic centimeter. Expected changes in sediment delivery and total suspended solids concentrations were modeled using the Pacific Southwest Interagency Committee (1968) method for sediment yield analysis. Sediment delivery to other streams and washes was not analyzed. Note that the analysis for soils resources concerns the effects on soil productivity resulting from loss of soil by erosion; effects on Davidson Canyon and Cienega Creek from delivery of this sediment downstream are more fully analyzed in the “Surface Water Quality” section.

At this time, sediment analysis for the Barrel Alternative is ongoing. This represents unknown information for this analysis, although results are expected to be similar to the Phased Tailings and Barrel Trail Alternatives.

Summary of Effects by Issue Measures by Alternative

Table 12 presents the summary comparison of impacts from each alternative.

Table 12. Summary of effects

Issue Measure	No Action	Proposed Action	Phased Tailings	Barrel	Barrel Trail	Scholefield-McCleary
1: Qualitative assessment of long-term stability of tailings and waste piles	None	Modeling indicates that waste rock and tailings will be more stable than required by regulations	Same as proposed action	Same as proposed action	Same as proposed action	Same as proposed action
1: Character of risks to stability through time, including expected results of reclamation; qualitative assessment of the potential for revegetation of tailings and waste rock piles	None	After 100 years, reclamation approaches historic climax conditions, with varying success by vegetation type and elevation	Same as proposed action	Same as proposed action	Same as proposed action	Same as proposed action
1: Area and quantitative level of disturbance leading to lost soil productivity (acres)	0	4,415	4,390	4,165	4,165	4,310

Issue Measure	No Action	Proposed Action	Phased Tailings	Barrel	Barrel Trail	Scholefield-McCleary
1: Sediment delivery to Davidson Canyon, Cienega Creek, or other streams and washes, compared with background sediment loading (tons per year)	32,600	16,000	16,500	Modeling not completed	20,300	24,200

Affected Environment

Relevant Laws, Regulations, Policies, and Plans

National Forest System resources are defined, protected, and maintained under the Organic Administration Act of 1897, Bankhead-Jones Farm Tenant Act of 1937, Multiple-Use Sustained-Yield Act of 1960, Forest and Rangeland Renewable Resources Planning Act of 1974, and National Forest Management Policy Act of 1976.

Soil resources and reclamation are managed in accordance with the following guidelines:

- U.S. Department of Agriculture National Soil Survey Handbook
- Forest Service Manual 2500, chapter 2550, “Soil Management” (U.S. Forest Service 2010e)
- Forest Service Manual 2840, Reclamation (U.S. Forest Service 1990)
- Forest Service Manual 1940, Inventory, Monitoring, and Assessment Activities (U.S. Forest Service 2009a)
- U.S. Department of Agriculture Soil Survey Manual (U.S. Department of Agriculture Soil Survey Division Staff 1993)
- Title 27 Arizona Revised Statutes Chapter 1, Article 4
- Forest Service Handbook 2509.18, “Soil Management,” R-3 Supplement No. 2509.18-99-1 (U.S. Forest Service 1999)
- Forest Service General Technical Report W0-68, “Terrestrial Ecological Unit Inventory Technical Guide: Landscape and Lane Unit Scales” (Winthers et al. 2005)
- Comprehensive Environmental Response, Compensation, and Liability Act, which establishes prohibitions and requirements concerning closed and abandoned hazardous waste sites, and provides for liability of persons responsible for releases of hazardous waste at these sites.
- Arizona Soil Remediation Levels, Arizona Administrative Code R18-7-201. Soil remediation levels would be applied to determine the extent to which reclamation must mitigate any known soil contamination during mine closure. Soil remediation levels are also applicable in the event of spills or contamination that occur during active mine life.
- Aquifer Protection Permit Closure Requirements, Arizona Administrative Code R18-9-A209. Investigation and characterization of potential soil contamination is a component of closure and contingency plans required under the Arizona Aquifer Protection Permit process.

Forest Service Guidance

General Management Direction for Soils on the Coronado National Forest

Federal policy for soil management requires that the Forest Service, in accordance with Forest Service Handbook 2509.18, section 2.03, assess, evaluate, and monitor the soil resource to detect significant changes in soil properties resulting from implementation of management plans (U.S. Forest Service 1999). Soils are managed by the Forest Service under the forest plan (U.S. Forest Service 1986), in recognition of the fact that soil productivity affects the quality and quantity of water that originates in the watersheds of the Coronado National Forest and provides water to southern Arizona and New Mexico. Management activities are directed to protect or enhance watershed conditions in recognition of the connection between hydrologic function and soil productivity. Under management directives in the forest plan, best management practices "will be used to minimize the time of recovery to a satisfactory erosion level, minimize soil productivity loss, improve water quality and minimize channel damage" (U.S. Forest Service 1986:38). Further, the forest plan states that management plans, including those for mineral extraction, should carefully consider activities that affect sensitive soils and riparian areas to minimize soil damage (U.S. Forest Service 1986:38–40).

The Forest Service's reclamation objectives and management policies for lands disturbed by mineral extraction and associated activities are outlined in Forest Service Manual 2840. The Forest Service manages reclamation efforts in order to reduce the environmental impacts of mineral extraction and ensure that disturbed lands are returned to a use that is consistent with long-term forest land and resource management plans. According to Forest Service Manual 2840, the following policies are implemented to achieve the Forest Service's reclamation objectives:

1. Reclamation shall be an integral part of plans of operation that propose surface disturbance.
2. All lands disturbed by mineral activities shall be reclaimed to a condition that is consistent with forest land and resource management plans, including applicable state air and water quality requirements.
3. All reclamation requirements included in a plan of operations shall include measurable performance standards. Reclamation requirements shall be those that are reasonable, practicable, and necessary to attain standards.
4. Reclamation shall be undertaken in a timely fashion and occur sequentially with ongoing mineral activities.
5. Reclamation bonds, sureties, or other financial guarantees shall ordinarily be required for all mineral activities that require a plan of operations; dollar amounts of such guarantees shall be sufficient to cover the full cost of reclamation.
6. To the extent practicable, reclaimed National Forest System land shall be free of long-term maintenance requirements.

Reclamation is also managed under the Arizona Mined Land Reclamation Act, which provides a mechanism for requiring the reclamation of mined lands to a safe, stable condition.

State Requirements

Title 27 Arizona Revised Statutes Chapter 1, Article 4, specifies the requirements for new mines to submit a reclamation plan to the Arizona State mine inspector. Two criteria contained in the statute specifically involve soils and soil productivity:

- Section 27-971(B)(9) requires that the plan include information on proposed reclamation measures that would be taken to address erosion control and stability.
- Section 27-974 specifies that prior to disturbance, soil shall be conserved unless otherwise unable or unnecessary.

Investigation and characterization of potential soil contamination is contained under the Arizona Aquifer Protection Permit regulations. Under these regulations a closure plan is required that includes the following:

- A site investigation plan that includes a summary of relevant site studies already conducted and a proposed scope of work for any additional site investigation necessary to identify the following: the lateral and vertical extent of contamination in soils and groundwater, using applicable standards; the approximate quantity and chemical, biological, and physical characteristics of each waste, contaminated water, or contaminated soil proposed for removal from the facility; the approximate quantity and chemical, biological, and physical characteristics of each waste, contaminated water, or contaminated soil that will remain at the facility; and information regarding site conditions related to pollutant fate and transport that may influence the scope of sampling necessary to characterize the site for closure.
- A closure design that identifies the following: the method used, if any, to treat any material remaining at the facility; the method used to control the discharge of pollutants from the facility; any limitation on future land or water uses created as a result of the facility's operations or closure activities; and the methods used to secure the facility.

Existing Conditions

Soil Occurrence and Characteristics

The project area is in the Basin and Range physiographic province of southeastern Arizona. The range of soil characteristics that occur in the project area includes mixed variations of sandy loam, cobbly loam, and gravelly loams, generally on gentle to steep slopes, rock outcrops, and valley bottoms.

Surface water and soils transported from the project area flow into various drainages that then flow first into Davidson Canyon and eventually into Cienega Creek. Figure 22 above shows the soil units. Table 13 describes each of the soil units represented in figure 22.

Table 13. Soil characteristics in the analysis area

Map Unit Symbol	Map Unit Name	Rating	Acres	Erosion Potential	Percent Analysis Area*	Number of Site Locations on Map
LgF	Lampshire-Graham-Rock outcrop association, steep	very cobbly loam	785	Severe	8.1%	3
FrF	Faraway-Rock outcrop complex, 30 to 60% slopes	very cobbly fine sandy loam	437	Severe	4.5%	2
McF	Mabray-Chiricahua-Rock outcrop association, steep	cobbly sandy loam	1,947	Severe	20.6%	3
CtB	Comoro soils, 0 to 5% slopes	gravelly sandy loam	99	Slight	1.0%	3
CoE	Chiricahua cobbly sandy loam, 10 to 45% slopes	cobbly sandy loam	1,279	Moderate	13.2%	2

Map Unit Symbol	Map Unit Name	Rating	Acres	Erosion Potential	Percent Analysis Area*	Number of Site Locations on Map
TrF	Tortugas-Rock outcrop complex, 25 to 60% slopes	very cobbly loam	405	Severe	4.2%	3
Rn	Rock outcrop-Lithic Haplustolls association	not applicable	111	Not Rated	1.1%	4
BhD	Bernardino-Hathaway association, rolling	gravelly clay loam	908	Slight	9.4%	1
CmE	Casto very gravelly sandy loam, 10 to 40% slopes	very gravelly sandy loam	153	Moderate	1.6%	1
WgE	White House gravelly loam, 10 to 35% slopes	gravelly loam	370	Moderate	3.8%	2
BgF	Barkerville-Gaddes association, steep	gravelly sandy loam	84	Severe	<1%	1
HhE2	Hathaway soils, 1 to 40% slopes, eroded	gravelly sandy loam	263	Moderate	2.7%	1
CgE	Caralampi gravelly sandy loam, 10 to 40% slopes	gravelly sandy loam	81	Moderate	<1%	3
HaF	Hathaway gravelly sandy loam, 20 to 50% slopes	gravelly sandy loam	1,374	Moderate	14.6%	2
LcF	Lampshire-Chiricahua association, steep	Very cobbly loam	1,141	Severe	11.8%	2
Subtotal Area with Slight Erosion Potential			*1,007*		*11%*	
Subtotal Area with Moderate Erosion Potential			*3,520*		*37%*	
Subtotal Area with Severe Erosion Potential			*4,799*		*51%*	
Total Analysis Area			**9,438**		**100%**	

Source: Natural Resources Conservation Service (2010b).

* Percentages may not total 100 because of rounding.

Existing Soil Disturbance

Existing Mineral Related Disturbance

Mineral related disturbance from previous mineral exploration and extraction is evident in the area, as described in the "Geology, Minerals, and Paleontology" section. Historic mining activity began in the mid-1800s. By the 1880s, the production of mines in the Rosemont and Helvetia mining districts supported the construction and operation of two smelters, one on each side of the Santa Rita Mountains, within the project area. Mine dumps, road ballast, and slag deposits from historic mining operations are visible, but not a dominant feature, in the landscape. A slag deposit in the southwest quarter of Section 29 (Township 18 South, Range 16 East) is visible from Forest Road 4058. Heavily vegetated dumps are downslope of the Naragansett Mine works. Mining production in the project area ceased in 1951.

Rosemont Copper recently conducted exploratory drilling in the project area to ascertain the location, distribution, and geological configuration of the mineral deposits within its mineral claim area. This recent exploration included 15 borehole sites consisting of drill pads measuring 30 by 60 feet and a new access road to reach the sites, for a cumulative total of 0.95 acre of soil disturbance.

The University of Arizona's School of Natural Resources and the Environment, in conjunction with Rosemont Copper, is currently conducting an onsite soil testing program to determine which

reclaimable soils within the proposed project area are conducive to vegetation growth on slopes similar to the proposed waste rock and tailings piles. Existing vegetation and topsoil were removed from the test site area, and soil profile samples were collected from the project area for testing. The cumulative total of the test plots' disturbance area is approximately 8 acres located on private land.

Existing Grazing Related Disturbance

The majority of Forest Service land surrounding the project area is currently under permit for livestock grazing. The Rosemont Copper property is part of an existing ranching facility with more than 22,190 acres of grazing allotments. Cattle grazing disturbs soil by removing protective vegetation and compacting soil surfaces (Shaw et al. 1991). The Coronado currently employs a rotational grazing system on all of its allotments as part of an adaptive management strategy in order to allow pastures to rest when necessary, which results in less soil disturbance. See the "Livestock Grazing" section for more detail.

Existing Recreation Related Disturbance

Existing soil disturbance from recreation related activities is the result of trails, access roads, off-highway vehicle areas, and other developed recreation facilities. Forest roads, routes, and trails in the project area total 28 miles. Immediately adjacent to the project area are two off-highway vehicle staging areas that see considerable recreation use. Travel in the project area is restricted to designated routes only; however, some off-trail motorized use does occur. See the "Recreation and Wilderness" section for more detail.

Overall Current Condition of Watershed

In the absence of actual sediment monitoring, the erosion potential for the entire watershed is a combination of the erosion potential of various soils (see table 13), as well as the state of vegetation on the watershed. There are two vegetative conditions to consider: the historic climax plant community and the current conditions. The historic climax plant community represents the plant community that existed at the time of European immigration and settlement. It is the plant community that was in dynamic equilibrium with its environment and was best adapted to the unique combination of environmental factors associated with the site. The historic climax plant community was obtained from the Ecological Site Descriptions prepared by the Natural Resources Conservation Service (2006; 2010a).

Fehmi (2007) notes that the Rosemont Copper Mine site is visibly degraded from the historic climax plant community, primarily because of the substantial cover of juniper and mesquite present, which resulted from historical fire prevention strategies and overgrazing by cattle. Once the canopy cover of these species increases to more than 25 percent, site instability and soil erosion can occur.

The "General Ecosystem Survey for the Coronado National Forest" (Shaw et al. 1991:5) further compares the current condition of the watershed with the historic climax condition (table 14). In general, vegetation basal area currently represents approximately 5 percent of the surface, whereas under historic climax conditions, it would represent 15 to 25 percent of the surface. Likewise, bare soil would represent 20 to 45 percent of the surface under historic climax conditions, but it currently represents 30 to 60 percent of the surface.

While describing "current" conditions, the general ecosystem survey is a regional document, and the descriptions are both generalized and dated. More recent current rangeland conditions have been

monitored by the Coronado but are not directly comparable to the historic climax plant community. Rangeland monitoring results are shown in table 15. Rangeland monitoring analysis results in a qualitative indication of vegetation and soil condition; with respect to soils, "satisfactory" is the highest level obtainable.

Table 14. Summary of the potential plant community and soil conditions based on the general ecosystem survey

Landform	State	Overstory	Rock Fragments	Litter	Vegetation Basal Area	Bare Soil
South-facing slopes	Historic Climax	15%	50%	5%	20%	25%
South-facing slopes	Current	25%	50%	5%	5%	40%
North-facing slopes	Historic Climax	50%	30%	40%	15%	20%
North-facing slopes	Current	50%	30%	40%	5%	30%
Elevated flats	Historic Climax	15%	30%	5%	25%	45%
Elevated flats	Current	25%	30%	5%	5%	60%

Source: Shaw et al. (1991 : Map Units 490.1–490.3).

Table 15. Rangeland conditions from 1965 to 2009

Allotment	1967 to 1969 Vegetation	1967 to 1969 Soils	1995 Vegetation	1995 Soils	2009 Vegetation	2009 Soils
Rosemont	Fair to Good	High Fair to Excellent	Fair to Excellent	Impaired to Satisfactory	Good to Excellent	Satisfactory
Greaterville	Good	High Fair to Excellent	Fair to Excellent	Satisfactory	Fair to Excellent	Satisfactory
DeBaud	Fair to High Fair	Fair to Good	Fair to Good	Impaired to Satisfactory	High Fair to Good	Satisfactory

Sources: Biedenbender (2010a; 2010b); (Lefevre 1995); Lockwood (2010).

Soils Suitable for Reclamation

In March 2007, Tetra Tech studied soil profiles from 25 sites that represent the characteristic soil types within the project area in order to assess the potential of soils in the project area to be used for vegetation growth media for reclamation (Tetra Tech 2007c; 2007e). The study analyzed soils for physical and chemical properties, including soil acidity and alkalinity, electrical conductivity, sodium absorption ratio nutrient content, and acid base accounting. Tetra Tech (2007e) concluded that potential soil salvage was available in three soil profiles: north-aspect soils, south-aspect soils, and alluvial fans. The locations of these three soil profiles approximately correspond to the Bernardino-Hathaway association (BhD) and Hathaway gravelly sandy loam (HaF), as depicted in figure 22.

The north-aspect soils in the southern portion of the project area available for salvage are sandy loams with 15 to 20 percent gravel, 0 to 5 percent cobbles, and between 45 and 65 percent surface coarse fragments. South-aspect soils in the southern portion of the project area have approximately 6 inches of suitable soil for salvage, with occasional deeper deposits in concave physiographic positions. The alluvial fans were limited in extent to the mouths of side drainages and have the deepest soil salvage potential.

Estimated Soil Salvage Volumes

The estimated soil salvage areas and volumes in the dry tailings, waste rock storage, and other disturbed areas of the Rosemont Copper Mine are based on soil texture, organic matter, coarse

fragments, and nutrient content. The total estimated volume of salvage soil in the disturbed areas is approximately 4,583,000 cubic yards. Underlying the salvageable soil throughout the project area, and specifically underlying the above disturbed areas, is a substantial amount of unconsolidated and weathered bedrock. The volume of these materials was estimated using a minimum depth of 4 feet. The estimated volume of unconsolidated and weathered bedrock is 17,230,000 cubic yards. The University of Arizona School of Natural Resources and the Environment studies, described in detail later in this section, would be used to determine the suitability of these deeper subgrade materials as growth media.

Revegetation success has reportedly been observed within the proposed pit area where weathered bedrock material has been used for reclamation of exploration sites (Tetra Tech 2007c). The primary physical properties limiting salvage include high clay content and high coarse fragment content. Soils on the ridgetops, especially in the northwestern portion of the project area, have high clay concentrations in the subsoil that may require special consideration for reclamation planning. High percentages of coarse fragments are generally common throughout the project area. The primary chemical property limiting salvage is nutrient content. Nutrient content is variable throughout the survey area, based on the sampling conducted in 2007 (Tetra Tech 2007e).

Environmental Consequences

Direct and Indirect Effects of Each Alternative

No Action Alternative

Under the no action alternative, there would be no impact on the existing soil conditions on public lands.

Impacts Common to All Action Alternatives

Although disturbed acreage varies slightly for the action alternatives, there are no substantial differences in impacts with respect to revegetation potential or long-term stability of tailings and waste rock slopes. Disturbed acreage and sediment delivery both vary among alternatives, but the overall impact trend (i.e., reduction of sediment yield) is similar. The following impacts apply to all action alternatives.

Stability of Tailings and Waste Rock

The overall stability of the tailings and waste rock piles is critical to reclamation success. Structurally, the tailings and waste rock must be designed to prevent mass wasting and collapse in order to provide a stable surface for vegetation growth. AMEC Earth and Environmental (AMEC Earth and Environmental Inc. 2009b) conducted stability analyses of the dry-stack tailings facility, and Tetra Tech (Zeller 2010b) conducted stability analyses of the waste rock storage area. In both cases, modeling indicated that the designed waste rock storage and tailings facilities are more stable than what is minimally required by regulations, based on the planned crest height, bench widths, and slopes. The minimum factor-of-stability values required under regulations as best available control technology are 1.0 for seismic failure and 1.3 for static failure. As modeled, the factor-of-stability values for the tailings and waste rock facilities range from 1.0 to 1.2 for seismic failure and from 1.9 to 2.3 for static failure.

Soil Productivity Directly Lost to Mine Activities

Soil productivity is the capability of a soil to produce and support plant and vegetation biomass. The primary impact to soil productivity is the actual loss of topsoil directly where mine activities would remove or disturb the soil. According to the preliminary MPO, the proposed action would impact approximately 4,415 acres of soils within the project area. Of the 4,415 impacted acres, 950 acres would be impacted by the open pit, and 2,895 acres would be impacted by the heap leach pad and tailings and waste rock piles. The remaining 570 acres would be impacted by the plant site, access roads, and utility corridor. Soils identified as salvageable for reclamation purposes would be harvested and stored as needed (approximately 4.5 million cubic yards). Approximately 200 acres of land would be set aside for stockpiling salvageable topsoil for reclamation purposes; the location of the salvage stockpile has not yet been determined. The acreage of the other action alternatives varies slightly but is substantially the same, ranging from 4,165 to 4,415 acres (table 16).

The loss of soil productivity within the mine footprint may occur gradually but would rise to 100 percent during the construction and operation phases.

Table 16. Direct soil productivity loss by alternative

Alternative	Acres Impacted
No action	0
Proposed action	4,415
Phased Tailings	4,390
Barrel	4,165
Barrel Trail	4,165
Scholefield-McCleary	4,310

Sediment Delivery during Construction and Operation

Sediment enters stormwater through erosion of native soils, tailings, and waste rock. The stormwater management facilities onsite have been designed to maintain total suspended sediment concentrations in stormwater runoff similar to baseline conditions. No actual sampling or measurement of total suspended sediment has occurred at the site; baseline conditions were estimated or modeled. Sediment delivery was modeled to the U.S. Geological Survey gaging station in Lower Barrel Canyon Wash, the downstream stormwater control point for postmining conditions for each alternative (Zeller 2010a; 2010b). The sediment delivery for the baseline conditions (no action) and all the action alternatives is summarized in table 17. Note that while the expected sediment delivery of the Barrel Alternative is pending, the results for this alternative are anticipated to be between the expected changes of sediment delivery under the Barrel Trail Alternative and the Phased Tailings Alternative, based on similarity of design with Phased Tailings and similarity of location with Barrel Trail.

Based on the sediment modeling, sediment delivery to the downstream watershed is expected to decrease from baseline conditions during mine activities, while suspended sediment concentrations are expected to remain relatively unchanged. The primary reason for decreases in sediment delivery to the downstream watershed is that stormwater runoff from the mine site will decrease; any precipitation falling over the mine pit and facility is collected and reused as process water, reducing the amount of water running off the watershed and carrying sediment. Potential impacts to downstream resources are analyzed in the “Surface Water Quality” section. With respect to soils, this modeling indicates that less soil is being removed from the watershed. However, this reduction may be the result of capture in sediment basins or stream channels. Even though soil may be captured

before entering the stream channel, soil may still be lost from site surfaces, impairing its function as a soil resource.

Table 17. Summary of expected changes to sediment delivery under alternatives

Condition	Contributing Watershed Area (square miles)	Average Annual Sediment Delivery (acre-feet)	Average Annual Sediment Delivery (tons)	Sediment Concentration (parts per million)	Percent Change from Baseline
No action	14	16.10	32,600	16,407	–
Proposed action	6.82	7.84	16,000	16,194	−50.9
Phased Tailings	7.06	8.12	16,500	16,210	−49.4
Barrel	Analysis in process	Analysis in process	Analysis in process	Analysis in process	Analysis in process
Barrel Trail	8.65	9.95	20,300	16,273	−37.7
Scholefield-McCleary	10.35	11.90	24,200	16,317	−25.8

Soil Development and Productivity Lost to Erosion after Reclamation

During the construction and operation phases, soil loss from the watershed would be reduced primarily using structural and engineered sediment controls. Postclosure, reduction of soil loss from the watershed would rely on structural and engineered sediment controls, but it would also rely on revegetation of the site to prevent erosion from occurring. Reducing the actual erosion of soil from surfaces can only be accomplished through revegetation of the site.

All natural soils would be lost during construction and operation. During reclamation, replacement growth media would be placed on the site surface and seeded for revegetation. Growth media would be a mix of salvaged soils from the site but would primarily consist of waste rock and tailings material. This growth media is expected to support vegetation but would not develop a natural soil profile for many decades after closure of the site. The presence of a natural soil profile typically results in higher productivity owing to better retention of soil moisture available for plants and less risk of loss by erosion.

Assessment of Revegetation Potential of Waste Rock and Tailings

Analysis of potential revegetation potential was approached using a two-part strategy through research conducted by Rosemont Copper in conjunction with the University of Arizona. The first part of the research focused on assessment of potential seed mixes for the site, including greenhouse testing to identify those seed mixes most likely to thrive in actual material from the site; this experimentation used substrate materials that would be identical to the waste rock and tailings from mine activities. The second part focused on long-term construction and testing of in situ reclamation plots at the mine site itself.

The revegetation potential on future waste rock and tailings can be both quantitatively and qualitatively analyzed, based on the University of Arizona greenhouse results. The likely outcome of reclamation efforts can be assessed by comparing soil productivity observed in the greenhouse experiments with soil productivity under theoretically ideal conditions. Soil productivity is measured as the amount of vegetation that can be potentially supported by the soil, as measured in pounds of vegetation per acre. The theoretically ideal level of soil productivity is represented by the historic climax plant community, which is the natural community of native plants that eventually would reoccupy the site with proper management. These historical climax plant communities have been

identified for different regions using the Natural Resources Conservation Service (2010a) Ecological Site Descriptions. Based on the ecological site descriptions, acceptable soil productivity for the Rosemont area ranges from roughly 450 to 2,400 pounds of vegetation per acre, as shown in table 18 (Fehmi et al. 2008).

Table 18. Soil productivity based on ecological site descriptions (in pounds per acre)

Ecological Site	Low Value	Representative Value	High Value
Clay-loam upland 16 to 20	451	1,072	1,525
Loamy slopes 12 to 16	425	902	1,501
Loamy slopes 16 to 20	761	1,515	2,342
Loamy upland 12 to 16	617	997	1,794
Sandy loam upland 16 to 20	1,080	1,639	2,367

Source: Natural Resources Conservation Service (2010a).

Three material types from the Rosemont area were tested by the University of Arizona to represent future waste rock or tailings: Gila, Glance, and Arkose materials. These materials are not technically soils; rather, they were created by mixing the top 3 meters of the soil profile, much as would happen during mining activities. The Gila material was collected at a location characterized by the Hathaway gravelly sandy loam soil type (HaF). The Glance material was collected at a location characterized by Chiricahua cobbly sandy loam (CoE). The Arkose material was collected at a location characterized by Casto very gravelly sandy loam (CmE). These soil samples were collected from private land.

Greenhouse results for the recommended seed mix grown in Gila and Glance materials were within the acceptable soil productivity range: 1,010 and 1,080 pounds of vegetation per acre, respectively. Arkose material, however, showed limited productivity, at 290 pounds of vegetation per acre, which suggests this particular material might have limited revegetation potential. These limitations were primarily because of the generally coarser texture of the material and its lack of ability to retain water. The researchers concluded that mixing it with the other soil types—as would be expected during mining—would likely improve its performance.

The University of Arizona greenhouse studies represent potential results under ideal conditions: adequate water, stable growth media, minimal slopes, and thorough and even seed coverage. While these studies have resulted in selection of a seed mix with the best likelihood of establishing vegetation, they do not represent expected real-world conditions. Actual revegetation potential is likely to be overall less successful and variable. Some areas likely would match the results indicated by the greenhouse studies; other areas may experience much less revegetation or may not revegetate at all. Such factors as drought conditions, slope instability, aggressive exotic vegetation (such as Lehmann lovegrass), poor growth media, and incomplete or patchy seed coverage could reduce revegetation potential.

Current conditions at the site are degraded from historic climax conditions, although they are still considered satisfactory. Based on the research conducted by the University of Arizona, use of the selected seed mix could potentially result in revegetation on waste rock and tailings piles that would approximate native vegetative conditions.

In practice, revegetation would only be considered complete when certain reclamation criteria have been met. Draft criteria are described below; these criteria could be modified prior to implementation. The following descriptions apply primarily to the waste rock and tailings piles but may also apply to

other revegetated areas. The timelines begin as soon as work on an area is considered "final" (i.e., waste rock cap graded, growth media placed, and seeding completed). If the following minimum revegetation criteria are not met, additional work would be needed. Compacted and rilled soils should be addressed appropriately and areas reseeded.

Per 30-square-meter area:

- At the end of the second monsoon season, 15 grasses per square meter (i.e., every plot must have 15 grass plants growing)
- At the end of the second monsoon season, 5 trees, shrubs, or cacti (i.e., every 30-square-meter area must have 5 larger species of plants growing)
- At the end of year 10, if the plant community is not making sufficient progress toward meeting year 20 conditions, additional work is needed. Compacted and rilled soils should be addressed appropriately and areas reseeded and/or planted.
- At year 20, the area is dominated by a robust cover of native perennial grasses and sub-shrubs, with randomly scattered and irregular clusters of large shrubs, trees, and succulents. Tree canopy cover may include species like Emory oak, Arizona white oak, alligator and oneseed junipers, and mesquite. The grass species include a variety of grama grasses (genus *Bouteloua*), including black, sideoats, slender, sprucetop, Santa Rita, and hairy gramas. Other grasses include wolftail, Arizona muhly, bullgrass, plains lovegrass, and Orcutt's threeawn. Shrubs and forbs include ocotillo, false mesquite, spreading ratany, shrubby buckwheat, Gregg's dalea, yerba de pasmo, Palmer's agave, mimosa species, manzanita, skunkbush, beargrass, wire lettuce, penstemon, and snake cotton. Gravel and rock cover is up to 65 percent. Plant basal cover is a minimum of 7 percent. Canopy cover is a minimum of 20 percent for perennial grasses and 5 percent for shrubs and succulents. Larger plants are growing individually and in irregular clusters in patterns similar to adjacent landscapes. Short-lived and cover crop species may be seen in very small quantities. Noxious weeds are absent.

Expected Progression of Plant Communities and Reclamation Efforts

Expected revegetation of the site would occur in stages as the concurrent reclamation takes place. The following tables represent an estimate of those stages. Descriptions are based on the general ecosystem survey (Shaw et al. 1991). The proposed tailings and waste rock piles would be oriented northeast-southwest, resulting in more east and west aspects than north and south. For the purpose of describing the expected effects, the east aspects are predicted to respond like the north aspects, and the west aspects are predicted to respond like the south aspects. In general, reclamation of flat areas is more successful than sloped areas, and southern slopes are more successful than northern slopes. The mix of grasses is based on the seed mix developed through the University of Arizona greenhouse research (Fehmi et al. 2008). Fehmi et al. (2008) recommend not planting juniper or mesquite trees; however, these species would become established naturally on the disturbed site. Gradient is assumed to be generally 3:1 (horizontal: vertical).

Five to 10 Years — Probable conditions after 5 years from the start of the operation—which would mean that less than 10 percent of the total material would be handled and either processed or stored as waste—are difficult to predict. Most of the area scheduled for becoming waste rock storage would still be undisturbed by mining activities. The beginning of the buttress and the first lift may have a few scattered plants but certainly no trees.

After 10 years, about 20 percent of the total material would be handled. The first lift areas may have some plants established (table 19).

Twenty Years — After 20 years, the entire operation should be complete, and reclamation should be established (table 20).

One Hundred Years — After 100 years (80 years after closure), reclamation conditions shown in table 21 would be expected.

For any alternative that promotes large areas of gentle slopes (flat or 25:1), there should be the potential for more plant basal areas. The short time frames may not produce this, but the long range may (table 22). A comparison of overall expected reclamation success after 100 years with historical climax conditions is shown in table 23.

Differences in Reclamation Landforms between Alternatives

Overall reclamation success is expected to be largely the same for all action alternatives, although there are slight differences. The areas unable to be reclaimed, primarily the open pit, are identical for all alternatives. However, the alternatives differ in the type of landforms and orientation of slopes created by the tailings and waste rock piles, which in turn would affect the overall amount of vegetation under eventual climax conditions (see tables 14 and 23). Approximate landform differences between alternatives and slope orientation are shown in table 24.

The proposed action and Phased Tailings Alternative provide the greatest amount of flat areas (900 to 1,100 acres) on which revegetation potential (measured by vegetation basal area) is typically greater than that of slopes, while the Barrel and Barrel Trail Alternatives provide the least amount of flat areas (500 acres). The proposed action and Scholefield-McCleary Alternative provide the greatest amount of south-facing slopes, while the Barrel and Barrel Trail Alternatives have the least amount of south-facing slopes and the greatest amount of north-facing slopes.

The estimates of expected vegetation basal area presented in table 23 and the slope aspects presented in table 24 are rough estimates of revegetation potential, as reflected by the large possible range in table 23 (from 10 to 25 percent vegetation basal area). Reclamation design and implementation are more important factors in overall reclamation success. While certain alternatives may have somewhat better slope aspects for reclamation, this is not enough to determine that reclamation might be more successful for one alternative than another.

Proposed Action and Action Alternatives

There are no impacts specific solely to the action alternatives.

Table 19. Estimated reclamation success after 5 to 10 years

Elevation (feet)	Aspect	Grasses and Forbs	Trees and Shrubs	Basal Area or Grasses	Canopy of Trees and Shrubs	Tree and Shrub Height
4,500 to 5,000	South and west	Grasses: green sprangletop, red three-awn, blue grama, Arizona cottontop, curly mesquite, sideoats grama, bottlebrush squirreltail Forbs: desert marigold, Mexican gold poppy	Shrubs: catclaw and mesquite (expected as occasional volunteers)	0 to 2%	0%	No trees or shrubs
4,500 to 5,000	North and east	Same as above	Shrubs: catclaw and mesquite (expected as occasional volunteers), false mesquite	0 to 10%	<1%	Shrubs to 1.5 feet tall No trees
5,000 to 6,000	South and west	Same as above	Shrubs: ocotillo (if it is planted), mesquite (expected as occasional volunteers), false mesquite	0 to 2%	<1%	Shrubs to 3 feet (ocotillo may be 6 feet if mature individuals are planted) No trees
5,000 to 6,000	North and east	Same as above	Shrubs: catclaw and mesquite (expected as occasional volunteers), false mesquite	0 to 5%	<1%	Shrubs to 1.5 feet tall No trees

Table 20. Estimated reclamation success after 20 years

Elevation (feet)	Aspect	Grasses and Forbs	Trees and Shrubs	Basal Area or Grasses	Canopy of Trees and Shrubs	Tree and Shrub Height
4,500 to 5,000	South and west	Grasses: green sprangletop, red three-awn, blue grama, Arizona cottontop, curly mesquite, sideoats grama, bottlebrush squirreltail Forbs: desert marigold, Mexican gold poppy	Shrubs: catclaw and mesquite (expected as occasional volunteers), false mesquite	10% on the oldest parts of the piles, 0 to 2% on the newer parts	<1%	Shrubs to 3 feet tall in oldest reclamation areas, 1.5 feet tall in more recent (<10) years No trees
4,500 to 5,000	North and east	Same as above	Shrubs: manzanita, beargrass, desert spoon, Mearns sumac (if planted), false mesquite Trees: alligator juniper (expected as occasional volunteers), pinyon pine, Emory oak (if planted)	10% on the oldest parts of the piles, 0 to 2% on the newer parts	1 to 5% on the oldest parts of the piles, <1% on the newer parts	Shrubs to 3 feet tall in oldest reclamation areas, 1.5 feet tall in more recent (<10) years Trees 4 feet tall in oldest areas, seedlings less than 3 feet tall in more recent (<10) years
5,000 to 6,000	South and west	Same as above	Shrubs: ocotillo, beargrass (if planted), mesquite (expected as occasional volunteers), false mesquite	10% on the oldest parts of the piles, 0 to 2% on the newer parts	1 to 5% on the oldest parts of the piles, <1% on the newer parts	Shrubs to 3 feet tall in oldest reclamation areas, 1.5 feet tall in more recent (<10) years No trees
5,000 to 6,000	North and east	Same as above	Shrubs: cercopcarus, manzanita (if planted), false mesquite Trees: alligator juniper (expected as occasional volunteers), pinyon pine, Emory oak (if planted)	10% on the oldest parts of the piles, 0 to 2% on the newer parts	1 to 5% on the oldest parts of the piles, <1% on the newer parts	Shrubs to 3 feet tall in oldest reclamation areas, 1.5 feet tall in more recent (<10) years Trees to 4 feet tall in oldest areas, seedlings less than 3 feet tall in more recent (<10) years

Table 21. Estimated reclamation success after 100 years

Elevation	Aspect	Grasses and Forbs	Trees and Shrubs	Basal Area or Grasses	Canopy of Trees and Shrubs	Tree and Shrub Height
4,500 to 5,000	South and west	Grasses: green sprangletop, red three-awn, blue grama, Arizona cottontop, curly mesquite, sideoats grama, bottlebrush squirreltail Forbs: desert marigold, Mexican gold poppy	Shrubs: catclaw and mesquite, false mesquite	20%	15%	Shrubs 1.5 to 3 feet tall No trees
4,500 to 5,000	North and east	Same as above	Shrubs: manzanita, beargrass, desert spoon, Mearns sumac, false mesquite Trees: alligator juniper, pinyon pine, Emory oak	15%	50%	Shrubs 1.5 to 3 feet tall Trees 8 to 20 feet tall, occasional seedlings less than 3 feet tall
5,000 to 6,000	South and west	Same as above	Shrubs: ocotillo, beargrass, mesquite, false mesquite	10%	5%	Shrubs 1.5 to 3 feet tall No trees
5,000 to 6,000	North and east	Same as above	Shrubs: cercocarpus, manzanita, false mesquite Trees: alligator juniper, pinyon pine, Emory oak	10%	30%	Shrubs 1.5 to 3 feet tall Trees 8 to 20 feet tall, occasional seedlings less than 3 feet tall

Table 22. Estimated reclamation success after 100 years for flat areas

Elevation	Aspect	Grasses and Forbs	Trees and Shrubs	Basal Area or Grasses	Canopy of Trees and Shrubs	Tree and Shrub Height
4,500 to 5,000	South and west	Grasses: green sprangletop, red three-awn, blue grama, Arizona cottontop, curly mesquite, sideoats grama, bottlebrush squirreltail Forbs: desert marigold, Mexican gold poppy	Shrubs: catclaw and mesquite, false mesquite	25%	15%	Shrubs 1.5 to 3 feet tall No trees
4,500 to 5,000	North and east	Same as above	Shrubs: manzanita, beargrass, desert spoon, Mearns sumac, false mesquite Trees: alligator juniper, pinyon pine, Emory oak	20%	50%	Shrubs 1.5 to 3 feet tall Trees 8 to 20 feet tall, occasional seedlings less than 3 feet tall
5,000 to 6,000	South and west	Same as above	Shrubs: ocotillo, beargrass, mesquite, false mesquite	10%	5%	Shrubs 1.5 to 3 feet tall No trees
5,000 to 6,000	North and east	Same as above	Shrubs: cercocarpus, manzanita, false mesquite Trees: alligator juniper, pinyon pine, Emory oak	10%	30%	Shrubs 1.5 to 3 feet tall Trees 8 to 20 feet tall, occasional seedlings less than 3 feet tall

Table 23. Expected overall success of reclamation after 100 years

	Vegetation Basal Area Historic Climax	Vegetation Basal Area Reclaimed	Canopy Cover Historic Climax	Canopy Cover Reclaimed
South-facing slopes	20%	10 to 20%	15%	5 to 15%
North-facing slopes	15%	10 to 15%	50%	30 to 50%
Flats	25%	10 to 25%	15%	5 to 50%

Table 24. Difference in reclamation landforms between alternatives

Alternative	Open Pit (Approximate Acreage)	Flat Areas (Approximate Acreage)	North (Approximate Slope Direction for Waste Rock and Tailings)	South (Approximate Slope Direction for Waste Rock and Tailings)	West (Approximate Slope Direction for Waste Rock and Tailings)	East (Approximate Slope Direction for Waste Rock and Tailings)
Proposed action	950	900	9%	26%	36%	29%
Phased Tailings	950	1,100	11%	20%	37%	32%
Barrel	950	500	30%	13%	22%	34%
Barrel Trail	950	500	30%	13%	22%	34%
Scholefield-McCleary	950	800	9%	24%	29%	38%

Cumulative Effects

The Council on Environmental Quality defines a cumulative impact as “the impact on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable actions regardless of what agency (federal or nonfederal) or person undertakes such other actions” (40 Code of Federal Regulations 1508.7). As outlined in the chapter 3 introduction, cumulative impacts of past and present actions are identified and analyzed in the “Affected Environment” part of each resource section, including for “Soils.” 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 chapter 3 introduction. The following reasonably foreseeable actions from that list were determined to contribute to a cumulative impact to soils:

- Maintenance of roads, both forest and private, for support of permitted grazing operations.
- Potential expansion of limestone quarry in the Davidson Canyon drainage system northeast of the Santa Rita Mountains.

These activities would be expected to cause some soil disturbance within the same watershed as the soil disturbance caused by the proposed mine. Maintenance of roads is expected to cause minimal additional disturbance, as the soils associated with these roads have already been disturbed.

The expansion of the limestone quarry in the Davidson Canyon drainage system would be expected to have an impact to soil resources from direct ground disturbance and possible erosion. This project would increase the amount of disturbed soil in the watershed, which would affect watershed function, contributing to changes in flow in Davidson Canyon and sediment load.

Mitigation Effectiveness

Four mitigation measures are proposed that would avoid direct impacts on soil resources, or prevent or reduce erosion of soil resources. These are as follows: site design, use of dry-stack tailings, implementation of a mine reclamation plan, and revegetation activities, including salvage of topsoil resources.

The design of the proposed action and other action alternatives includes a mine footprint that is substantially smaller than conventional mines with similar production capacity. This is attributable to the use of dry-stack tailings technology; implementation of 3:1 (horizontal: vertical) side slopes on tailings and waste rock facilities; and a revegetation program on mine waste rock and mine tailings.

The use of dry-stack tailings facilities would also enhance reclamation, compared with the use of traditional tailing settling ponds. Filtered tailings would be transported, spread, and compacted to form an unsaturated, dense, stable tailings stack, which would include a surrounding rock and soil buttress seeded for revegetation.

A mine reclamation plan is required by Forest Service regulations and is subject to approval by the Arizona State mine inspector. The policy requires that disturbed lands shall be reclaimed to a condition that is consistent with forest land and resource management plans. Revegetation is one key aspect of the reclamation plan.

In order to enhance revegetation efforts, specifications and goals for the salvage, storage, and reuse of growth media (topsoil) from disturbed areas would be developed, with the goal of providing sufficient cover on all disturbed areas to be reclaimed. Unless otherwise specified, Rosemont Copper would provide for a minimum of 1 foot of growth media cover over final waste rock slopes, waste rock surfaces, waste rock benches, completed tailings buttress, water diversion fill slopes, plant site fill slopes, construction laydown areas, facility plant site following final removal of equipment, and temporary roads. The areas to be revegetated would be contoured, graded, prepared, and seeded. Storage of growth media would require placement of growth media stockpiles in locations that are protected from mining operations and associated activities, stable, isolated from surface water, gently sloping, and well drained. Stockpiles would be revegetated with native species no later than the first growth season following construction to minimize erosion. No persistent nonnative species would be used in reclamation except as specifically allowed and approved by the Forest Service, where some locally important nonnative species may already be established. Sediment control structures would be installed or other best management practices implemented as needed to protect growth media from loss. Finally, growth media stockpiles would be used quickly during concurrent reclamation to minimize the length of storage time.

The mitigation measures described above are already incorporated into the analysis of impacts to soil resources and will not further reduce described soil impacts.

Irretrievable and Irreversible Commitment of Resources

Soils are a finite resource, and any loss of soils resulting from their removal for tailings and waste rock storage and from erosion and delivery to downstream channels is irreversible. With respect to the proposed project, the loss of soil production from the locations in which they developed to the top of the tailings and waste rock piles is not irreversible because a stable new plant community would eventually develop. While not irreversible, redevelopment of soils would take many decades, with natural soil profiles likely not appearing for 50 to 100 years postclosure. However, the area of the

open pit does represent an irretrievable and irreversible loss of approximately 950 acres of soil that would not be reclaimed.

Air Quality and Climate Change

Introduction

The primary factors that influence regional air quality in the project area are the locations of air pollution sources, the quantity and chemical characteristics of the pollutants emitted by those sources, the topography of the region, and the local meteorological conditions. Potential direct and indirect impacts to air quality from the proposed project were assessed within spatial and temporal limits defined by the length of the project and anticipated pollutant dispersion range. The size of the analysis area for air quality can vary, depending on the air quality parameter being analyzed and the sensitivity of the impact receptor(s). Protection of National Ambient Air Quality Standards is assessed at the fence line (project boundary), near vicinity (5 to 10 kilometers), Saguaro National Park East, Saguaro National Park West, Chiricahua National Monument, Chiricahua Wilderness, Galiuro Wilderness, and Superstition Wilderness. The near-field air quality study area is an approximately 300-square-mile area centered on the project site that includes the mine operations, residential areas, and public land within Pima and Santa Cruz Counties (figure 23).

Reports by the Intergovernmental Panel on Climate Change (2007) and the U.S. Global Change Research Program (Karl et al. 2009; U.S. Global Change Research Program 2009) conclude that the climate is changing, that the change will accelerate, and that human caused emissions of greenhouse gases (in particular, carbon dioxide (CO_2)) are the primary cause of accelerated climate change. The primary factors that influence greenhouse gas emissions from the project are the combustion of fossil fuels in highway and nonroad vehicles for project construction, operations, and employee personal use and the combustion of fossil fuels in project processing equipment. The primary greenhouse gas emitted by these activities is CO_2; therefore, the analysis focuses on the emission of this gas. The analysis area for greenhouse gas emissions is generally limited to direct emissions occurring within the project area, although emissions from employees commuting in personal vehicles are also included. The analysis area for the effects of climate change on the project area is the southwest region of the United States, as defined by the U.S. Global Change Research Program (Karl et al. 2009). Projected impacts of climate change on the project area include changes to regional temperature and precipitation levels and patterns.

Issues, Cause and Effect Relationships of Concern

Construction, mining, and reclamation activities at the mine and along transportation and utility corridors may increase fugitive dust, airborne chemicals, and vehicular emissions in the project area and lead to a change in air quality in Class I and Class II airsheds. During construction of the project, temporary and localized increases in atmospheric concentrations of nitrogen dioxide (NO_2), carbon monoxide (CO), sulfur dioxide (SO_2), volatile organic compounds (VOCs), particulate matter less than or equal to 2.5 microns in diameter ($PM_{2.5}$), and particulate matter less than or equal to 10 microns in diameter (PM_{10}) would result from exhaust emissions of workers' vehicles, heavy construction vehicles, diesel generators, and other machinery and equipment. Increased emissions of fugitive dust would also result from clearing, excavation, and grading activities associated with mine, transportation, and utility corridor construction.

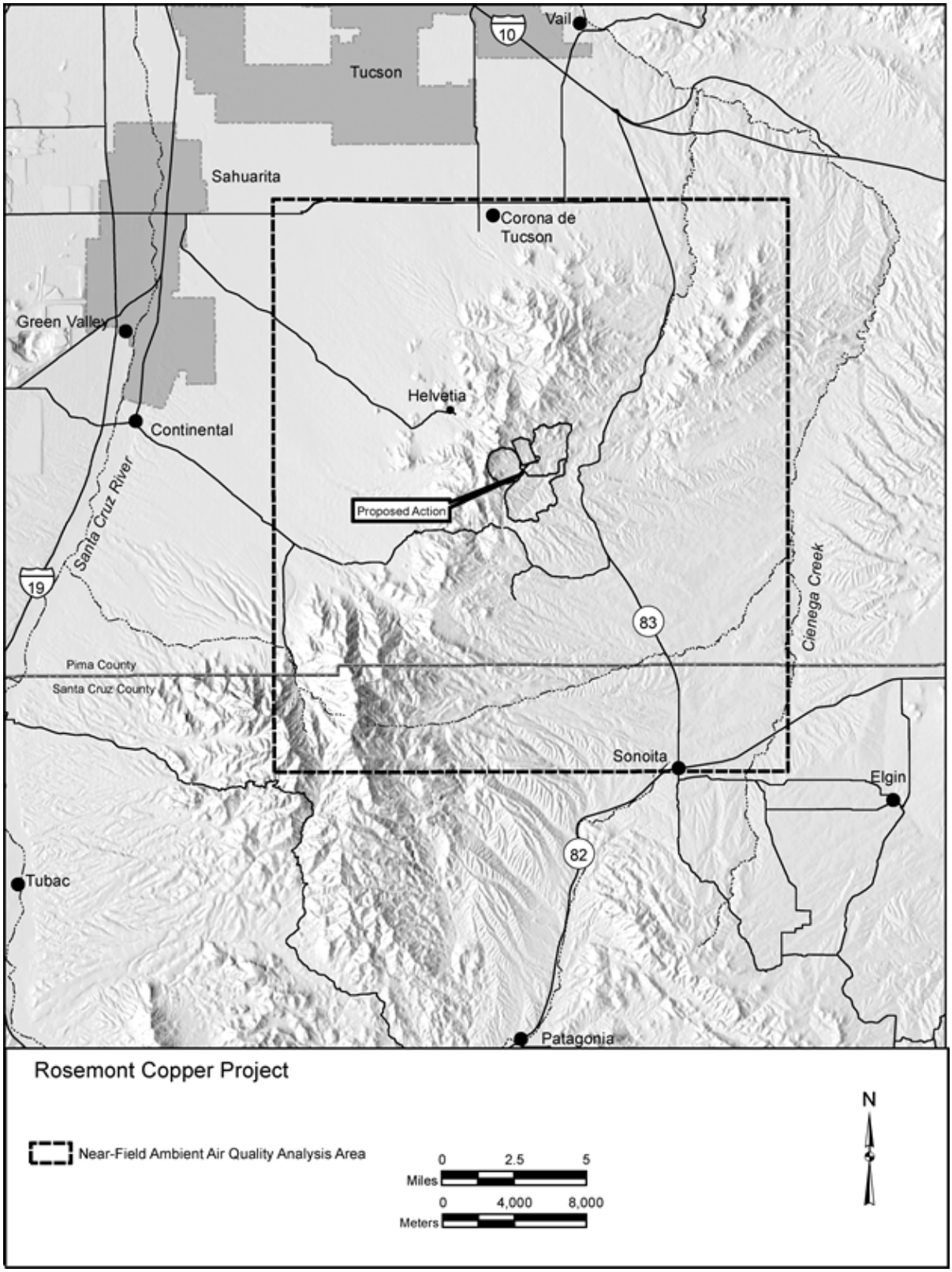


Figure 23. Near-vicinity analysis area for air quality

Mine operations would result in emissions of criteria and hazardous air pollutants. Mobile sources (worker and plant/facility vehicles) would provide an ongoing source of emissions for the life of the project. The project would also lead to decreased visibility and increased haze in the region, caused by increased particulate matter and pollutant emissions. Mine operations would also result in emissions of CO_2, a greenhouse gas linked to global warming and climate change.

Issue 2: Impact on Air Quality

Changes in air quality that may occur from the mine operation were identified as a significant issue. Construction, mining, and reclamation activities at the mine and along transportation and utility corridors would increase dust, airborne chemicals, and transportation related (mobile) emissions in the affected area. Air quality standards would be compromised. The Clean Air Act and other laws, regulations, policies, and plans set thresholds for air quality, including Class I airsheds. The emission of greenhouse gases has been implicated in global climate change, and the policy of the Federal Government is to reduce these emissions when possible (Executive Order 13514).

Greenhouse gases are those in the atmosphere that retain heat. They are natural and keep the earth from becoming too cold. The specific gases known as greenhouse gases are CO_2, methane (CH_4), nitrous oxide (N_2O), and fluorocarbons. CH_4, N_2O, and fluorinated gases would be emitted; however, the anticipated level of emissions of these gases is much smaller than the level of CO_2 emissions.

Issue 2 Factors for Alternative Comparison

- Particulate emission estimates, compared with background and threshold ($PM_{2.5}$, PM_{10})
- Greenhouse gas emission estimates, compared with background (tons) during construction, operation, and postclosure
- VOC and nitrogen oxide (NO_x) emissions and emissions rates to air
- Quantitative assessment of the ability to meet air quality standards

Analysis Methodology, Assumptions, Uncertain and Unknown Information

For both the air quality and greenhouse gas emissions analyses, the temporal bounds of analysis is defined by the four operational phases of the mine: construction, operation, reclamation, and closure. The total project life is anticipated to be 25 years. For the analysis of climate change impacts on the project area, the temporal bounds of analysis is defined by the best temporal resolution of existing studies on the region, at 2050 and 2100. The spatial analysis area is described below.

Predictive (Near-Field) Modeling Approach

Evaluation of air quality impacts from the proposed project to adjacent areas (up to 50 kilometers away, the near-field analysis area) was conducted using AERMOD, the U.S. Environmental Protection Agency's regulatory default model for near-field analysis. Model inputs and control parameter options were selected in accordance with the protocol established in the "User's Guide for the AMS/EPA Regulatory Model – AERMOD" (U.S. Environmental Protection Agency 2004). A detailed description of the AERMOD modeling approach, including modeling assumptions and data availability, is provided in the "Modeling Protocol to Assess Ambient Air Quality Impacts" for the project (Applied Environmental Consultants 2009b).

The U.S. Environmental Protection Agency VISCREEN screening model was applied to the proposed action in order to evaluate the effect of the emissions to visibility levels at the Saguaro East National

Park Class 1 area. VISCREEN is recommended by the U.S. Environmental Protection Agency to calculate the potential visual impact of a plume of specified emissions for specific meteorological conditions at Class 1 airsheds within 31 miles (50 kilometers) of an air pollution source.
The VISCREEN model uses steady-state, gaussian based plume dispersion techniques to calculate 1-hour concentrations within an elevated plume. The model calculates the change in the color difference index (ΔE) and contrast between the plume and the viewing background (U.S. Forest Service et al. 2010). The specified emissions used in this analysis are particulate matter, NO_x, soot, and sulfates. The meteorological conditions used in this analysis are the worst case scenario for wind speeds and atmospheric stability. A detailed description of the VISCREEN model used for this analysis is provided in "VISCREEN: Visibility Impacts Analysis at Saguaro East NP" (Applied Environmental Consultants 2011d).

Class I Area Related (Far-Field) Modeling Approaches

Evaluation of air quality impacts and potential effects on air quality related values from the project to Class I areas was conducted using CALPUFF Version 5.8, which is the recommended model for long-range transport applications (40 Code of Federal Regulations 51, "Revision to the Guidelines on Air Quality Models," November 2005). The CALPUFF modeling system includes three main components: CALMET, CALPUFF, and CALPOST. In the simplest terms, CALMET is a meteorological model that develops hourly wind and temperature fields on a 3-dimensional gridded modeling domain. CALPUFF is a transport and dispersion model that advects "puffs" of material emitted from modeled sources, simulating dispersion and transformation processes along the way. CALPOST is used to process these files, producing tabulations that summarize the results of the simulation. The CALPUFF model is also used to determine impacts to visibility at Class 1 airsheds that are greater than 31 miles (50 kilometers) away from an air pollution source. A detailed description of the CALPUFF modeling approach, including modeling assumptions and data availability, is provided in "CALPUFF Modeling Protocol for Rosemont Copper Project to Assess Impacts on Class I Areas" (Applied Environmental Consultants 2009a).

Climate Change

Greenhouse gas emissions sources included in the climate change analysis were point sources and mobile sources located within the project area. The analysis area for greenhouse gas emissions is the project area.

Uncertainty Regarding Climate Change

Although it is possible to quantify a project's direct effects on greenhouse gas emissions, the actual intensity of individual project indirect effects on global climate is uncertain. Uncertainty in climate change effects is expected because it is not possible to meaningfully link individual project actions to quantitative effects on climatic patterns.

Climate change is a global problem that results from global greenhouse gas emissions. There are more sources and actions emitting greenhouse gases (in terms of both absolute numbers and types) than are typically encountered when evaluating the emissions of other pollutants. These emissions are often categorized as either anthropogenic (human caused) or nonanthropogenic (naturally occurring). From a quantitative perspective, there is no single dominating anthropogenic source and fewer sources that would even be close to dominating total greenhouse gas emissions. The global climate change problem is much more the result of numerous and varied sources, each of which might seem

to make a relatively small addition to global atmospheric greenhouse gas concentrations. Currently, there are no sites within the study area that are collecting ambient greenhouse gas data. Ambient background data that exist are parametrically derived from fossil fuel combustion and other industrial sources.

Summary of Effects by Issue Measures by Alternative

Table 25 presents the summary comparison of impacts from each alternative. Emissions, and consequently impacts, will remain the same or less than the proposed action for all action alternatives based on equipment described and the number of hours it will operate. Distances driven will not affect total emissions per hour or year, as the same number of vehicles for the same number of hours will operate.

Table 25. Summary of effects

Issue Measure	No Action	Proposed Action	Phased Tailings	Barrel	Barrel Trail	Scholefield-McCleary
2: $PM_{2.5}$ versus background and threshold	No impact	2× increase versus background levels; maintenance of the National Ambient Air Quality Standards (NAAQS) threshold.	Same as proposed action	8.8× increase versus background levels; exceedance of the NAAQS threshold.	3.5× increase versus background levels; exceedance of the NAAQS threshold.	7.4× increase versus background levels; exceedance of the NAAQS threshold.
2: PM_{10} versus background and threshold	No impact	More than 3× increase versus background levels; near exceedance of NAAQS threshold.	Same as proposed action	4.6× increase versus background levels; exceedance of the NAAQS threshold.	5.2× increase versus background levels; exceedance of the NAAQS threshold.	14.1× increase versus background levels; exceedance of the NAAQS threshold.
2: Greenhouse gas emissions versus background	No impact	1% increase in Pima County CO_2 emissions.	Same as proposed action	Same as proposed action	Same as proposed action	Same as proposed action
2: VOC emissions	No impact	Less than 1% increase in Pima County VOC emissions; emission rate of about 105 tons per year.	Same as proposed action	Same as proposed action	Same as proposed action	Same as proposed action
2: NO_x emissions	No impact	4% increase in Pima County NO_x emissions; emission rate of about 1,250 tons per year; risk of exceedance of ozone NAAQS threshold in Tucson area.	Same as proposed action	4% increase in Pima County NO_x emissions; 6.7× increase versus background levels; near exceedance of the NAAQS threshold.	4% increase in Pima County NO_x emissions; 7.1× increase versus background levels; exceedance of the NAAQS threshold.	4% increase in Pima County NO_x emissions; 8.4× increase versus background levels; exceedance of the NAAQS threshold.

Issue Measure	No Action	Proposed Action	Phased Tailings	Barrel	Barrel Trail	Scholefield-McCleary
2: Effects on air quality in Class I airsheds	No impact	Causes and contributes to degradation of visibility in the Saguaro National Park East and Galiuro Wilderness Area Class I airsheds.	Same as proposed action	Same as proposed action	Same as proposed action	Same as proposed action
2: Effects on air quality outside Class I airsheds	No impact	Risk of exceedance of ozone and PM_{10} NAAQS thresholds in the Tucson and Saguaro National Park East areas	Same as proposed action	Same as proposed action	Same as proposed action	Same as proposed action
2: Meeting of air quality standards	No impact	Risk of exceedance of PM_{10} and ozone NAAQS thresholds in the Tucson and Saguaro National Park East areas; risk of exceedance of NO_2 1-hour standards; causes and contributes to degradation of visibility in the Saguaro National Park East and Galiuro Wilderness Area Class I airsheds.	Same as proposed action	Same as proposed action	Same as proposed action	Same as proposed action

Affected Environment

Relevant Laws, Regulations, Policies, and Plans

Mine operations are subject to a wide range of Federal, State, and local requirements. Many of these require permits before the mine operations begin; others may require approvals or consultations, mandate the submission of various reports, and/or establish specific prohibitions or performance based standards. Table 26 provides a summary of air quality laws, regulations, policies, and plans at the Federal, State, and local level.

Table 26. Air quality laws, ordinances, regulations, and standards

Laws, Ordinances, Regulations, and Standards	Description	Applicability
Federal		
Federal New Source Review (NSR)/Prevention of Significant Deterioration (PSD), 40 Code of Federal Regulations (CFR) 51, subpart I, and 40 CFR 52.2(1)	The PSD program was developed to prevent significant deterioration in the air quality of those areas that meet the National Ambient Air Quality Standards (NAAQS). In general, the NSR/PSD rules define a "major source" as any source with the potential to emit 250 tons per year (tpy) or more of a criteria pollutant. A more stringent threshold is defined for a limited number of "categorical sources," source categories for which the PSD applicability threshold is 100 tpy of any criteria pollutant.	Based on the estimated maximum potential emissions for the proposed mine operation, the project would not be a "major source;" therefore, the NSR/PSD programs do not apply to this project.
New Source Performance Standards (NSPS), 40 CFR 60	The federal NSPS are technology-based standards applicable to new and modified stationary sources of regulated air emissions. While the NAAQS emphasize air quality in general, the NSPS focus on particular sources of pollutants. The NSPS program sets uniform emission limitations for approximately 70 industrial source categories or subcategories of sources that are designated by size as well as type of process.	The NSPS are applicable to metallic mineral-processing plants. A processing plant is defined as "any combination of equipment that produces metallic mineral concentrates from ore; metallic mineral processing commences with the mining of the ore." NSPS particulate emission concentration standards apply only to stack emissions.
NAAQS, 40 CFR 50	The establishment of the NAAQS set maximum concentrations in ambient air for lead, NO_x, SO_2, CO, suspended PM_{10}, and ozone.	Rosemont Copper must demonstrate that the proposed project would not result in exceedances or violations of applicable NAAQS.
National Emission Standards for Hazardous Air Pollutants (NESHAP), 40 CFR 61 and 63	NESHAP rules address health concerns that are considered too localized to be included under the scope of NAAQS. In general, NESHAP regulations apply to affected sources that are located at (or are themselves) major sources of hazardous air pollutant (HAP) emissions, as defined in 40 CFR 63.2. That is, any stationary source that emits or has the potential to emit (considering controls in the aggregate) 10 tpy or more of any single HAP or 25 tpy or more of any combination of HAPs.	Based on the estimated, maximum potential emissions for the proposed mine operation, the project would not be a "major HAP source;" therefore, NESHAP does not apply to this project.
Acid Rain Program Emission Monitoring, 40 CFR 72 and 75	The U.S. Environmental Protection Agency (EPA) established a program to control emissions that contribute to the formation of acid rain. The overall goal of the Acid Rain Program is to achieve significant environmental and public health benefits through reductions in emissions of SO_2 and NO_x, the primary causes of acid rain. The acid rain regulations are applicable to "affected units" as defined in the regulations.	Mine operations are not regulated under the Acid Rain Program. Based on the estimated maximum potential emissions for the proposed mine operation, the project would not be a major source of SO_2 emissions.
Regional Haze Rule, 40 CFR 51	The Regional Haze Rule addresses visibility impairment in national parks and wilderness (Class I) areas.	Under PSD requirements, a new source of criteria and air toxics emissions must analyze its impacts to Class I areas, including visibility and regional haze.

Laws, Ordinances, Regulations, and Standards	Description	Applicability
Compliance Assurance Monitoring Program, 40 CFR 64	The federal regulations implementing compliance-assurance monitoring apply to major sources that must obtain a Title V operating permit pursuant to 40 CFR 70. The compliance-assurance monitoring rules are primarily aimed at emission units that are individually above major source thresholds and that use control devices in order to comply with an emission limitation (40 CFR 64.2).	The proposed mine is not a major source of criteria pollutants; consequently, the facility would not be subject to compliance-assurance monitoring requirements.
Accidental Release Prevention Program/Risk Management Plans, 40 CFR 68	The Accidental Release Prevention Program applies to facilities that may store quantities of toxic or flammable chemicals above listed thresholds. The requirements include process hazards analyses, implementation of work practices to prevent releases, and development of site-specific risk management plans.	Based on its process and design, the proposed mine would not store onsite quantities of listed chemicals above the thresholds listed in 40 CFR 68; therefore, this program would not be applicable to the facility.
Stratospheric Ozone Protection Regulations, 40 CFR 82, subpart F	Under Title VI of the Clean Air Act (CAA), the EPA is responsible for programs that protect the stratospheric ozone layer.	Processes at the planned mine would not involve the use of chlorofluorocarbon compounds. Therefore, these operations would not be subject to chlorofluorocarbon related regulations.
General Conformity Analysis, 40 CFR 51, subpart W, and 40 CFR 93	States and local authorities have the responsibility for bringing their regions into compliance with NAAQS or more stringent standards they may adopt. State implementation plans (SIPs) are EPA-approved plans that set forth the pollution control requirements applicable to the various sources addressed by each SIP. Federal actions must be evaluated for conformity to the local SIP if the project: (1) is located within an EPA-designated nonattainment or maintenance area, (2) would result in emissions above major source threshold quantities of a criteria pollutants, (3) is not a listed exempt action, and (4) has not been accounted for in an EPA-approved SIP.	The project site is in attainment for all criteria pollutants, but the greater Tucson area contains a PM_{10} nonattainment area and a CO maintenance area. The Forest Service must demonstrate that the project would do the following: (1) conform to an enforceable State, Tribal, or Federal implementation plan; (2) not cause or contribute to new violations of an ambient standard; (3) not increase the severity or frequency of existing violations; and (4) not otherwise delay achieving attainment of the NAAQS.
Arizona		
49 Arizona Revised Statutes; 18 Arizona Administrative Code	The policies, regulations, and responsibilities of the Arizona Department of Environmental Quality, including State and County air pollution control measures, are defined in 49 Arizona Revised Statutes and 18 Arizona Administrative Code.	The State of Arizona has the primary authority in the state for air pollution control and abatement and is responsible for administration of the Clean Air Act under EPA Region IX.

Laws, Ordinances, Regulations, and Standards	Description	Applicability
Pima County		
17 Pima County Municipal Code	Pima County Department of Environmental Quality (PDEQ) periodically updates and conforms to the CFR in an effort to achieve consistency and accuracy in 17 Pima County Municipal Code. The PDEQ is adopting new and updated incorporations by reference of the following federal regulations: Acid Rain Program, NESHAP, NSPS, and other parts of 40 CFR.	PDEQ is the local air pollution control agency for Pima County with jurisdiction over air pollution sources not under State jurisdiction and delegated authority from the State. PDEQ is responsible for monitoring the ambient air quality of the region by collecting and analyzing air quality data. Point source emissions of criteria pollutants from the facility will be less than the Title V source threshold of 100 tpy. Consequently, the facility will operate under a Class II permit issued by the PDEQ.
Town of Sahuarita		
General Plan	The Town of Sahuarita's General Plan is a comprehensive effort to guide decisionmakers and staff in planning for the future of the Town. The Town has a land ordinance that requires dust mitigation on roads and is enforced by the Town engineer. Additionally, paving of new roads is encouraged by the Town engineer to alleviate air quality concerns.	Coordinate with Pima Association of Governments, Pima County, and the State of Arizona to attain regional air quality goals.

Existing Conditions

Local and Regional Climate

The project area lies in one of the most distinctive regions of Arizona, with a mixture of desert plains, lush grasslands, and pine-topped mountains. The climate is semiarid, with precipitation varying by season and with elevation. The 30-year normal (1971 to 2000) annual average precipitation for the Santa Rita Experimental Range station (approximately 5 miles northwest of the project area) is 23.41 inches (Western Regional Climate Center 2009). Over this 30-year period, nearly one-half of the precipitation occurred in July, August, and September. The smallest amount of precipitation occurred in April, May, and June.

Temperatures regionally are moderate to extreme, with maximums and minimums also varying with elevation. The 30-year normal average monthly maximum temperatures at the Santa Rita Experimental Range station ranged from a low of 60.4 degrees Fahrenheit (°F) in January to a high of 93.3°F in June. Average monthly minimum temperatures ranged from a low of 37.5°F in December and January to a high of 66.8°F in July (table 27). Temperature inversions can occur throughout the year but are most intense in the winter, trapping pollutants in a cold air layer near the surface until the air is heated and able to rise and mix with other air layers. During colder winter mornings, vehicular pollutant concentrations increase in the area because of stagnant air conditions, especially in areas of heavy vehicle congestion.

Winds predominantly flow from the west to the east, corresponding to the slope of the terrain from the higher mountain elevations to the west and the lower canyon elevations to the east. Figure 24 shows the distribution of wind direction and wind speed at the project area during 2008. Hot, humid,

and windy conditions during the summer monsoon period contribute to naturally occurring windblown dust in the region, although dust storms may be exacerbated by land disturbances that destroy soil crusts and/or result in the removal of vegetation.

Table 27. Climatological summary, Santa Rita Experimental Range, Arizona, 1971 to 2000

Month	Average Temperature (°F)	Average Daily Maximum Temperature (°F)	Average Daily Minimum Temperature (°F)	Average Precipitation (inches)	Monthly Maximum Precipitation (inches)
January	49.0	60.4	37.5	1.73	4.71
February	52.0	64.3	39.7	1.66	5.19
March	55.9	68.6	43.2	1.78	5.21
April	62.2	76.0	48.3	0.66	3.11
May	69.8	83.8	55.8	0.30	1.65
June	79.0	93.3	64.6	0.55	3.30
July	79.4	92.0	66.8	4.83	11.15
August	77.2	89.1	65.2	4.26	8.02
September	74.4	86.5	62.3	2.40	8.31
October	66.6	78.6	54.5	2.06	7.87
November	55.3	67.7	42.8	1.30	4.36
December	49.1	60.7	37.5	1.88	7.29
Annual	**64.2**	**76.8**	**51.5**	**23.41**	**11.15**

Source: (Western Regional Climate Center 2009).

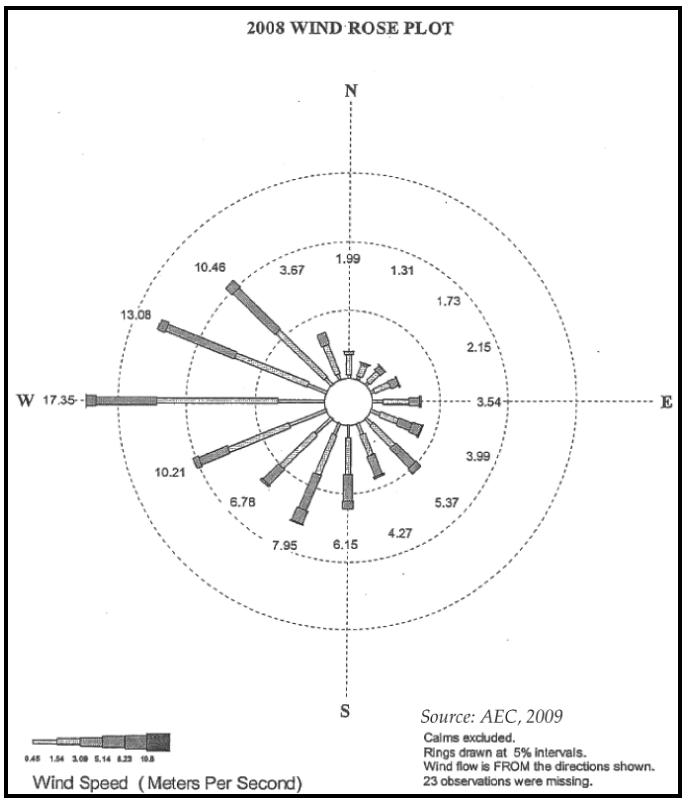


Figure 24. Distribution of winds (percent) at the project site

Local and Regional Air Quality

National Ambient Air Quality Standards

As directed by the Federal Clean Air Act, the U.S. Environmental Protection Agency has established National Ambient Air Quality Standards for seven "criteria" pollutants (table 28). These standards were adopted by the U.S. Environmental Protection Agency to protect public health (primary standards) and public welfare against decreased visibility as well as damage to animals crops, vegetation and buildings (secondary standards). The seven pollutants are CO, NO_2, ozone (O_3), inhalable particulate matter (PM_{10}), fine particulate matter ($PM_{2.5}$), SO_2, and lead (Pb). States and other delegated entities are required to adopt standards that are at least as stringent as the National Ambient Air Quality Standards. The Arizona Ambient Air Quality Standards and Pima County Ambient Standards are identical to the National Ambient Air Quality Standards (40 Code of Federal Regulations 50.4–50.16; 18 Arizona Administrative Code Chapter 2, Article 2, Sections 201–206: Pima County Code Title 17 Chapter 17.08). The Pima County Department of Environmental Quality has original jurisdiction pursuant to state law and receives delegated authority from the U.S. Environmental Protection Agency to implement and enforce applicable federal air quality standards in Pima County.

Table 28. National Ambient Air Quality Standards

Pollutant	Averaging Time	Primary Standards micrograms per cubic meter (µg/m³) (parts per million (ppm))	Secondary Standards µg/m³ (ppm)
CO	1-hour	40 (35)[c]	–[e]
CO	8-hour	10 (9)	–[e]
NO_2	1-hour	189 (0.100)	–[e]
NO_2	Annual	100 (0.053)	100 (0.053)
O_3	1-hour[a]	(0.12)	(0.12)
O_3	8-hour	(0.075)	(0.075)
PM_{10}	24-hour	150	150
PM_{10}	Annual[b]	50	50
$PM_{2.5}$	24-hour	35[d]	35[e]
$PM_{2.5}$	Annual	15	15
SO_2	3-hour	–[e]	1300 (0.5)
SO_2	1-hour	195 (0.075)[f]	–[e]
Pb	Rolling 3-month average	0.15[g]	0.15[g]

Source: 40 Code of Federal Regulations 50.

[a] 1-hour standard revoked in Arizona 6/15/05

[b] Annual standard revoked effective 12/18/06

[c] milligrams per cubic meter (ppm)

[d] New 24-hour standard effective 12/18/06

[e] No standard

[f] New standard effective 06/02/10

[g] New standard effective 01/12/09

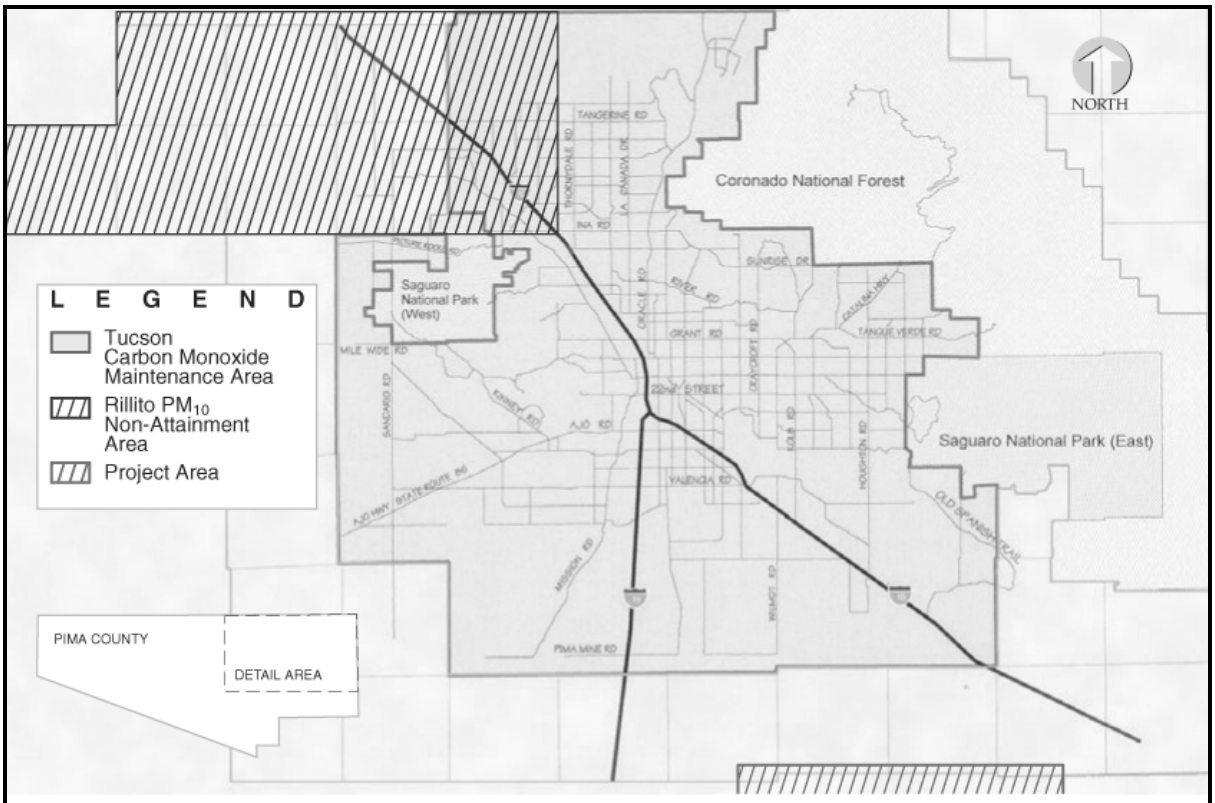
The air quality in Tucson and surrounding areas is generally within compliance; criteria pollutant levels are normally below the Federal and State health standards. However, the Tucson region does contain an area for which PM_{10} levels exceed the National Ambient Air Quality Standards (a "nonattainment area"); it also contains an area for which CO levels exceeded health standards in the past but for which, through management of area emissions, the levels have been reduced to meet

existing standards (a "maintenance area"). Sources of pollution in the region include on-road, nonroad, area, and point sources. On-road sources include cars, trucks, buses, motorcycles, and any other motorized road vehicle. Nonroad sources include construction and mining equipment, lawn equipment, and any other motorized nonroad equipment. Area sources include residential fireplaces, woodstoves, or unpaved lots. Point sources include power plants, cement plants, mining operations, and any other emission source with a single point of pollution release.

The major pollutants in the Tucson region are CO, particulate matter, and O_3. Mobile sources are the largest emission source in the region and are the largest contributor to levels of CO and NO_x, one of the precursors to the formation of O_3. Area and point sources are the largest contributors to levels of particulate matter.

Clean Air Act Attainment Status

Based on National Ambient Air Quality Standards, the Clean Air Act requires that states classify air basins (or portions thereof) as either attainment or nonattainment with respect to the criteria pollutants. A particular geographic region may be designated an attainment area for some pollutants and a nonattainment area for others. The project is within the Pima Intrastate Air Quality Control Region and is classified as "attainment" (better than national standards) or nonclassifiable/attainment for total suspended particulates, PM_{10}, CO, SO_2, NO_2, and O_3 (40 Code of Federal Regulations 81.303). Regionally, the Tucson area contains a PM_{10} nonattainment area and a CO maintenance area; the remaining criteria pollutants are in attainment (figure 25).



Source: PAG, 2005

Figure 25. Nonattainment and maintenance areas

Recent Air Quality Monitoring Data and National Ambient Air Quality Standards Exceedances

The Pima County Department of Environmental Quality and Arizona Department of Environmental Quality maintain a network of air quality monitoring sites throughout Pima County. The locations of the Pima County Department of Environmental Quality monitoring sites are presented in figure 26. The assessment of existing criteria pollutants levels in the area is based on data collected and reported by the Pima County Department of Environmental Quality in 2008, 2009, and 2010 (Pima County Department of Environmental Quality 2009a, 2009b, 2011). Monitoring results are provided in table 29.

Carbon Monoxide

CO is formed from the combustion of carbon based products. Of the criteria pollutants, CO is one of the most commonly occurring pollutants in Pima County. Motor vehicles are the primary source of CO in the Tucson area; total emissions of CO per vehicle-mile traveled exceed all other pollutants combined. In 2008, the Pima County Department of Environmental Quality operated six CO monitoring sites; none of these sites reported an exceedance of either the 1- or 8-hour standard.

Nitrogen Dioxide

NO_2 is a gas that forms primarily when fuel is burned at high temperatures; common sources include vehicle exhaust or industry/power plant emissions. NO_2 is a precursor to O_3 and can contribute to haze and visibility reduction. Ambient concentrations of NO_2 are well below the standard in the Tucson metropolitan area. In 2008, the Pima County Department of Environmental Quality operated two sites for the measurement of ambient concentrations of NO_2. There was no exceedance or violation of the National Ambient Air Quality Standards for NO_2.

Ozone

Stratospheric O_3 occurs naturally, but O_3 can also be formed at ground level from the reaction of VOCs and NO_x in the presence of heat and sunlight. In 2008, the Pima County Department of Environmental Quality operated nine O_3 monitoring sites. Maximum concentrations of O_3 were moderate to high, but no site had an exceedance of the 8-hour standard. The average 8-hour level across all O_3 monitoring stations was 0.068 part per million, or 91 percent of the National Ambient Air Quality Standards. The Saguaro National Park East monitoring site recorded the highest O_3 levels, with the 8-hour level reaching 0.74 part per million, or 99 percent of the allowable level under the National Ambient Air Quality Standards.

Particulate Matter

Particulate matter occurs from a wide range of activities, such as construction, agriculture, industrial processes, vehicular travel, and fugitive dust. Particle matter pollution is made up of a number of components, including acids (such as nitrates and sulfates), organic chemicals, metals, and soil or dust particles. Particulate matter can cause adverse health and environmental effects, including visibility reduction, environmental damage, and aesthetic damage.

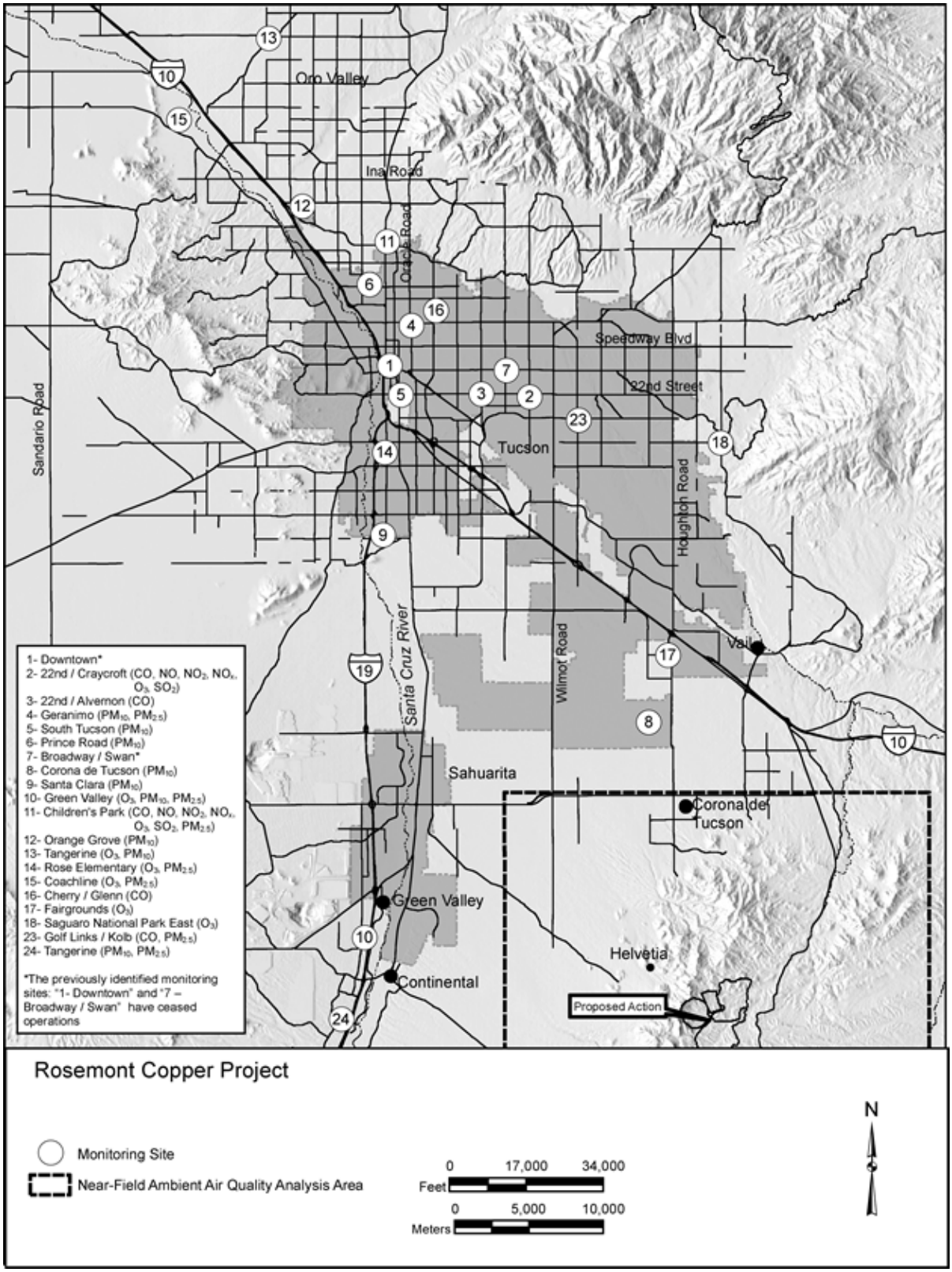


Figure 26. Pima County monitoring sites (Pima County Department of Environmental Quality 2009c)

Table 29. 2008 through 2010 Pima County monitoring data

Year	National Ambient Air Quality Standards	CO Max Concentration 1-hour 35 parts per million (ppm)	CO Max Concentration 8-hour 9 ppm	O_3 Max Concentration 1-hour 0.12 ppm	O_3 4th Highest Concentration 8-hour 0.075 ppm	PM_{10} Max Concentration 24-hour 150 micrograms per cubic meter (µg/m^3)	$PM_{2.5}$ Max Concentration 24-hour 35 µg/m^3	$PM_{2.5}$ Arithmetic Annual Mean 15 µg/m^3	NO_2 Max Concentration 1-hour 0.100 ppm	NO_2 Arithmetic Annual Mean 0.053 ppm	SO_2 Max Concentration 3-hour 0.5 ppm	SO_2 Max Concentration 24-hour 0.14 ppm
2008	Max Recorded (Monitor Location)	2.9 (22nd/ Alvernon)	1.9 (Cherry/ Glenn)	0.090 (Saguaro National Park)	0.074 (Saguaro National Park East)	146* (South Tucson)	28.2 (Geronimo)	7.64 (Coachline)	0.054 (22nd/ Craycroft)	0.0134 (22nd/ Craycroft)	0.014 (22nd/ Craycroft)	0.004 (22nd/ Craycroft)
2009		2.3 (22nd/ Alvernon)	1.3 (Cherry/ Glenn)	0.084 (Tangerine)	0.068 (Tangerine)	270 (Orange Grove)	31 (Geronimo)	8.2 (Geronimo)	0.050 (22nd/ Craycroft)	0.012 (22nd/ Craycroft)	0.005 (22nd/ Craycroft)	0.002 (22nd/ Craycroft)
2010		2.8 (Golf Links and Kolb)	1.4 (Golf Links and Kolb)	0.082 (Children's Park)	0.069 (Fairgrounds)	79 (South Tucson)	29 (Geronimo)	9.5 (Geronimo)	0.0637 (22nd/ Craycroft)	0.0116 (22nd/ Craycroft)	0.007 (22nd/ Craycroft)	0.002 (22nd/ Craycroft)
Number of Stations		6	6	9	9	9	6	6	2	2	1	1

Notes:

Max = Maximum

ppm = parts per million parts of air, by volume

µg/m³ = micrograms per cubic meter of air

* The PM_{10} value of 146 µg/m³ represents the second highest concentration measured at this location. A PM_{10} value of 173 µg/m³ is awaiting approval for a U.S. Environmental Protection Agency designation as a natural event because of high winds.

The U.S. Environmental Protection Agency is concerned about particles that are 10 micrometers (PM_{10} and $PM_{2.5}$) in diameter or smaller because those are the particles that generally pass through the throat and nose and enter the lungs. Once inhaled, these particles can affect the heart and lungs and cause serious health effects. Numerous scientific studies have linked particle pollution exposure to a variety of problems, including the following:

- increased respiratory symptoms, such as irritation of the airways, coughing, or difficulty breathing, for example;
- decreased lung function;
- aggravated asthma;
- development of chronic bronchitis;
- irregular heartbeat;
- nonfatal heart attacks; and
- premature death in people with heart or lung disease.

People with heart or lung diseases, children, and older adults are the most likely to be affected by particle pollution exposure. However, even if a person is healthy, that person may experience temporary symptoms from exposure to elevated levels of particle pollution.

Fine particles ($PM_{2.5}$) are the major cause of reduced visibility (haze) in parts of the United States, including many of our treasured national parks and wilderness areas.

Particles can be transported over long distances by wind and then deposited on the ground or in water. The effects of this deposition include the following: making lakes and streams acidic, changing the nutrient balance in coastal waters and large river basins, depleting the nutrients in soil, damaging sensitive forests and farm crops, and affecting the diversity of ecosystems.

Particle pollution can also stain and damage stone and other materials, including culturally important objects such as statues and monuments.

Nine monitoring sites for PM_{10} were operated by the Pima County Department of Environmental Quality in 2008. Across all monitoring sites, there was one exceedance (173 micrograms per cubic meter) of National Ambient Air Quality Standards at the Santa Clara site, but the exceedance is awaiting approval from the U.S. Environmental Protection Agency for designation as a natural event because of high winds.

The Pima County Department of Environmental Quality operated six monitoring sites for $PM_{2.5}$ in eastern Pima County in 2008. There was no exceedance or violation of the National Ambient Air Quality Standards for $PM_{2.5}$ in 2008 and none since monitoring began in 1999.

Sulfur Dioxide

SO_2 exists as a gas associated with the burning of high-sulfur coal, oil, or diesel fuel. It can combine with water and oxygen to form sulfuric acid (acid rain), a highly corrosive chemical. Ambient concentrations of SO_2 are extremely low in the Tucson metropolitan area because of the lack of major sources. One Pima County Department of Environmental Quality site monitored ambient concentrations of SO_2 in 2008; there was no exceedance or violation of the National Ambient Air Quality Standards.

Lead

Monitoring for Pb, a toxic metal, by the Pima County Department of Environmental Quality began in 1975 and was discontinued in 1997; Pb concentrations were extremely low, and Pima County has no major sources of Pb. On October 15, 2008, the U.S. Environmental Protection Agency strengthened the national Pb standard. As a result of the revised standard, Pima County will be required to begin area monitoring at the Children's Park location. The monitoring equipment has been purchased, and monitoring will begin on the U.S. Environmental Protection Agency scheduled start date in January 2012.

Air Toxics

Hazardous air pollutants, also known as air toxics, are those pollutants that have been shown to cause or possibly cause cancer in humans or may cause adverse environmental and ecological effects. In 2001, the U.S. Environmental Protection Agency developed a national network for monitoring ambient levels of air toxics. There is one National-scale Air Toxics Assessment monitoring site operated by the Arizona Department of Environmental Quality in Phoenix; no monitoring sites are located in or near the project area. Based on the latest 2002 assessment, resident cancer, neurological, and respiratory risks from hazardous air pollutants in the project area are estimated to be low (average total risk is 21 in 1 million). Approximately 89 percent of hazardous air pollutants in Pima County originate from background sources; mobile sources account for the majority of remaining hazardous air pollutant emissions. Primary hazardous air pollutants for the county include benzene, carbon tetrachloride, acetaldehyde, and 1,4-dichlorobenzene.

Proximity to Class I and II Areas

In addition to the National Ambient Air Quality Standards, national air quality standards exist for the prevention of significant deterioration. The prevention of significant deterioration requirements provide maximum allowable increases in pollutant concentrations for areas that are already in compliance with the National Ambient Air Quality Standards (i.e., attainment or management areas). Under the prevention of significant deterioration, a Class I area is one in which only a small amount of new pollution is allowed. These areas include national parks, wilderness areas, monuments, and other areas of special national and cultural significance. There are no Class I areas within the analysis area. The closest Class I area to the analysis area is Saguaro National Park, at approximately 27 and 41 miles, respectively, from its east and west side. The Galiuro Wilderness is approximately 59 miles from the project area. As part of the National Environmental Policy Act process, Class I areas within the air quality study area of a proposed project must be evaluated with regard to the potential impact and impairment concerns of the project on air quality related values such as visibility, flora/fauna, water quality, soils, odor, and any other resources specified by the federal land manager to ensure compliance with Forest Service Manual 2580.1 (2d); Forest Service Manual 2580.2; and 42 United States Code 7475(d)(2)(B) and (C) (U.S. Forest Service et al. 2010). The project area is located within a Class II airshed and, as such, is required to be in compliance with Class II allowable increases in pollutant concentrations. Class II areas include all other clean air regions and allow moderate pollution increases. Allowable prevention of significant deterioration increments currently exist for three criteria pollutants: SO_2, NO_2, and PM_{10}.

Visibility

Visibility is the degree to which the atmosphere is transparent to visible light. It is an important air quality value, particularly in scenic and recreational areas. Scenic vistas in most U.S. parklands can

be diminished by haze that reduces contrast, dilutes colors, and reduces the distinctness or visibility of distant landscape features. Visibility degradation in national park lands and forests is a consequence of broader, regional-scale visibility impairment from visibility-reducing particles and their precursors, which are often carried long distances to these remote locations.

Sulfates, organic matter, elemental carbon (soot), nitrogen compounds, soil dust, and their interaction with water cause most anthropogenic visibility impairment. The causes and severity of visibility impairment vary over time and space, depending on meteorological conditions, sunlight, and the size and proximity of emission sources.

Visibility protection requirements are included in prevention of significant deterioration regulations requiring protection of air quality related values for Class I areas. The Clean Air Act, Title I, Part C, states, “Congress declares as a national goal the prevention of any future, and the remedying of any existing, impairment of visibility in mandatory Class I federal areas which impairment results from manmade air pollution.” More specifically, Congress expressed the national desire to preserve the ability to see long distances, entire panoramas, and specific features associated with the statutory Class I areas. Meeting these visibility objectives occurs when “reasonable progress” is made toward achieving the U.S. Environmental Protection Agency’s regional haze regulation goal of restoring natural background visibility conditions by 2064.

The Cooperative Institute for Research in the Atmosphere operates a network of visibility monitoring stations in or near Class I areas and publishes IMPROVE data. The purpose of this monitoring is to identify and evaluate patterns and trends in regional visibility. A change in contrast of not more than 5 percent at sensitive view areas is considered acceptable.

In July 1999, the U.S. Environmental Protection Agency published the Regional Haze Rule to address visibility impairment in Class I areas. The Regional Haze Rule prevents visibility degradation to Class 1 areas on the top 20 percent least impaired (clearest) days and requires visibility improvement in Class 1 areas on the top 20 percent most impaired (haziest) days. Within its boundary, Arizona has 12 Class I areas, including the two areas discussed above. From 1998 to 2007, visibility in most Arizona Class I areas was within background conditions. Those locations with visibility conditions that were above the background were few, and the degradation was slight. The Saguaro National Park was the only location that exceeded the background conditions for more than 1 year. From 2002 through 2006, visibility at Saguaro National Park was slightly less than background conditions (Arizona Department of Environmental Quality 2008).

Estimated natural background from the U.S. Environmental Protection Agency’s “Guidance for Estimating Natural Visibility Conditions Under the Regional Haze Rule” for Saguaro National Park is 4.28 deciviews for the 20 percent worst days. Baseline or current condition for determining the glide path to natural background for Saguaro National Park is 15 deciviews for similar days in the 2000 to 2004 baseline period.

Visibility conditions are commonly quantified in deciviews, a measure of visibility based on light extinction because of haze. The lower the deciview level, the better the visibility. Figure 27 shows recent visibility levels for the total average annual deciviews and average deciviews on the top 20 percent clearest days at Saguaro National Park East (Interagency Monitoring of Protected Visual Environments 2010).

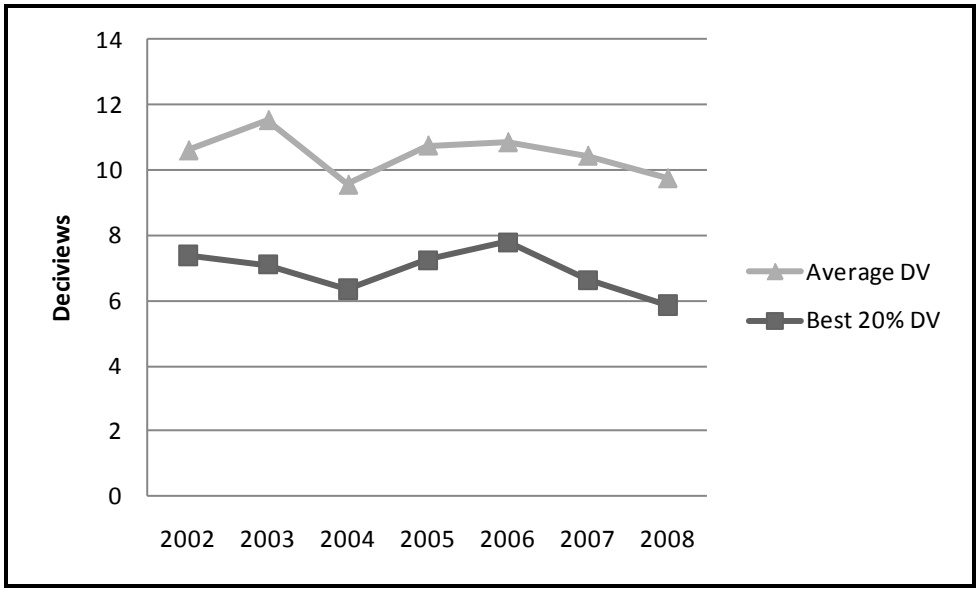


Figure 27. Visibility at Saguaro National Park East

Pima County Emission Inventory

Data from the U.S. Environmental Protection Agency's National Emissions Inventory (Applied Environmental Consultants 2010d) can be used to illustrate air pollutant emission levels for the Tucson region. These data are divided into various source categories:

- Point Sources: Stationary sources that emit a significant amount of pollution into the air, such as power plants, industrial processes, and large manufacturing facilities.
- Area Sources: Sources that consist of smaller residential and commercial combustion outputs, manufacturing processes not vented to stacks, dust from earthmoving, landscaping, and windblown dust.
- Nonroad Mobile Sources: Sources that consist of exhaust emissions from construction, mining and agricultural equipment, and vehicles that do not travel on highways.
- On-road Mobile Sources: Sources that consist of exhaust emissions and fugitive dust associated with vehicles traveling on roads (paved and unpaved).
- Biogenic Sources: Sources that consist of emissions from plants, including crops, indigenous vegetation, and landscaping.
- Refueling Sources: Sources that consist of emissions associated with vehicle refueling activities.

Table 30 summarizes the various emissions sources in Pima County. On-road vehicle emissions contribute the largest portion of gaseous pollutants to total county air pollutant emissions. Area sources contribute the largest portion of particulate pollutants to total county particulate emissions.

Table 30. Pima County 2005 emissions inventory (tons per year)

Emissions Source Type	NO_x	CO	SO_2	PM_{10}	$PM_{2.5}$	VOCs	CO_2*
On-road Vehicles	17,338	128,269	370	467	311	15,128	–
Nonroad Equipment	5,864	59,104	596	527	497	4,962	–

Emissions Source Type	NO_x	CO	SO_2	PM_{10}	$PM_{2.5}$	VOCs	CO_2*
Industrial Processes	3,321	4,814	75	2,155	1,081	166	–
Electricity Generation	2,247	152	3714	127	110	25	–
Fossil Fuel Combustion	1,515	726	1359	463	112	52	–
Fires	60	2,093	26	240	204	502	–
Residential Wood Combustion	51	3,986	8	556	556	855	–
Waste Disposal	12	35	8	11	8	200	–
Miscellaneous	1	54	–	10,528	1,107	3,315	–
Road Dust	–	–	–	9,589	832	–	–
Solvent Use	–	–	–	–	–	5,939	–
Total	**30,409**	**199,233**	**6,156**	**24,663**	**4,818**	**31,144**	**17,426,666**

Source: Applied Environmental Consultants (Applied Environmental Consultants 2010d).

* U.S. Environmental Protection Agency's National Emissions Inventory does not include CO_2 emissions. Data are from Regional Greenhouse Gas Inventory, Pima Association of Governments, November 2008, encompassing the eastern Pima County area, which consists of a rectangular area, with the northern line stopping at the Pima County line, the southern line stopping at the southern edge of Sahuarita, the eastern line stopping at Vail, and the western line stopping at Three Points.

Environmental Consequences

Direct and Indirect Effects of Each Alternative

No Action Alternative

This alternative would not change the Forest Service's responsibility to preserve air quality resources. It would result in no impacts to air quality, including National Ambient Air Quality Standards and visibility. It would also result in no greenhouse gas emissions that would otherwise result from the action alternatives. There would continue to be limited impacts to air quality in the form of fugitive dust from continuing activities, such as recreational off-highway vehicle use on dirt roads.

Impacts Common to All Action Alternatives

The five action alternatives (proposed action, Phased Tailings, Barrel, Barrel Trail, and Scholefield-McCleary) would involve constructing, operating, reclaiming, and closing an open-pit mine of sulfide and oxide copper ore for the recovery ore. The projected active mine life would be approximately 25 years, including construction, operation, reclamation, and closure.

The action alternatives would share the following components:

- Heavy equipment mining operations, including drilling, blasting, loading, and hauling of ore and rock;
- Major processing operations, including crushing, grinding, flotation, leaching, and solvent extraction;
- Tailings and waste rock placement and storage;
- Secondary processing operations, including the use of fuel burning equipment, reagent systems, storage tanks, an analytical laboratory, crud treatment and recovery, and onsite mobile vehicles;
- Shipment to market for copper cathodes and copper, molybdenum, and silver concentrates to the Port of Tucson via State Route 83; and
- Vehicle travel by employees to and from the project site.

The above components would result in the direct emissions of all criteria pollutants, as well as VOCs, sulfuric acid, the greenhouse gases, and several regulated hazardous air pollutants from the exhaust emissions of vehicles, heavy equipment, and other fuel burning equipment (e.g., diesel electrowinning hot water generator). In addition, fugitive dust emissions would result from vehicular traffic on unpaved surfaces, processing equipment (e.g., pebble crusher area scrubber, copper concentrate scrubber 1 and 2, molybdenum concentrate dryer, various pieces of laboratory equipment, and the dry-stack tailings storage). However, haul truck travel represents more than 70 percent of total particulate related emissions. Moreover, NO_x and VOC emissions from the exhaust emissions of vehicles, heavy-equipment and other fuel burning equipment would lead to the formation of ground-level O_3.

Other greenhouse gases such as methane (CH_4), nitrous oxide (N_2O), and fluorinated gases would also be emitted; however, the anticipated level of emissions of these gases is much smaller than the level of CO_2 emissions. When considering greenhouse gas emissions from the combustion of gasoline or #2 fuel oil (diesel), more than 99.99 percent of those emissions are in the form of CO_2; therefore, for this analysis, only CO_2 emissions are considered. However, not all greenhouse gases have uniform global warming potentials. N_2O has a global warming potential of 200 times the potential of CO_2. If the remaining 0.01 percent of emissions were N_2O, it would only account for approximately 2 percent of the global warming potential, a figure that is insignificant in relation to other uncertainties in this analysis.

The methodology, calculation process rates, determination of emission factors, and application of control efficiencies are discussed in detail for each emission source within “Addendum to: Emission Inventory Information Years 1, 5, 10. 15. 20 Rosemont Copper Project Southeastern Arizona” (Applied Environmental Consultants 2011b). Emission unit process rates, regulatory emission limitations and standards, manufacturer estimates, U.S. Environmental Protection Agency AP-42 documents, engineering experience from other similar projects, and U.S. Environmental Protection Agency modeling programs were used to estimate criteria air pollutants from the proposed action and action alternatives.

These emission rates are based on the following main assumptions:

- The facility is anticipated to have a projected operating life of 25 years with peak mining rates of up to 376,000 tons per day of total material (ore and waste);
- Haul trucks will be operated 6,600 hours per year for each haul truck;
- Use on Tier 4 emission standards on selected nonroad engines (all except haul trucks and the 2,000 horsepower front-end loaders);
- Maximum blasting process rate of 1 blast per day; and
- Modeled emissions represent controlled rates.

Fugitive PM emissions that result from erosion of the tailings storage areas are susceptible to moderate to high wind speeds and wind erosion. Tailing storage emissions were estimated assuming the annual, daily, and hourly process rates for wind erosion of the tailings storage are equal to the maximum area of the land containing the tailings or 1,500 acres and continuous operation of the storage area (i.e., 8,760 hours/yr, 24 hours/day, 1 hour/hour). Uncontrolled PM, PM_{10}, and $PM_{2.5}$ emissions from the tailings storage were calculated using the methodology and equations from U.S. Environmental Protection Agency’s AP-42, Section 13.2.5, “Industrial Wind Erosion,” dated

November 2006. The smallest threshold friction velocity of 0.43 meter per second was assumed to approximate the tailings.

Furthermore, based on the hourly data collected at the meteorological station at the Rosemont Copper Project site from April 2006 through May 2009, the highest wind speed, of 10.70 meters per second, for the time period between disturbances was used to estimate the uncontrolled emissions from tailings storage. Emissions of PM resulting from wind erosion would be mitigated by constructing the tailings storage area using waste rock. The waste rock would be used to break up the air flow and reduce exposure of tailings storage area to windy conditions (Applied Environmental Consultants 2011a).

Table 31 shows maximum annual emissions from the proposed action in 5-year increments. The highest projected mining rate will occur during year 1 of mine operation, and the highest projected haul truck travel will occur during year 5 of operation (Applied Environmental Consultants 2011a). Therefore, between them, years 1 and 5 have the highest emissions levels of all pollutants listed, and air quality impacts during any subsequent year should be less than those during years 1 and 5.

Table 31. Summary of maximum hourly, daily, and annual emissions from sources operating under the proposed action

Pollutant	Period	Year 1	Year 5	Year 10	Year 15	Year 20
Particulate matter	lb/hr	1,270.89	1539.91	1,371.61	1,356.90	1,010.66
	tpd	9.37	12.63	10.61	10.43	6.27
	tpy	2,895.49	3,353.03	2,841.79	2,770.53	1,660.94
PM_{10}	lb/hr	448.16	517.43	474.16	468.85	377.33
	tpd	2.78	3.62	3.10	3.03	1.94
	tpy	864.40	977.26	845.72	817.47	516.00
$PM_{2.5}$	lb/hr	57.05	64.10	59.77	58.95	48.86
	tpd	0.47	0.56	0.50	0.49	0.37
	tpy	147.16	158.46	145.33	141.56	107.87
CO	lb/hr	3,715.92	3,716.08	3,716.13	3,715.45	3,707.99
	tpd	4.52	4.52	4.52	4.51	4.42
	tpy	1,468.63	1,436.26	1,432.98	1,266.26	971.89
NO_x	lb/hr	1,199.40	1,200.13	1,200.13	1,200.06	1,195.86
	tpd	4.20	4.21	4.21	4.21	4.16
	tpy	1,251.27	1,243.68	1,242.81	1,200.92	1,117.15
SO_2	lb/hr	105.08	105.03	105.03	105.03	105.03
	tpd	0.06	0.06	0.06	0.06	0.06
	tpy	20.06	19.67	19.57	14.68	6.83
VOCs	lb/hr	23.53	23.54	23.54	23.51	23.11
	tpd	0.28	0.28	0.28	0.28	0.28
	tpy	83.09	82.95	82.96	82.80	81.11
Sulfuric acid	lb/hr	0.004	0.004	0.004	0.004	0.004
	tpd	0.00005	0.00005	0.00005	0.00005	0.00005
	tpy	0.02	0.02	0.02	0.02	0.02
CO_2	lb/hr	76,250.91	76,281.57	76,290.15	76,160.62	74,733.31
	tpd	566.86	567.56	567.66	566.11	548.98
	tpy	172,943.86	172,292.11	172,301.40	170,404.31	162,275.23
Hazardous air pollutants	lb/hr	0.77	0.77	0.77	0.77	0.77
	tpd	0.009	0.009	0.009	0.009	0.009
	tpy	3.35	3.35	3.35	3.35	3.35

Source: Applied Environmental Consultants (Applied Environmental Consultants 2010d).
Notes:
lb/hr = pound(s) per hour
tpd = ton(s) per day
tpy = ton(s) per year

Table 32 shows maximum hourly emissions (in pounds per hour) of criteria pollutants from each of the action alternatives. For all of the action alternatives except the Phased Tailings Alternative, there is a change in the vehicle miles traveled associated with the haul trucks hauling waste rock to the waste rock storage areas. This difference in vehicle miles traveled is a result of the alternatives proposing different locations for dumping of the waste rock. The vehicle miles traveled inside the pit will remain the same for each alternative since the mining rates remain unaffected by the different alternatives. Consequently, year 1 continues to represent the year with the highest projected mining rate, and year 5 continues to represent the year with the highest projected haul truck vehicle miles traveled. However, for the Barrel Alternative, no waste rock dumping is projected during the first 5 years of mine operation. Therefore, year 7 was selected, as it is projected to have the highest amount of waste rock deposited in the Barrel Canyon waste rock storage area. The Phased Tailings Alternative is a variation of the proposed action and does not lead to any change in emissions or location of emission sources (Applied Environmental Consultants 2011a).

Table 32. Emissions under the action alternatives

Alternative	Year	Period	Pollutant PM	Pollutant PM_{10}	Pollutant $PM_{2.5}$	Pollutant SO_2	Pollutant NO_X	Pollutant CO
Proposed action	1	lb/hr	1,270.89	448.16	57.05	105.08	1,199.4	3,715.92
Proposed action	5	lb/hr	1,539.91	517.43	64.1	105.03	1,200.13	3,716.08
Phased Tailings	1	lb/hr	1,270.89	448.16	57.05	105.08	1,199.4	3,715.92
Phased Tailings	5	lb/hr	1,539.91	517.43	64.1	105.03	1,200.13	3,716.08
Barrel	7	lb/hr	1,407.88	480.62	60.68	105.00	1,225.36	3,730.64
Barrel Trail	1	lb/hr	1,329.39	476.24	59.78	105.05	1,224.64	3,730.51
Barrel Trail	5	lb/hr	1,607.00	535.34	68.62	105.00	1,225.37	3,730.67
Scholefield-McCleary	1	lb/hr	1,367.86	486.93	61.62	104.98	1,283.53	3,764.53
Scholefield-McCleary	5	lb/hr	1,726.27	567.18	73.16	104.94	1,284.26	3,764.69

Source: Applied Environmental Consultants (Applied Environmental Consultants 2010d).

Notes:

lb/hr = pound(s) per hour

Projected emissions from the project can be compared with countywide emissions for Pima County. The project has the potential to increase county emission levels of air pollutants and greenhouse gases by 0.3 to 4.1 percent, as shown in table 33 (note that these values are for year 5 of the proposed action).

Based on these emissions results, modeling work was conducted to examine the effects of projected emissions on the following: (1) compliance with National Ambient Air Quality Standards at the project site and at national parks and wilderness areas (Class I areas), and (2) compliance with the U.S. Environmental Protection Agency Regional Haze Rule regarding visibility in Class I areas.

Figure 28 shows the locations of the modeled values for evaluating impacts to Class I areas (both visibility and National Ambient Air Quality Standards).

Table 33. Pima County emissions and emissions under action alternatives (in tons per year)

	NO_x	CO	SO_2	PM_{10}	$PM_{2.5}$	VOCs	CO_2
Pima County	30,409	199,233	6,156	24,663	4,818	31,144	17,426,666
Rosemont Copper Project (Year 5)	1,243	1,436	20	977	158	83	172,292
% Additional	4.09%	0.72%	0.32%	3.96%	3.28%	0.26%	0.99%

Proposed Action's Projected Effects on National Ambient Air Quality Standards

Criteria pollutants for which modeling work was done were PM_{10}, $PM_{2.5}$, NO_2, CO, and SO_2. Because the project area is located in a rural area without air quality monitoring stations nearby, background concentrations of NO_2, CO, and SO_2 were assumed to be at levels recommended by the Arizona Department of Environmental Quality for use in rural areas and are presented in "Revised AERMOD Modeling Report to Assess Ambient Air Quality Impacts" (Applied Environmental Consultants 2011b).

According to the "Revised AERMOD Modeling Report to Assess Ambient Air Quality Impacts," modeling for NO_2 was conducted under four scenarios (Applied Environmental Consultants 2011b).

- Scenario 1 included emissions from sources subject to the air quality permitting requirements of the Clean Air Act. This included emissions from all point sources such as boilers and blasting and was based on an NO_2 to NO_x ratio of 0.5.
- Scenarios 2, 3, and 4 included emissions from all sources of NO_2 emissions at NO_2 to NO_x ratios of 0.5, 0.1, and 0.05, respectively.
- Scenario 1 is not acceptable, as it only includes emission sources subject to the air quality permitting requirements of the Clean Air Act. The National Environmental Policy Act requires full disclosure of impacts. The NO_2 to NO_x ratio of 0.5 that is used for scenario 2 is higher than most ratios shown in research and field studies; therefore, scenarios 1 and 2 are not carried forward in the analysis.
- In-stack NO_2/NO_X data is available for industrial point sources. However, there is minimal in-stack data available for mobile sources as mobile-source emissions are typically measured after mixing with ambient air. Documentation from Rosemont Copper and Caterpillar, Inc., identifies a range of NO_2 from 0.05 to 0.15 of the engine-out NO_X emissions as being typical. However, oxidation catalysts and diesel particulate filters can increase the ratio of engine-out NO_2 (Hockridge 2011). Furthermore, in-stack NO_2/NO_X ratio must be representative of exhaust gases before leaving the stack and before any mixing or oxidation by ambient air has occurred. Since the model's in-stack parameter requires measurements that are representative of NO_X emissions before they leave the stack, data derived from U.S. Environmental Protection Agency test procedures are inappropriate for model input. The Forest Service decided to move forward with scenarios 3 and 4 for the analysis of NO_2 impacts in order to present a range of potential impacts, as shown in tables 34 and 35.
- The Petrified National Forest in Navajo County has a $PM_{2.5}$ monitoring station, and the 3-year (2006 to 2008) maximum of the 24-hour concentrations recorded at this station was used as the $PM_{2.5}$ background concentration. An ambient PM_{10} monitoring station was set up at the project site in June 2006, and the 3-year (July 2006 to June 2009) maximum of the 24-hour PM_{10} concentrations recorded was used as the PM_{10} background concentration.

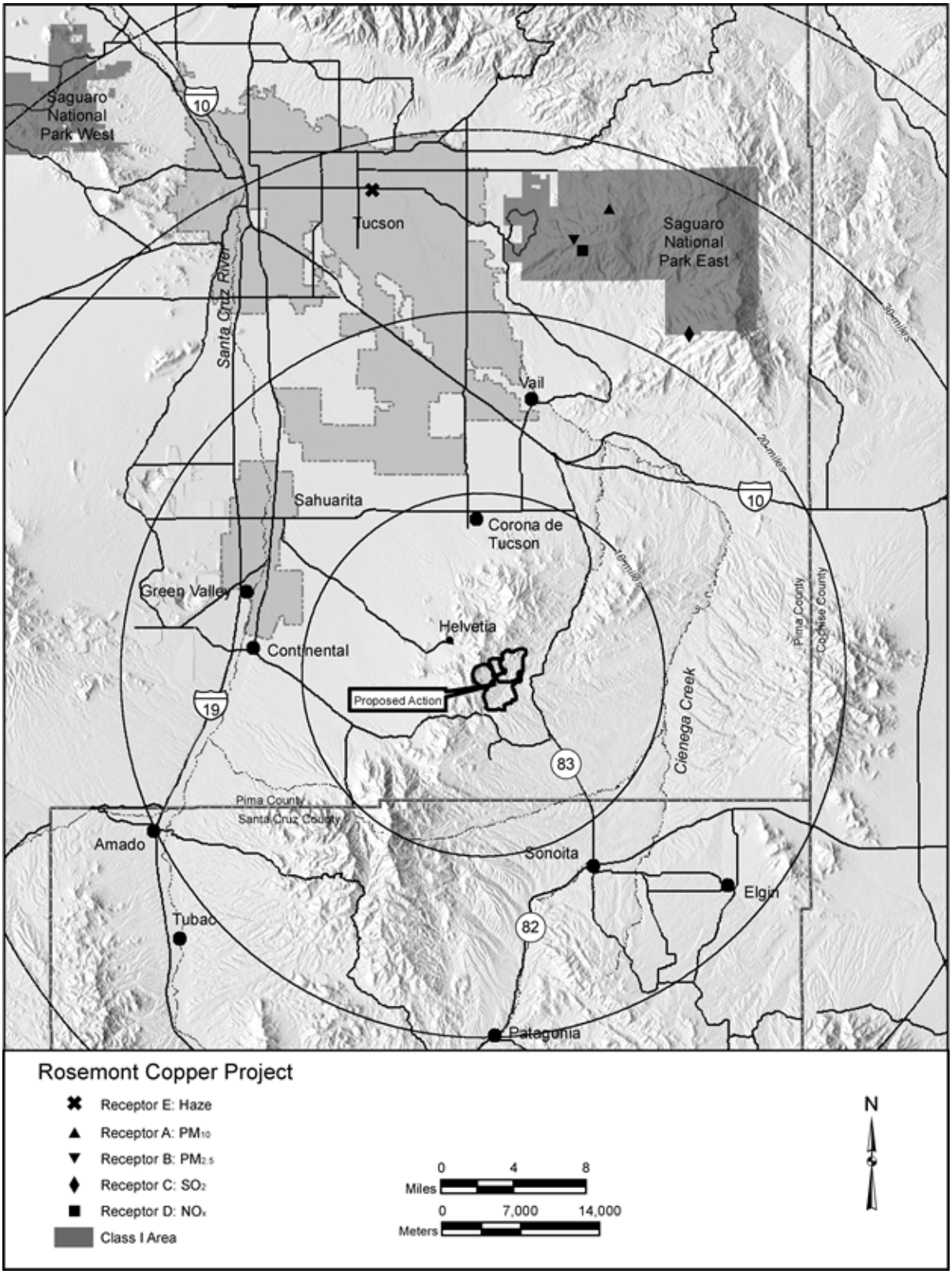


Figure 28. Locations of Class I areas and receptors for air quality modeling (from Applied Environmental Consultants Inc. (2009b))

- Based on the Applied Environmental Consultants review of the PM_{10} concentration data and the large differences between the highest measured value (71.3 micrograms per cubic meter) and the second highest value (40.3 micrograms per cubic meter), a statistical analysis was conducted on all data to determine its probability of occurrence. This analysis is provided within appendix C of the "Modeling Protocol to Assess Ambient Air Quality Impacts" for the project (Applied Environmental Consultants 2009b). The statistical analysis indicates that the probability of occurrence of the concentration of 71.3 micrograms per cubic meter is 5.9×10^{-11}. This low probability indicates that the concentration of 71.3 micrograms per cubic meter is an outlier to the distribution and should not be included in the determining the background concentration. Therefore, the 24-hour background PM_{10} concentration was based on the average of 27.0, 40.3, and 31.6 or 33.0 micrograms per cubic meter.

These background concentrations, as well as the modeled concentration increases at the project site from implementation of the proposed action, are shown in tables 34 and 35.

Table 34. Maximum ambient concentrations at the project site from emissions for proposed action year 1

Type of Emission	Averaging Period	Modeled Concentration (micrograms per cubic meter (μg/m^3))	Background Concentration (μg/m^3)	Maximum Ambient Concentration (μg/m^3)	National Ambient Air Quality Standards (μg/m^3)
CO	1-hour[e]	1,394.9	582.0	1,976.9	40,000
CO	8-hour[e]	375.2	582.0	957.2	10,000
NO_2 (scenario 3)	1-hour[a]	208.3	24.5	232.8	188.7
NO_2 (scenario 3)	Annual	26.8	4.0	30.8	100
NO_2 (scenario 4)	1-hour[a]	146.7	24.5	171.2	188.7
NO_2 (scenario 4)	Annual	24.5	4.0	28.5	100
PM_{10}	24-hour[f]	111.9	33.0	144.9	150
PM_{10}	Annual	26.5	11.9	38..4	50
$PM_{2.5}$	24-hour[b]	18.2	9.7	27.9	35
$PM_{2.5}$	Annual	4.3	3.6	7.9	15
SO_2	1-hour[c]	17.2	31.9[d]	49.1	195
SO_2	3-hour[e]	7.75	43.0	50.8	1,300
SO_2	24-hour[e]	1.2	17.0	18.2	365
SO_2	Annual	0.1	3.0	3.1	80

[a] Represents the 98th percentile concentration over a 3-year period.

[b] Represents the average of the highest 24-hour concentrations over a 3-year period.

[c] Represents the 99th percentile concentration over a 3-year period.

[d] Background concentration was set equal to the highest modeled impact as a result of the lack of available appropriate data.

[e] Represents the 2nd highest concentration.

[f] Represents the 4th highest concentration over a 3-year period.

As stated above, National Ambient Air Quality Standards would be maintained at the project site under the proposed action for all criteria pollutants, with the exception of NO_2 in scenario 3.
The Forest Service is currently reviewing scenarios 3 and 4 to determine which one most accurately predicts NO_x emissions. If scenario 4 is chosen, NO_x emissions would meet National Ambient Air Quality Standards. However, if scenario 3 is chosen, NO_x emissions would exceed standards and

additional mitigation measures would need to be applied. PM_{10} concentrations could come to within 97 percent of National Ambient Air Quality Standards.

Table 35. Maximum ambient concentrations at the project site from emissions for proposed action year 5

Type of Emission	Averaging Period	Modeled Concentration (micrograms per cubic meter (μg/m^3))	Background Concentration (μg/m^3)	Maximum Ambient Concentration (μg/m^3)	National Ambient Air Quality Standards (μg/m^3)
CO	1-hour[e]	1,200.63	582.0	1,782.63	40,000
CO	8-hour[e]	293.8	582.0	875.8	10,000
NO_2 (scenario 3)	1-hour[a]	190.9	24.5	215.4	188.7
NO_2 (scenario 3)	Annual	25.6	4.0	29.6	100
NO_2 (scenario 4)	1-hour[a]	141.8	24.5	166.3	188.7
NO_2 (scenario 4)	Annual	23.5	4.0	27.5	100
PM_{10}	24-hour[f]	102.9	33.0	135.9	150
PM_{10}	Annual	24.0	11.9	35.9	50
$PM_{2.5}$	24-hour[b]	19.5	9.7	29.2	35
$PM_{2.5}$	Annual	3.8	3.6	7.4	15
SO_2	1-hour[c]	17.2	31.9[d]	49.1	195
SO_2	3-hour[e]	7.75	43.0	50.75	1,300
SO_2	24-hour*	1.1	17.0	18.1	365
SO_2	Annual	0.1	3.0	3.1	80

[a] Represents the 98th percentile concentration over a 3-year period.
[b] Represents the average of the highest 24-hour concentrations over a 3-year period.
[c] Represents the 99th percentile concentration over a 3-year period.
[d] Background concentration was set equal to the highest modeled impact as a result of the lack of available appropriate data.
[e] Represents the 2nd highest concentration.
[f] Represents the 4th highest concentration over a 3-year period.

National Ambient Air Quality Standards maintenance at surrounding Class I areas must also be examined. Regarding analysis in Class I areas, the analysis results presented are for Saguaro National Park East because of the following: it is the nearest area to the project site, wind conditions are more likely to direct pollutant emissions to that area, and it is the location with the highest predicted pollutant concentrations (Applied Environmental Consultants 2010c). Because Saguaro National Park East is near the Tucson area, air quality data from monitors in Tucson were used for the background pollutant concentrations. As shown in tables 36 and 37, National Ambient Air Quality Standards would be maintained at Saguaro National Park East for all criteria pollutants.

Table 36. Modeled impacts at Saguaro National Park East from year 1 emissions

Type of Emission	Averaging Period	Modeled Concentration (micrograms per cubic meter (μg/m^3))	Background Concentration (μg/m^3)	Maximum Ambient Concentration (μg/m^3)	National Ambient Air Quality Standards (μg/m^3)
CO	1-hour[a]	133	582.0	715.0	40,000
CO	8-hour[a]	17.9	582.0	599.9	10,000
NO_x	1-hour[b]	78.8	24.5	103.3	188.7
NO_x	Annual	0.45	1.7	2.15	100
PM_{10}	24-hour[c]	1.8	47.6	49.4	150

Type of Emission	Averaging Period	Modeled Concentration (micrograms per cubic meter (μg/m^3))	Background Concentration (μg/m^3)	Maximum Ambient Concentration (μg/m^3)	National Ambient Air Quality Standards (μg/m^3)
PM_{10}	Annual	0.13	12.6	12.7	50
$PM_{2.5}$	24-hour[d]	0.6	11.4	12.0	35
$PM_{2.5}$	Annual	0.02	5.1	5.12	15
SO_2	1-hour[e]	0.5	0.84[f]	1.34	195
SO_2	3-hour[a]	0.26	81.3	81.6	1,300
SO_2	24-hour[a]	0.04	23.6	23.64	365
SO_2	Annual	0.0008	1.7	1.7	80

[a] Represents the 2nd highest concentration.
[b] Represents the 98th percentile concentration over a 3-year period.
[c] Represents the 4th highest concentration over a 3-year period.
[d] Represents the average of the highest 24-hour concentrations over a 3-year period.
[e] Represents the 99th percentile concentration over a 3-year period.
[f] Background concentration was set equal to the highest modeled impact as a result of the lack of available appropriate data.

Table 37. Modeled impacts at Saguaro National Park East from year 5 emissions

Type of Emission	Averaging Period	Modeled Concentration (micrograms per cubic meter (μg/m^3))	Background Concentration (μg/m^3)	Maximum Ambient Concentration (μg/m^3)	National Ambient Air Quality Standards (μg/m^3)
CO	1-hour[a]	169.7	582.0	751.7	40,000
CO	8-hour[a]	21.2	582.0	603.2	10,000
NO_x	1-hour[b]	93.3	24.5	117.8	188.7
NO_x	Annual	0.44	1.7	2.1	100
PM_{10}	24-hour[c]	2.4	47.6	50.0	150
PM_{10}	Annual	0.14	12.6	12.7	50
$PM_{2.5}$	24-hour[d]	0.6	11.4	12.0	35
$PM_{2.5}$	Annual	0.03	5.1	5.1	15
SO_2	1-hour[e]	0.43	0.82[f]	1.25	195
SO_2	3-hour[a]	0.27	81.3	81.7	1,300
SO_2	24-hour[a]	0.04	23.6	23.6	365
SO_2	Annual	0.0008	1.7	1.7	80

[a] Represents the 2nd highest concentration.
[b] Represents the 98th percentile concentration over a 3-year period.
[c] Represents the 4th highest concentration over a 3-year period.
[d] Represents the average of the highest 24-hour concentrations over a 3-year period.
[e] Represents the 99th percentile concentration over a 3-year period.
[f] Background concentration was set equal to the highest modeled impact as a result of the lack of available appropriate data.

PM_{10} levels in the Tucson area near Saguaro National Park East are already elevated, with average levels at 111 micrograms per cubic meter and maximums at 146 micrograms per cubic meter. The action alternatives could increase the risk of exceeding National Ambient Air Quality Standards for PM_{10}. The higher end of the modeled impacts, compared with the maximum PM_{10} level for the Tucson area in 2008, is consistently within 98 percent of the National Ambient Air Quality Standards

or closer, and it exceeded the National Ambient Air Quality Standards once. All other pollutant levels modeled are within the National Ambient Air Quality Standards.

In addition, O_3 levels in the Tucson and Saguaro National Park East areas are also already elevated, with the 8-hour National Ambient Air Quality Standards at 0.075 part per million, average O_3 levels at 0.068 part per million, and maximum levels at 0.074 part per million, or 99 percent of the National Ambient Air Quality Standards. The action alternatives could increase Pima County NO_x emissions by 5 percent and are projected to increase annual average NO_x levels in the Saguaro National Park East area by approximately 1 percent. Increases to the 8-hour average NO_x levels could be higher. NO_x are a key precursor to O_3 formation, and the action alternatives could increase the risk of exceeding O_3 National Ambient Air Quality Standards in Saguaro National Park East and the Tucson area.

Action Alternatives' Projected Effects on National Ambient Air Quality Standards

The modeling results presented in "Rosemont Copper Company: Revised Modeling Report to Assess Ambient Air Quality Impacts," dated April 4, 2011, demonstrate that the closest proximity to exceeding ambient air quality standards at the process area boundary (i.e., perimeter fence) were the 1-hour NO_2, 24-hour PM_{10}, and 24-hour $PM_{2.5}$. The maximum ambient concentrations of CO and SO_2 were 10 percent and 25 percent, respectively, of the applicable NAAQS. Because of the low impacts relative to the NAAQS for CO and SO_2, exceedances of these standards cannot occur as a result of the rerouting of the haul truck routes outside the pit. Therefore, criteria pollutants for which modeling work was done for the action alternatives were limited to PM_{10}, $PM_{2.5}$, and NO_2.

Based on comments provided by the Forest Service, the haul roads were split into two lanes in order to represent two-way traffic. The result of this revision doubled the number of haul road sources and resulted in a maximum modeled PM_{10} concentration of 111.9 micrograms per cubic meter. This represents an increase of 6.25 percent from the initially modeled fourth highest PM_{10} concentration of 104.6 micrograms per cubic meter. This doubling of the haul road sources also resulted in the model run times to also be doubled. Therefore, because of the inordinately long model run times required for the two-way traffic simulations, the alternatives were modeled as a single lane road, with all modeled concentrations subsequently scaled up by 6.25 percent to account for the effect of two-way traffic.

Because the project area is located in a rural area without air quality monitoring stations nearby, background concentrations of NO_2 were assumed to be at levels recommended by the Arizona Department of Environmental Quality for use in rural areas and are presented in "Alternative Scenarios Modeling Summary" (Applied Environmental Consultants 2011b).

According to the "Alternative Scenarios Modeling Summary," modeling for NO_2 was conducted under four scenarios (Applied Environmental Consultants 2011b):

- Scenario 1 included emissions from sources subject to the air quality permitting requirements of the Clean Air Act. This included emissions from all process sources such as boilers and blasting and was based on an NO_2 to NO_x ratio of 0.5.
- Scenarios 2, 3, and 4 included emissions from all sources of NO_2 emissions at NO_2 to NO_x ratios of 0.5, 0.1, and 0.05, respectively.

Scenario 1 is not acceptable, as it only includes emission sources subject to the air quality permitting requirements of the Clean Air Act. The National Environmental Policy Act requires full disclosure of impacts. The NO_2 to NO_x ratio of 0.5 that is used for scenario 2 is higher than most ratios shown in

research and field studies; therefore, scenarios 1 and 2 are not carried forward in the analysis. Documentation from Rosemont Copper and Caterpillar, Inc., identifies a range of ratios from 0.05 to 0.15 as being typical. The Forest Service decided to move forward with scenarios 3 and 4 for the analysis of NO_2 impacts in order to present a range of potential impacts.

The Petrified National Forest in Navajo County has a $PM_{2.5}$ monitoring station, and the 3-year (2006 to 2008) maximum of the 24-hour concentrations recorded at this station was used as the $PM_{2.5}$ background concentration. An ambient PM_{10} monitoring station was set up at the project site in June 2006, and the 3-year (July 2006 to June 2009) maximum of the 24-hour PM_{10} concentrations recorded was used as the PM_{10} background concentration.

The following sections provide a brief description of the differences of each of the alternatives, as well as the modeled, background, and maximum ambient concentrations increases at the project site and Saguaro National Park East from implementation of each action alternative.

Phased Tailings Alternative

Like the proposed action, the Phased Tailings Alternative incorporates a waste rock perimeter buttress that would completely surround the dry-stack tailings. Furthermore, the heap leach facility would be located in the same place as for the other alternatives. Although the construction of the tailing phases is reversed from that of the proposed action, at the end of mine life, the final waste rock and tailings facility would occupy the same location as the proposed action. Therefore, the Phased Tailings Alternative was not modeled, as it is no different from the proposed action.

Barrel Alternative

The Barrel Alternative proposes to place all of the tailings and waste rock in upper Barrel Canyon and the lower portion of Wasp Canyon. However, for the Barrel Alternative, no waste rock dumping is projected during the first 5 years of mine operation. Therefore, year 7 was selected, as it is projected to have the highest amount of waste rock deposited in the Barrel Canyon waste rock storage area.

The modeled, background, and maximum ambient concentrations at the project site from implementation of the Barrel Alternative for year 7 are shown in table 38.

The maximum predicted ambient concentrations for NO_2 (1-hour; scenario 3), PM_{10} (24-hour), and $PM_{2.5}$ (24-hour) are above the corresponding National Ambient Air Quality Standards at the project site. Under scenario 4, the maximum predicted ambient concentration for 1-hour NO_2 is just below the corresponding National Ambient Air Quality Standards (99.6 percent). The modeled impacts for this alternative indicate elevated impacts on State Route 83, which runs in close proximity to the perimeter fence on the east side of the project. This elevated impact is attributable to the proximity of the haul roads and waste rock storage areas to the process area boundary on the east side.

Please see the “Mitigation Effectiveness” part of this section for further details and discussion on additional mitigation measures and strategies that are currently being evaluated. Additionally, further modeling will be conducted to demonstrate the additional measures have reduced impacts to the National Ambient Air Quality Standards and air quality related values, thus, bringing the alternatives back into compliance with the applicable standards.

Table 38. Maximum ambient concentrations from emissions for Barrel Alternative–year 7

Type of Emission	Averaging Period	Modeled Concentration (micrograms per cubic meter (μg/m^3)[e]	Background Concentration (μg/m^3)	Maximum Ambient Concentration (μg/m^3)	National Ambient Air Quality Standards (μg/m^3)
At the Project Site (Near-Field and Fence Line Modeling)					
NO_2 (scenario 3)	1-hour[a]	224.7	24.5	249.2	188.7
NO_2 (scenario 4)	1-hour[b]	163.5	24.5	188.0	188.7
PM_{10}	24-hour[c]	152.6	33.0	185.6	150
$PM_{2.5}$	24-hour[d]	85.2	9.7	94.8	35
Saguaro National Park East Modeling					
NO_2 (scenario 3)	1-hour[a]	72.9	24.5	97.4	188.7
NO_2 (scenario 4)	1-hour[a]	70.4	24.5	94.9	188.7
PM_{10}	24-hour[d]	2.3	47.6	49.9	150
$PM_{2.5}$	24-hour[b]	0.6	11.4	12.0	35

[a] Represents the 98th percentile concentration over a 3-year period with an NO_2/NO_X ratio of 0.1.

[b] Represents the 98th percentile concentration over a 3-year period with an NO_2/NO_X ratio of 0.05.

[c] Represents the average of the highest 24-hour concentrations over a 3-year period.

[d] Represents the 4th highest concentration over a 3-year period.

[e] Concentrations have been scaled by 6.25 percent to represent concentrations from haul roads modeled as 2-way traffic.

The modeled results indicate this alternative is in compliance with the National Ambient Air Quality Standards at Saguaro National Park East.

Barrel Trail Alternative

The Barrel Trail Alternative proposes to place all of the tailings and waste rock in upper Barrel, Trail, and Wasp Canyons. Year 1 continues to represent the year with the highest projected mining rate and year 5 represent the year with the highest projected haul truck vehicle miles traveled. For the purposes of modeling the year 5 emissions, the leach pad and nearby haul roads were modeled as a pit since the waste dumps on the south and east side and the tailings on the north side are at a much higher elevation, compared with that of the leach pad.

The modeled, backgrounds, and maximum ambient concentrations from implementation of the Barrel Trail Alternative for years 1 and 5 are shown in tables 39 and 40.

Table 39. Maximum ambient concentrations from emissions for Barrel Trail Alternative–year 1

Type of Emission	Averaging Period	Modeled Concentration (micrograms per cubic meter (μg/m^3)[e]	Background Concentration (μg/m^3)	Maximum Ambient Concentration (μg/m^3)	National Ambient Air Quality Standards (μg/m^3)
At the Project Site (Near Field and Fence Line Modeling)					
NO_2 (scenario 3)	1-hour[a]	264.3	24.5	288.8	188.7
NO_2 (scenario 4)	1-hour[b]	173.4	24.5	197.9	188.7
PM_{10}	24-hour[c]	172.4	33.0	205.4	150
$PM_{2.5}$	24-hour[d]	31.0	9.7	40.7	35

Type of Emission	Averaging Period	Modeled Concentration (micrograms per cubic meter (μg/m^3)[e]	Background Concentration (μg/m^3)	Maximum Ambient Concentration (μg/m^3)	National Ambient Air Quality Standards (μg/m^3)
Saguaro National Park East Modeling					
NO_2 (scenario 3)	1-hour[a]	68.8	24.5	93.3	188.7
NO_2 (scenario 4)	1-hour[a]	67.4	24.5	91.9	188.7
PM_{10}	24-hour[d]	1.8	47.6	49.4	150
$PM_{2.5}$	24-hour[b]	0.5	11.4	11.9	35

[a] Represents the 98th percentile concentration over a 3-year period with an NO_2/NO_X ratio of 0.1.

[b] Represents the 98th percentile concentration over a 3-year period with an NO_2/NO_X ratio of 0.05.

[c] Represents the average of the highest 24-hour concentrations over a 3-year period.

[d] Represents the 4th highest concentration over a 3-year period.

[e] Concentrations have been scaled by 6.25 percent to represent concentrations from haul roads modeled as 2-way traffic.

Table 40. Maximum ambient concentrations from emissions for Barrel Trail Alternative–year 5

Type of Emission	Averaging Period	Modeled Concentration (micrograms per cubic meter (μg/m^3)[e]	Background Concentration (μg/m^3)	Maximum Ambient Concentration (μg/m^3)	National Ambient Air Quality Standards (μg/m^3)
At the Project Site (Near Field and Fence Line Modeling)					
NO_2 (scenario 3)	1-hour[a]	233.0	24.5	257.5	188.7
NO_2 (scenario 4)	1-hour[b]	160.0	24.5	184.5	188.7
PM_{10}	24-hour[c]	202.0	33.0	235.0	150
$PM_{2.5}$	24-hour[d]	33.8	9.7	43.5	35
Saguaro National Park East Modeling					
NO_2 (scenario 3)	1-hour[a]	79.5	24.5	104.0	188.7
NO_2 (scenario 4)	1-hour[a]	77.6	24.5	102.1	188.7
PM_{10}	24-hour[d]	2.6	47.6	50.2	150
$PM_{2.5}$	24-hour[b]	0.7	11.4	12.1	35

[a] Represents the 98th percentile concentration over a 3-year period with an NO_2/NO_X ratio of 0.1.

[b] Represents the 98th percentile concentration over a 3-year period with an NO_2/NO_X ratio of 0.05.

[c] Represents the average of the highest 24-hour concentrations over a 3-year period.

[d] Represents the 4th highest concentration over a 3-year period.

[e] Concentrations have been scaled by 6.25 percent to represent concentrations from haul roads modeled as 2-way traffic.

The maximum predicted ambient concentrations for NO_2 (1-hour; scenario 3 and 4), PM_{10} (24-hour), and $PM_{2.5}$ (24-hour) are all above the corresponding National Ambient Air Quality Standards at the project site. The modeled impacts for this alternative indicate the highest impacts on State Route 83, which runs in close proximity to the perimeter fence on the east side of the project. Similarly to the Barrel Alternative, this elevated impact is attributable to the proximity of the haul roads and waste rock storage areas to the process area boundary on the east side.

Extending the distance from the perimeter fence, adjusting the process area boundary, or implementation of additional haul road control measures would allow for lower modeled emissions, which could lead to demonstration of compliance with the National Ambient Air Quality Standards for this alternative.

Please see the "Mitigation Effectiveness" part of this section for further details and discussion on additional mitigation measures and strategies that are currently being evaluated. Additionally, further modeling will be conducted to demonstrate the additional measures have reduced impacts to the National Ambient Air Quality Standards and air quality related values, thus, bringing the alternatives back into compliance with the applicable standards.

The modeled results indicate this alternative is in compliance with the National Ambient Air Quality Standards at the Saguaro National Park East.

Scholefield-McCleary Alternative

The Scholefield-McCleary Alternative proposes to place all tailings and the majority of the waste rock north of the McCleary Canyon drainage channel. While the dry-stack tailings would be placed in Scholefield Canyon and an unnamed tributary drainage. The remaining waste rock would be placed on the northern slope of McCleary Canyon above the drainage bottom and on top of the tailings. Year 1 continues to represent the year with the highest projected mining rate, and year 5 represent the year with the highest projected haul truck vehicle miles traveled.

The modeled, backgrounds, and maximum ambient concentrations from implementation of the Scholefield-McCleary Alternative for years 1 and 5, are shown in tables 41 and 42.

Table 41. Maximum ambient concentrations from emissions for Scholefield-McCleary Alternative–year 1

Type of Emission	Averaging Period	Modeled Concentration (micrograms per cubic meter ($\mu g/m^3$)[e]	Background Concentration ($\mu g/m^3$)	Maximum Ambient Concentration ($\mu g/m^3$)	National Ambient Air Quality Standards ($\mu g/m^3$)
At the Project Site (Near Field and Fence Line Modeling)					
NO_2 (scenario 3)	1-hour[a]	343.6	24.5	368.1	188.7
NO_2 (scenario 4)	1-hour[b]	218.6	24.5	243.1	188.7
PM_{10}	24-hour[c]	394.4	33.0	427.4	150
$PM_{2.5}$	24-hour[d]	65.0	9.7	74.7	35
Saguaro National Park East Modeling					
NO_2 (scenario 3)	1-hour[a]	85.1	24.5	109.6	188.7
NO_2 (scenario 4)	1-hour[a]	82.3	24.5	106.8	188.7
PM_{10}	24-hour[d]	2.2	47.6	49.8	150
$PM_{2.5}$	24-hour[b]	0.6	11.4	12.0	35

[a] Represents the 98th percentile concentration over a 3-year period with an NO_2/NO_X ratio of 0.1.

[b] Represents the 98th percentile concentration over a 3-year period with an NO_2/NO_X ratio of 0.05.

[c] Represents the average of the highest 24-hour concentrations over a 3-year period.

[d] Represents the 4th highest concentration over a 3-year period.

[e] Concentrations have been scaled by 6.25 percent to represent concentrations from haul roads modeled as 2-way traffic.

Table 42. Maximum ambient concentrations from emissions for Scholefield-McCleary Alternative–year 5

Type of Emission	Averaging Period	Modeled Concentration (micrograms per cubic meter ($\mu g/m^3$)[e]	Background Concentration ($\mu g/m^3$)	Maximum Ambient Concentration ($\mu g/m^3$)	National Ambient Air Quality Standards ($\mu g/m^3$)
At the Project Site (Near Field and Fence Line Modeling)					
NO_2 (scenario 3)	1-hour[a]	317.5	24.5	342.0	188.7
NO_2 (scenario 4)	1-hour[b]	204.9	24.5	229.4	188.7
PM_{10}	24-hour[c]	467.0	33.0	500.0	150
$PM_{2.5}$	24-hour[d]	72.0	9.7	81.7	35
Saguaro National Park East Modeling					
NO_2 (scenario 3)	1-hour[a]	94.8	24.5	119.3	188.7
NO_2 (scenario 4)	1-hour[a]	89.7	24.5	114.2	188.7
PM_{10}	24-hour[d]	3.2	47.6	50.8	150
$PM_{2.5}$	24-hour[b]	0.8	11.4	12.2	35

[a] Represents the 98th percentile concentration over a 3-year period with an NO_2/NO_X ratio of 0.1.

[b] Represents the 98th percentile concentration over a 3-year period with an NO_2/NO_X ratio of 0.05.

[c] Represents the average of the highest 24-hour concentrations over a 3-year period.

[d] Represents the 4th highest concentration over a 3-year period.

[e] Concentrations have been scaled by 6.25 percent to represent concentrations from haul roads modeled as 2-way traffic.

The maximum predicted ambient concentrations for NO_2 (1-hour; scenario 3 and 4), PM_{10} (24-hour), and $PM_{2.5}$ (24-hour) are all above the corresponding National Ambient Air Quality Standards at the project site. The highest modeled impacts for this alternative are attributable to the proximity of the haul road and waste rock storage areas to the process area boundary on the northwest and east side.

Extending the distance from the perimeter fence, adjusting the process area boundary, or implementation of additional haul road control measures would allow for lower modeled emissions, which could lead to demonstration of compliance with the National Ambient Air Quality Standards for this alternative.

Please see the “Mitigation Effectiveness” part of this section for further details and discussion on additional mitigation measures and strategies that are currently being evaluated. Additionally, further modeling will be conducted to demonstrate the additional measures have reduced impacts to the National Ambient Air Quality Standards and air quality related values, thus, bringing the alternatives back into compliance with the applicable standards.

The modeled results indicate this alternative is in compliance with the National Ambient Air Quality Standards at the Saguaro National Park East.

Action Alternatives’ Projected Effects on Visibility in Class I Areas

The action alternatives would lead to reduced visibility in Saguaro National Park East, a Class I area 27 miles northwest of the project area. The VISCREEN model is used for near-field analysis of visibility impacts to Class 1 airsheds that are within 31 miles of an air pollution source. The model calculates the change in the color difference index (ΔE) and contrast between the plume and the viewing background that result from an elevated plume emanating from a point source. As shown in table 43, impacts to visibility at Saguaro National Park East would occur under the action alternatives.

Viewers at Saguaro National Park East would notice a change to the color and contrast of background views (sky and terrain) through the plume at various angles during worst case scenario wind speeds and atmospheric stability conditions. These conditions appear for about 303 hours during the entire year, which translates to approximately 6.8 percent of the daylight hours per year (Applied Environmental Consultants 2011d).

Table 43. Visibility impacts at Saguaro National Park East Class 1 airshed

Background	ΔE Criteria	ΔE Plume	Contrast Criteria	Contrast Plume
Sky	2.0	1.531	0.05	−0.05*
Terrain	2.0	3.326*	0.05	0.023

* Indicates that screening criteria have been exceeded.

The following text is excerpted from Section 3.2, Level 2 Screening Analysis, "VISCREEN: Visibility Impacts Analysis at Saguaro East NP," dated April 1, 2011 (Applied Environmental Consultants 2011d):

> Level 2 Screening Analysis
>
> The Level 2 analysis used the actual worst case meteorological conditions. Upon evaluation of the met data for the Year 2002 from the Tucson NWS Airport Site, the worst case meteorological conditions were found to be; extremely stable (F) atmospheric conditions, coupled with a wind speed of 2 m/s. During the day light hours (6 AM to 6 PM), these conditions appear for about 303 hours during the entire year; which translates to approximately 3.4% of the hours during a year. Table 3.2 [table 44] presents the summary results from the Level 2 screening analysis using actual worst case meteorological conditions. All default particle characteristics were assumed.

Table 44. Level 2 screening: maximum visual impacts inside the Saguaro East National Park Class I area

Background	Theta (º)	Azi (º)	Distance (km)	Alpha (º)	Delta E		Contrast	
					Criteria	Plume	Criteria	Plume
Sky	10	141	46.5	28	2.00	0.975	0.05	−0.011
Sky	140	141	46.5	28	2.00	1.531	0.05	−0.05*
Terrain	10	84	34.3	84	2.00	3.326*	0.05	0.023
Terrain	140	84	34.3	84	2.00	0.379	0.05	0.004

Note: This is table 3.2 from Section 3.2, Level 2 Screening Analysis, "VISCREEN: Visibility Impacts Analysis at Saguaro East NP," dated April 1, 2011 (Applied Environmental Consultants 2011d).

*Indicates screening criteria are exceeded.

Summarizing the table above, (Applied Environmental Consultants 2011d) write,

> The Level 2 analysis reduces the magnitude of the impacts significantly although it still shows an exceedance of the Terrain Delta E criteria and the Sky Contrast Criteria.

> VISCREEN assumes all emissions as being emitted from a point source, but almost all of the emissions from the Rosemont facility are emitted by sources which are characterized by volume sources dispersed throughout the mine and process area.

Therefore, the VISCREEN Level 2 analysis merged the emissions from the projects numerous volume and point sources into a single virtual point source, which was recommended by the National Park Service as a correct and conservative modeling methodology.

Other Class 1 areas that were analyzed for visibility impacts include Saguaro National Park West, Chiricahua Wilderness Area, Chiricahua National Monument, Galiuro Wilderness Area, and the Superstition Wilderness Area.

The following text is excerpted from Section 5 of the "Revised CALPUFF Modeling Report to Assess Impacts In Class I Areas," dated April 4, 2011 (Applied Environmental Consultants 2011d):

> Natural Conditions and Monthly Relative Humidity Factors f(RH) at Class I Areas
>
> For these Class I areas, natural background conditions must be established in order to determine a change in natural conditions related to a source's emissions. The EPA lists three types of Natural Conditions (natural background conditions) in their guidance document, Annual Average, Best 20% Days and Worst 20% Days (U.S. Environmental Protection Agency 2003). Based on the FLAG 2010 guidance as well as ongoing FLM discussion, Annual Average Natural Visibility Conditions were used for this analysis. These EPA estimates were taken from the Federal Land Managers Air Quality Related Values Workgroup (FLAG) Phase 1 Report Revised Table 6 (2010).
>
> The EPA, in its BART Guidelines (2005), concluded that by using monthly average Relative Humidity Adjustment Factors f(RH) the likelihood that the highest modeled visibility impacts that were caused by short-term and geographically different meteorological phenomena (e.g., weather events) would be minimized. The FLAG (2010) report agrees with the EPA, therefore the visibility analysis was conducted using monthly average f(RH) values for large hygroscopic particles, small hygroscopic particles and sea salt, rather than hourly values.
>
> Light Extinction and Haze Impact Calculations
>
> In keeping with FLM guidance, the CALPOST version 6.221 postprocessor was used for the calculation of the impact from the modeled source's primary and secondary particulate matter concentrations on light extinction. The formula that is used is the existing IMPROVE/EPA formula, which is applied to determine a change in light extinction [Bext] due to increases in the particulate matter component concentrations. Using the notation of CALPOST, the formula is the following:
>
> Bext = 2.2 x fS(RH) x [Small Sulfates] + 4.8 x fL(RH) x [Large Sulfate]
>
> + 2.4 x fS(RH) x [Small Nitrates] + 5.1 x fL(RH) x [Large Nitrates]
>
> + 2.8 x [Small Organic Mass] + 6.1 x [Large Organic Mass]
>
> + 10 x [Elemental Carbon]
>
> + 1 x [Fine Soil]

+ 0.6 x [Coarse Mass]

+ 1.7 x fSS(RH) x [Sea Salt]

+ [Rayleigh Scattering]

+ 0.33 x [NO2 (ppb)]

The concentrations, in square brackets, are in $\mu g/m^3$ and bext is in units of Mm^{-1}.

For each Class I areas analyzed, values for fs(RH), fl(RH), fss(RH) and the Rayleigh scattering term were acquired from the Federal Land Managers Air Quality Related Values Workgroup (FLAG) Phase 1 Report Revised Tables 6, 7, 8 and 9. (2010).

The assessment of visibility impacts at the Class I areas were conducted using CALPOST Method 8 sub-mode 5. In Method 8_5, each hour's source-caused extinction is calculated by first using the hygroscopic components of the source-caused concentrations, due to ammonium sulfate and nitrate, and monthly Class I area-specific f(RH) values.
The contribution to the total source-caused extinction from ammonium sulfate and nitrate is then added to the other, non-hygroscopic components of the particulate concentration (from coarse and fine soil, secondary organic aerosols, and from elemental carbon) to yield the total hourly source-caused extinction.

The far-field CALPUFF model was used to determine visibility impacts these Class 1 airsheds because they are more than 31 miles (50 kilometers) away from the project area. It is important to note the U.S. Environmental Protection Agency allows the use of the CALPUFF model for distances as far as 186 miles (300 kilometers), which is considered the limit for a far-field air quality impact analysis. These values are shown in table 45 (Applied Environmental Consultants 2011c).

Table 45. Visibility impacts at other Class I airsheds from year 1 and year 5 emissions

Criteria	Year 1 Emissions	Year 5 Emissions
Saguaro National Park West		
Days above 0.5 deciview (dv)	21	24
Days above 1.0 dv	1	1
Maximum dv impact	1.31	1.43
Chiricahua Wilderness Area		
Days above 0.5 dv	1	1
Days above 1.0 dv	0	0
Maximum dv impact	0.504	0.938
Chiricahua National Monument		
Days above 0.5 dv	0	2
Days above 1.0 dv	0	1
Maximum dv impact	0.456	1.119
Galiuro Wilderness Area		
Days above 0.5 dv	9	20
Days above 1.0 dv	3	8
Maximum dv impact	2.69	4.354

Criteria	Year 1 Emissions	Year 5 Emissions
Superstition Wilderness Area		
Days above 0.5 dv	0	0
Days above 1.0 dv	0	0
Maximum dv impact	0.34	0.366

Source: (Applied Environmental Consultants 2011c).

The U.S. Environmental Protection Agency has stated (40 Code of Federal Regulations 51) that a delta deciview level of 0.5 or more is considered to contribute to visibility impairment, and a delta deciview level of 1.0 or more is considered to cause visibility impairment. According to these metrics, during the fifth year of operation, the proposed action would contribute to noticeable visibility impairment at Saguaro National Park West for 24 days out of the year, Chiricahua Wilderness Area for 1 day out of the year, Chiricahua National Monument for 2 days out of the year, and Galiuro Wilderness Area for 20 days out of the year. The proposed action would cause visibility impairment at Saguaro National Park West for 1 day out of the year, at Chiricahua National Monument for 1 day out of the year, and at Galiuro Wilderness Area for 8 days out of the year. At their highest modeled impact, the proposed action could change visibility by 4.35 deciviews at the Galiuro Wilderness Area.

Far-field CALPUFF modeling results were not available for each of the action alternatives. However, based on the relatively small potential increases in $PM_{2.5}$, PM_{10}, and NO_2 mass emission rates under the action alternatives, the visibility results as provided for the proposed action are likely representative of the result one would obtain for the action alternatives. The largest percent increase for PM_{10} was approximately 9.6 percent, when comparing the pound per hour emission rates for the Scholefield-McCleary Alternative to that of the proposed action. The largest percent increase for $PM_{2.5}$ was approximately 14.1 percent, when comparing the pound per hour emission rates for the Scholefield-McCleary Alternative to that of the proposed action. The largest percent increase for NO_2 was approximately 7.0 percent when comparing the pound per hour emission rates for the Scholefield-McCleary Alternative to that of the proposed action.

Action Alternatives' Projected Effects on Deposition of Sulfates and Nitrates

Based on the CALPUFF model output files, predicted deposition impacts for sulfates and nitrates, resulting from SO_2 and NO_X emitted by the proposed project were calculated. Table 46 summarizes the maximum predicted deposition rates for years 1 and 5 for these chemical species. Deposition was calculated to include both dry and wet deposition flux and the total deposition impacts on a per Class I area basis. These values are compared with the Deposition Analysis Threshold for the western United States. The modeling results indicate that the maximum annual average deposition for sulfur from the project is very limited for all Class I areas. However, the modeling results also indicate that the maximum annual average deposition for nitrogen from the project exceeds the Deposition Analysis Threshold in Saguaro National Park West and Galiuro Wilderness Area. While above the screening threshold, these values remain quite low, compared with other regional emission sources.

As indicated by the "Federal Land Managers' Air Quality Related Values Work Group (FLAG) – Phase I Report – Revised (U.S. Forest Service et al. 2010)," the Deposition Analysis Threshold is a deposition threshold and not necessarily an adverse impact threshold. The Deposition Analysis Threshold is the additional amount of deposition that triggers a management concern, not necessarily the amount that constitutes an adverse impact to the environment.

Table 46. Deposition Impacts for Each Class I Area

Pollutant	Class I Area	Maximum Modeled Deposition Rate Year 1 (kg/ha/yr)	Maximum Modeled Deposition Rate Year 5 (kg/ha/yr)	NPS Class I Deposition Analysis Thresholds (kg/ha/yr)
Sulfur	Saguaro National Monument West	0.0003	0.0003	0.005
	Chiricahua Wilderness Area	0.0001	0.0001	
	Chiricahua National Monument	0.0001	0.0001	
	Galiuro Wilderness Area	0.0002	0.002	
	Superstition Wilderness Area	0	0	
Nitrogen	Saguaro National Monument - West	0.0245	0.0234	0.005
	Chiricahua Wilderness Area	0.0020	0.0024	
	Chiricahua National Monument	0.0023	0.0029	
	Galiuro Wilderness Area	0.0076	0.0106	
	Superstition Wilderness Area	0.0017	0.0017	

Source: (Applied Environmental Consultants 2011c).

Note:

kg/ha/yr = kilogram per hectare year

Based on information obtained from the National Park Service,

> studies currently underway have identified certain soils in the park [Saguaro National Park] that appear to be very sensitive to acidification; small potholes or other waterbodies on these soils may also be vulnerable to acidification. Small potholes may also be sensitive to nutrient enrichment from nitrogen deposition. Nitrogen enrichment may result in algae blooms and oxygen depletion, but no studies have been done to study these potential effects in the park.

Action Alternatives' Projected Effects on Bioaccumulation of Heavy Metals from Fugitive Dust

Bioaccumulation of heavy metals from fugitive dust emissions will be assessed and included between issuance of the DEIS and FEIS.

All soils naturally contain trace levels of metals. The presence of metals in soil is, therefore, not indicative of contamination. The concentration of metals in uncontaminated soil is primarily related to the geology of the parent material from which the soil was formed.

Action Alternatives' Projected Effects on Climate Change

The proposed action would result in emissions averaging 169,905 tons per year CO_2. This is roughly equivalent to the emissions from approximately 15,000 U.S. households.

Pima County greenhouse gas emissions in 2007 were 17,426,666 tons CO_2, so the action alternatives would increase emissions of CO_2 within the county by approximately 0.97 percent. Because climate change results from the cumulative past and present greenhouse gas emissions around the globe, emissions from the action alternatives cannot be said to cause any particular effect of climate change.

Mitigation Effectiveness

The Pima County Department of Environmental Quality is the local air pollution control agency for Pima County with jurisdiction over air pollution sources not under state jurisdiction and delegated

authority by the State. The Air Quality Permit issued by the Pima County Department of Environmental Quality will include the required mitigation measures applied to the source. Because this Air Quality Permit has not yet been issued, the mitigation measures listed below are based on information contained in the preliminary MPO and air quality permit application. Furthermore, as part of the air quality permitting process, Rosemont Copper developed a dust control plan, which includes measures to reduce fugitive dust and its potential effects on air quality.

Rosemont Copper has committed to using the following measures to minimize emissions and their impacts:

- The project will use a variety of operational and engineering controls for controlling fugitive dust associated with the tailings. These dust control measures will consist of the following controls, as stated in the preliminary MPO (WestLand Resources Inc. 2007a) and the "Rosemont Copper Company: Application for a Class II Permit Rosemont Copper Project Southeastern Arizona" (Applied Environmental Consultants 2010b):
    - Buttresses constructed of waste rock material will be used to break up air flow and reduce exposure of large areas of tailings to windy conditions.
    - The moisture content of the tailings will be sufficient to ensure that dust is not generated on the conveyor belts or during the stacking operations.
    - Tailing will be stacked using a tripper arrangement on mobile conveyors. This method allows placement of the tailings in an irregular shape to break up air flow patterns. The tripper also reduces the need for wheeled vehicles to drive across the tailings.
    - Materials from the grinders will be such that 80 percent of the material will pass 150 mesh (0.0041 inch), rather than the conventional tailings size of 80 percent passing 250 to 325 mesh (0.0025 to 0.0017 inch). The larger size of the material will reduce the likelihood of the tailings' becoming airborne.
    - Application of a binder material (such as Enviro Tac) to the surface of the tailings, agglomeration chemical to lines within the conveyor system to make larger overall grain size in the placed tailings, or the use of water to suppress dust emissions.
- Water sprays will be used to control dust emissions at the primary crusher dump pocket, and wet scrubbers will be used in the primary crushing building and crushed-ore stockpile building and tunnels. Use of point source pollution control equipment on all process equipment with significant emissions potential (under Pima County Code 17.04.304(A)(212), "significant" means in terms of the potential of a source to emit more than 15 tons per year of PM_{10});
    - Dust will be controlled with the use of various wet scrubber dust collection systems. These scrubber systems have a 100 percent capture efficiency of dust pickups, which directs the PM entrained in the air to the scrubber with a 99 percent control efficiency (rated and operating for processing). Specific wet scrubber dust collection systems, the emission points controlled, the respective exhaust flow rates in actual cubic feet per minute, and the voluntarily accepted PM_{10} grain loading/limits in pounds of PM_{10} per hour (pounds per hour) for the project are as follows:
        - Crushing area scrubber controls the primary crusher, crusher discharge hopper to crusher discharge feeder, and crusher discharge feeder to stockpile feed conveyor (exhaust flow rate = 18,000 actual cubic feet per minute and PM_{10} grain loading/limit = 1.28 pounds per hour)

- Stockpile area scrubber controls the stockpile feed conveyor to stockpile tripper conveyor, stockpile tripper conveyor to covered coarse ore stockpile, and general ventilation of the stockpile building (exhaust flow rate = 36,500 actual cubic feet per minute and PM_{10} grain loading/limit = 2.59 pounds per hour)
- Reclaim tunnel scrubber controls reclaim feeders to reclaim conveyor (exhaust flow rate = 15,000 actual cubic feet per minute and PM_{10} grain loading/limit = 1.07 pounds per hour)
- Pebble crusher area scrubber controls the pebble crusher, reclaim conveyor to semiautogenous grinding mill feed conveyor, pebble conveyor no. 2 to semiautogenous grinding oversize surge bin, semiautogenous grinding oversized surge bin to pebble crusher feeder, pebble crusher to pebble conveyor no. 3, and pebble conveyor no. 3 to semiautogenous grinding mill feed conveyor (exhaust flow rate = 22,000 actual cubic feet per minute and PM_{10} grain loading/limit = 1.56 pounds per hour)
- Copper concentrate scrubber 1 controls the copper concentrate conveyor to copper concentrate loadout stockpile, copper concentrate loadout stockpile to shipment truck via front-end loader, and general ventilation of the copper concentrate loadout building (exhaust flow rate = 50,000 actual cubic feet per minute and PM_{10} grain loading/limit = 3.55 pounds per hour)
- Copper concentrate scrubber 2 controls the copper concentrate conveyor to copper concentrate loadout stockpile, copper concentrate loadout stockpile to shipment truck via front-end loader, and general ventilation of the copper concentrate loadout building (exhaust flow rate = 50,000 actual cubic feet per minute and PM_{10} grain loading/limit = 3.55 pounds per hour)
- Molybdenum scrubber/electrostatic precipitator controls the molybdenum concentrate dryer (exhaust flow rate = 500 actual cubic feet per minute and PM_{10} grain loading/limit = 0.02 pounds per hour)

o Dust will also be controlled with the use of various dust collector systems. These dust collection systems have a rated and operating control efficiency of 99 to 99.9 percent. Specific dust collector systems, the emissions points controlled, their respective exhaust flow rates (actual cubic feet per minute) and the voluntarily accepted PM_{10} grain loading/limits in grains per dry standard cubic foot for the project are as follows:

- Molybdenum dust collector controls the molybdenum concentrate dryer to molybdenum concentrate bin and molybdenum concentrate conveyor to molybdenum packing and weigh system (exhaust flow rate = 1,500 actual cubic feet per minute and PM_{10} grain loading/limit = 0.010 grains per dry standard cubic foot)
- Laboratory dust collector 1 controls laboratory equipment (exhaust flow rate = 10,000 actual cubic feet per minute and PM_{10} grain loading/limit = 0.005 grains per dry standard cubic foot)
- Laboratory dust collector 2 controls laboratory equipment (exhaust flow rate = 10,000 actual cubic feet per minute and PM_{10} grain loading/limit = 0.005 grains per dry standard cubic foot)

- Laboratory dust collector 3 controls laboratory equipment (exhaust flow rate = 10,000 actual cubic feet per minute and PM_{10} grain loading/limit = 0.005 grains per dry standard cubic foot)

Emissions of VOCs and hazardous air pollutants resulting from the mix tanks and settlers used in the solvent extraction system are controlled by the use of covers. The use of covers is estimated to reduce the fugitive VOC and hazardous air pollutant emissions by 67 percent (Young et al. 1999).

- Containment (via water sprays or physical enclosures) on processes with low emissions potential;
  - Emissions of PM resulting from the unloading of concentrate ore to the primary crusher dump hopper will be controlled with water sprays. Spray systems at transfer points and material handling operations are estimated to reduce fugitive dust emissions by 70 to 95 percent (U.S. Environmental Protection Agency 1995).
- The coarse ore stockpile and concentrate loadout areas are contained within the enclosed stockpile building. The enclosed building would include a four-walled structure, covered by a roof, and access to the interior controlled by a movable door or flexible strip curtains. It would use a discharge grain loading and emission limits that represent voluntarily accepted limits, according to the air permit application. The specific regulatory citation for the applicable requirement is Pima County Code 17.12.190, “Permits containing synthetic emission limitations and standards.” Moreover, the proposed method to demonstrate compliance with these voluntarily accepted emission limitations is U.S. Environmental Protection Agency Reference Method 5 or 17, in accordance with 40 Code of Federal Regulations 60, appendix A. Once the air quality permit is issued, these voluntarily accepted limits/standards will be mandatory, and Rosemont Copper may face enforcement actions such as fines and even permit termination for failing to comply with the standards in the permit.
- Use of newer engine designs in mobile sources, which are subject to stricter Federal regulation and result in lower emissions;
  - Use of Tier 4 emission standards on selected nonroad engines (all except haul trucks and the 2,000 horsepower front-end loaders).
  - Tier 2 diesel engines will be used for all haul trucks.
- Dust control on access, haul, service, and maintenance roads during construction, operation, and closure periods;
  - Mine haul roads will be constructed using material excavated within the open pit, which may be crushed and screened to produce a smooth surface.
  - Haul truck speeds will not exceed 35 miles per hours and will usually be less than 25 miles per hours on ramp gradients of 10 percent or more.
  - Dust will be suppressed by wetting the road surface using a fleet of appropriately sized water trucks with up to 30,000-gallon tank capacities. Sufficient watering of unpaved roads can result in a control efficiency of up to 95 percent (U.S. Environmental Protection Agency 2006). The roads at the project site will be watered sufficiently to achieve 90 percent control efficiency.
- Compliance with materials safety data sheet specified procedures to reduce the impacts of chemical releases into the atmosphere;
- Use of low-sulfur diesel fuel onsite for all stationary equipment;

- Proper maintenance of construction equipment and reduction of unnecessary construction equipment idling;
- Expedited construction of electrical lines to reduce the need for onsite power generation and associated emissions;
- Demonstration of the potential to reduce emissions from the generation of electrical power used by mining and related operations by using alternative methods of power generation, such as solar and wind, to power mine administration buildings;
- Design of the project administration building to showcase use of leadership in environmental and energy design and sustainable energy concepts; and
- Application of acid leaching solution to the heap using emitters (similar to drip irrigation) to avoid aerosol losses to the wind.

These discharge grain loading and emission limits represent voluntarily accepted limits, according to the air permit application. The specific regulatory citation for the applicable requirement is Pima County Code 17.12.190, "Permits Containing Synthetic Emission Limitations and Standards." Moreover, the proposed method to demonstrate compliance with these voluntarily accepted emission limitations is U.S. Environmental Protection Agency Reference Method 5 or 17, in accordance with 40 Code of Federal Regulations 60, Appendix A.

All of these measures were included in the analytical and modeling work referred to in the discussion of environmental consequences for the action alternatives. Therefore, the effects remaining after these mitigation efforts are those effects described in the preceding sections.

The current modeling for the Barrel, Barrel Trail, and Scholefield-McCleary Alternatives demonstrates the potential for PM_{10} (24-hour), $PM_{2.5}$ (24-hour), and NO_2 (1-hour) concentrations at the process area boundary to exceed the National Ambient Air Quality Standards and for degraded visibility at the Saguaro National Park East through the life of the project. The derivation of those concentrations was through the use of an AERMOD dispersion model. For unpaved roads, the modeled data used controlled emissions (i.e., an application of mitigation measure resulting in a 90 percent control efficiency). In this case, the mitigation measure was the use of watering. To achieve the 90 percent control efficiency, the project would need to apply water at a rate of 1.08 gallons per square yard for the greatest traffic volume (Applied Environmental Consultants 2010b). However, the implementation of additional mitigation measures (i.e., control efficiencies greater than 90 percent) and/or revisions to certain aspects of the alternative layouts could be selected to potentially reduce these impacts. These elevated impacts are attributable to the proximity of the haul roads and waste rock storage areas to the process area boundaries for each of the alternatives to the fact that these sources release pollutants at ground level. The additional control measures and/or strategies that could be selected to reduce these impacts include the following:

- Use of sufficient watering (the application of water at a rate sufficient to produce a ratio of 5:1 surface moisture content of the watered road over the surface moisture content of the uncontrolled road) of unpaved roads to achieve a 95 percent control efficiency of PM;
- Use of a combination of watering, chemical dust suppressants, gravel, and/or paving to further control PM emissions;
- Use of higher tier compliant engines in vehicles and equipment to further control tailpipe NO_x emissions, if available;

- Rerouting/relocating of the unpaved haul roads so the roads are farther from the process area boundary; and
- Extension of the process area boundary.

The modeled impacts presented within this section assume the unpaved roads will be watered to achieve a 90 percent control efficiency of particulate matter ($PM_{2.5}$ and PM_{10}). Through the use of a combination of additional watering, chemical dust suppressants, gravel, and/or paving, a greater control of fugitive particulate emissions from unpaved roads would be realized. According to the U.S. Environmental Protection Agency, sufficient watering of unpaved roads can result in a control efficiency of up to 95 percent (assuming the water is applied to achieve a ratio of 5:1 surface moisture content of the watered road over the surface moisture content of the uncontrolled road (U.S. Environmental Protection Agency 2006).

To illustrate, if the additional application of water on the unpaved surfaces is assumed to be at its maximum (95 percent control efficiency), the additional 5 percent control effectively reduces the fugitive dust emissions resulting from truck travel on the unpaved roads by 50 percent. This is a significant reduction in particulate emissions and would therefore be assumed to have an effect on lowering the modeled $PM_{2.5}$ and PM_{10} impacts at the process area boundary and other modeled receptors.

Vehicle restriction measures seek to limit the amount and type of traffic present on the road or to lower the mean vehicle speed. For example, many industrial plants have restricted employees from driving on plant property and have instead instituted busing programs. This eliminates emissions attributable to individual employees traveling to/from their worksites. Although the heavier average vehicle weight of the buses increases the base emission factor, the decrease in employee vehicle miles traveled results in a lower overall emission rate. Traffic controls provide moderate emission reductions (often at little cost), but are difficult to enforce. These measures could provide a significant reduction in particulate and combustion related emissions and would therefore be assumed to have an effect on lowering the modeled $PM_{2.5}$, PM_{10}, and NO_2 impacts at the process area boundary and other modeled receptors.

Although paving is highly effective mitigation measure for unpaved roadways, its high initial cost is often prohibitive. Furthermore, paving is not feasible for industrial roads subject to very heavy vehicles and/or spillage of material in transport. Watering and chemical suppressants, on the other hand, are potentially applicable to most industrial roads at moderate to low cost. However, these measures require frequent reapplication to maintain an acceptable level of control. Chemical suppressants are generally more cost effective than water, but not in cases of temporary roads. A more effective technique is to apply chemical agents (such as surfactants) that permit more extensive wetting. Continuous chemical treating of material loaded onto piles, coupled with watering or treatment of roadways, can reduce total particulate emissions from aggregate storage operations by up to 95 percent (U.S. Environmental Protection Agency 2006).

The use of higher tier compliant engines could potentially reduce tailpipe emissions (specifically NO_x) from the vehicles and equipment associated with the project. Emissions from these diesel engines could also be reduced through a variety of strategies, such as add-on emission control retrofit technologies (e.g., selective catalytic reduction), idle-reduction technologies, cleaner fuel use, engine repowers, engine upgrades, and/or vehicle or equipment replacement. These measures could provide significant reduction in diesel fuel combustion related emissions and would therefore be assumed to

have an effect on lowering the modeled $PM_{2.5}$, PM_{10}, and NO_2 impacts at the process area boundary and other modeled receptors.

Rerouting/relocating the unpaved haul roads farther from the process area boundary is another strategy to potentially reduce impacts. The modeled impacts from these ground-level sources (e.g., haul-truck travel on unpaved surfaces and haul truck tailpipe emissions) are assumed to be reduced if the proximity from the haul road to the process area boundary is increased. Typically, the conditions that will drive maximum modeled impacts are slow wind speed and stable atmospheric conditions (i.e., stagnant), in which the emission source is in close proximity to the receptor. It is these stagnant conditions where dust plumes are assumed to travel near the ground surface and interact closely with ground features. Increasing the distance of the emission source to the receptor would allow for lower modeled impacts, as the emissions deposit nearer the source.

Similar to that of the rerouting/relocating strategy, extension of the process area boundary would allow for lower modeled impacts. The existing modeled data show that those impacts exceeding the National Ambient Air Quality Standards are located in very close proximity of the process area boundary. The impacts are not numerically reduced by extending the process area boundary, but the extension of the process area boundary means that the significant impacts would be located within the project area and therefore not accessible to the public.

Furthermore, as described in the individual process description sections within the air permit application, the current design of the project includes the use of six wet scrubbers, one cyclone scrubber, one baghouse, and one electrostatic precipitator for controlling particulate matter emissions from the metallic mineral processing equipment. Rosemont Copper is investigating the possible replacement of one or more scrubbers with cartridge filter dust collectors or baghouses. Replacement of the scrubbers with dust collectors or baghouses will reduce particulate emissions further because of their better control efficiency (99.9 percent versus 99.0 percent) (Applied Environmental Consultants 2010b).

These additional mitigation measures and strategies are currently being evaluated, and further modeling will be conducted to demonstrate that the additional measures have reduced impacts to the National Ambient Air Quality Standards and air quality related values, thus, bringing the alternatives back into compliance with the applicable standards. The modeling of the additional mitigation measures will be conducted during the interim period between the issuance of the DEIS and publication of the FEIS.

Direct, Indirect, and Cumulative Effects

The action alternatives would result in long-term direct and indirect effects on air quality at the project site and nearby Class I areas. Short-term effects on air quality (from construction) are anticipated to be minimal, relative to the long-term effects from mine operation. No effects on air quality are permanent; upon closure, the action alternatives' impact to air quality would not continue. However, the potential for wind-blown dusts will continue, just as there is with natural conditions.

Direct Effects

"Direct effects" refer to impacts from an action that are closely related to the action in space and time. For the proposed action and Phased Tailings Alternative, these effects include the following:

- PM_{10} concentrations at the project site to reach 97 percent of the PM_{10} National Ambient Air Quality Standards;

- Increase (2× current levels) of pollutant concentrations for $PM_{2.5}$, CO, and NO_x at the project site, to levels still below National Ambient Air Quality Standards;
- Degraded visibility at Saguaro National Park East through the life of the project, with the action alternatives causing noticeable visibility impairment up to 34 days per year, contributing to noticeable visibility impairment up to 91 days per year and by themselves reducing visibility by one-half (49.7 percent) at their highest potential impact;
- Increased risk of exceedance of the PM_{10} National Ambient Air Quality Standards in the Tucson and Saguaro National Park East areas and the risk of a "nonattainment" designation of these areas;
- Increased risk of exceedance of the O_3 National Ambient Air Quality Standards in the Tucson and Saguaro National Park East areas and the risk of "nonattainment" designation of these areas. While O_3 levels (8-hour average) in the Tucson and Saguaro National Park East areas are already within 99 percent of the National Ambient Air Quality Standards, and as the mining operations could be expected to increase NO_x emissions by 5 percent in Pima County, O_3 levels could reach even higher, thereby increasing the risk of National Ambient Air Quality Standards exceedances;
- Degradation of the two high-priority vital signs identified by the Sonoran Desert Network for Saguaro National Park East: O_3 and visibility (Sonoran Desert Network 2010); and
- Emissions of 192,594 tons per year CO_2, a greenhouse gas and contributor to global climate change.

For the Barrel, Barrel Trail, and Scholefield-McCleary Alternatives, these effects include the following:

- PM_{10} (24-hour), $PM_{2.5}$ (24-hour), and NO_2 (1-hour) concentrations at the project site to exceed the National Ambient Air Quality Standards;
- Increase (2× current levels) of pollutant concentrations for CO, and SO_2 at the project site, to levels still below National Ambient Air Quality Standards;
- Degraded visibility at Saguaro National Park East through the life of the project, with the action alternatives causing noticeable visibility impairment up to 34 days per year, contributing to noticeable visibility impairment up to 91 days per year and by themselves reducing visibility by one-half (49.7 percent) at their highest potential impact;
- Increased risk of exceedance of the PM_{10} National Ambient Air Quality Standards in the Tucson and Saguaro National Park East areas and the risk of a "nonattainment" designation of these areas;
- Increased risk of exceedance of the O_3 National Ambient Air Quality Standards in the Tucson and Saguaro National Park East areas and the risk of "nonattainment" designation of these areas. While O_3 levels (8-hour average) in the Tucson and Saguaro National Park East areas are already within 99 percent of the National Ambient Air Quality Standards, and as the mining operations could be expected to increase NO_x emissions by 5 percent in Pima County, O_3 levels could reach even higher, thereby increasing the risk of National Ambient Air Quality Standards exceedances;
- Degradation of the two high-priority vital signs identified by the Sonoran Desert Network for Saguaro National Park East: O_3 and visibility (Sonoran Desert Network 2010); and
- One percent increase in Pima County CO_2 emissions, a greenhouse gas and contributor to global climate change.

Indirect Effects

"Indirect effects" refer to impacts from an action that are removed from the action in space and time. An indirect effect of the project would be the air pollutant emissions generated by power plants to meet the electrical power demand of the project. The electric utility service provider for the project would be Tucson Electric Power (TEP). However, the power consumed by the project can come from a wide geographic area (i.e., Western Interconnect), and the manner in which this power is generated varies (e.g., fossil fuels, nuclear, solar, wind, hydro power, geothermal, etc.). It is estimated the project would require up to 133 megawatts (WestLand Resources Inc. 2007a). If the power demand of the project were to be supplied solely by a fossil fuel-fired plant(s), there would be an indirect increase in criteria pollutant and greenhouse gas emissions. However, the calculation of indirect impacts cannot e made because the quantity of these emissions and location of the generation facility/facilities are unknown, as the Forest Service has no control over how or where the energy is created.

For the action alternatives, emissions of criteria air pollutants would cease with closure of the project. However, CO_2 is long-lived within the atmosphere, and CO_2 emissions from the action alternatives would continue to contribute to an incremental amount of global climate change. Because global climate change results from emitting activities taking place around the world, the indirect effects of greenhouse gas emissions from the action alternatives cannot be directly linked to particular regional or global effects of climate change.

Cumulative Effects

The Council on Environmental Quality defines a cumulative impact as "the impact on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable actions regardless of what agency (federal or nonfederal) or person undertakes such other actions" (40 Code of Federal Regulations 1508.7). As outlined in the chapter 3 introduction, cumulative impacts of past and present actions are identified and analyzed in the "Affected Environment" part of each resource section, including for "Air Quality and Climate Change." 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 chapter 3 introduction. The following reasonably foreseeable action from that list was determined to contribute to a cumulative impact to air quality:

- Stakaer Parsons concrete plant

Reasonably foreseeable future actions within 62 miles of the Saguaro and Galiuro Class I areas include the proposed Stakaer Parsons concrete batch plant and crushed aggregate plant, about 10 miles northwest of the project area and about 15 miles south of Tucson. While the final emissions levels anticipated from this plant are not yet known, plant activities are anticipated to generate criteria pollutants, including PM_{10} and NO_x, from aggregate hauling and crushing, concrete mixing, unpaved haul roads, silos, and an 800-kilowatt diesel generator that will power the aggregate plant. PM_{10} and NO_x emissions from the generator have been estimated at 1 to 3 percent of the levels associated with the action alternatives, based on an assumed 80 percent capacity factor. Emissions of criteria pollutants from other sources associated with the plant cannot be estimated at this time and would add to the total plant emissions. However, this plant, overall, would be a smaller emissions source than the

action alternatives. The additional plant would further degrade air quality in ways similar to the action alternatives, although to a lesser extent. These cumulative effects would result in the following:

- Further increases to the risk of exceedances of the PM_{10} and O_3 National Ambient Air Quality Standards in the Tucson and Saguaro National Park East areas and to the risk of "nonattainment" designation of these areas for PM_{10} and/or O_3;
- Further increases to concentrations of other air pollutants in the Tucson and Saguaro areas; and
- Further degradation of visibility in the Saguaro National Park area.

In addition, the effects of climate change on the project area are also considered a cumulative effect, as they result from the cumulative emissions of greenhouse gases across the globe.

Current research (Southwestern Region Climate Change and Forest Planning Work Group 2010) suggests that climate change will have several effects on the project area. Temperature levels in the Southwest are anticipated to rise as a result of global climate change. By the end of the twenty-first century, they could rise by 5°F to 8°F. Overall precipitation levels in the Southwest are anticipated to fall by as much as 10 percent as a result of global climate change. The effects of these changes on the project are expected to be an increased risk of drought and wildfire.

All projected effects of climate change on the project area, including temperature, precipitation, drought, wildfire, and flooding effects, are anticipated under all alternatives (including the no action alternative). All alternatives except the no action alternative would be net contributors of greenhouse gas emissions, but these emissions cannot be tied to the climate change effects described above.

Irretrievable and Irreversible Commitment of Resources

The action alternatives would result in the irretrievable and irreversible emission of an average of 192,594 tons CO_2 per year, or 3.9 million tons CO_2 over the life of the project. Once emitted, CO_2 remains in the atmosphere for centuries and contributes to the warming of the Earth and changes to the planet's climate.

Additionally, under the emissions scenarios identified in the "Action Alternatives' Projected Effects on National Ambient Air Quality Standards" part of this section, climate change would likely have irreversible temperature and precipitation impacts to project area climate, as well as irreversible impacts to the risk of project area drought, wildfire, and flash flooding. The action alternatives would contribute to these impacts. The no action alternative would not contribute to additional emissions of CO_2. Irreversible temperature and precipitation impacts to project area climate, as well as irreversible impacts to the risk of project area drought, wildfire, and flash flooding, would still occur under the no action alternative, although this alternative would not contribute to these effects.

Groundwater Quantity

Introduction

The proposed action involves potential impacts to groundwater quantity in two groundwater basins (figure 29). The mine water supply is proposed to 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 would be located in the Davidson Canyon drainage east of the Santa Rita Mountains, which is adjacent to the Cienega Creek Basin. In addition

to the active removal of groundwater from the mine pit during operations, the presence of the mine pit would have a long-term impact on groundwater hydrology in the vicinity of the mine even after mine closure.

Issues, Cause and Effect Relationships of Concern

Cause and Effect Relationships

Pumping of mine supply water in the Upper Santa Cruz Sub-Basin would remove water from the regional aquifer and would lower groundwater levels, which could cause reduced groundwater availability to existing wells and water users. In the Davidson Canyon/Cienega Basin, development of the mine pit would intercept groundwater from fractures in the rock formations in the immediate vicinity of the mine, as well as the adjacent basin fill. Together, the fractured rock and basin fill form the regional aquifer of that groundwater basin (see figure 29). During mine operation, water from the mine pit would be actively pumped, which would cause drawdown in the regional aquifer. After closure, a mine pit lake would form that would lose water through evaporation, which would perpetuate the drawdown in the regional aquifer. This drawdown will cause impacts to wells, springs, streams, and riparian areas.

Identified Significant Issues

Numerous significant issues were identified with respect to groundwater resources, as discussed in chapter 1. Issues 3A and 3B relate directly to groundwater quantity. Issue 3D has been included in this section because it refers to impacts to springs and seeps, which are most appropriate to address in this section. While technically referring to surface water, Issue 4 has also been included because several of the assessment factors are related to groundwater, including impacts to perennial or intermittent streams and impacts to springs and seeps, which are addressed in this section. Impacts to riparian resources are addressed in the “Biological Resources” section of this DEIS; however, the impact to riparian vegetation from the potential reduction in springs or streamflow is assessed here.

Issue 3: Impact on Water Resources

This group of issues relates to the effects of mine construction, operation, closure, and postclosure on the quality and quantity of water for beneficial uses, wells, and stock watering. The loss of water availability to riparian and other plant and animal habitat is addressed in Issues 4 and 5.

Issue 3A: East Side Groundwater Availability

The proposed open-pit mine may reduce groundwater availability to private and public wells in the vicinity of the open pit. Household water availability may be reduced.

Issue 3A Factors for Alternative Comparison

- Direction and degree of change in water table level (feet), including annual average, range, and rate, compared with background
- Impairment of mountain-front groundwater recharge function
- Locations in which water resources may be impacted (geographic extent)
- Duration of the effect (in years)
- Comparison of mine pit water loss by evaporation with overall basin water balance
- Potential reduction in groundwater outflow from Davidson Canyon
- Approximate number of wells within the geographic extent of the impact

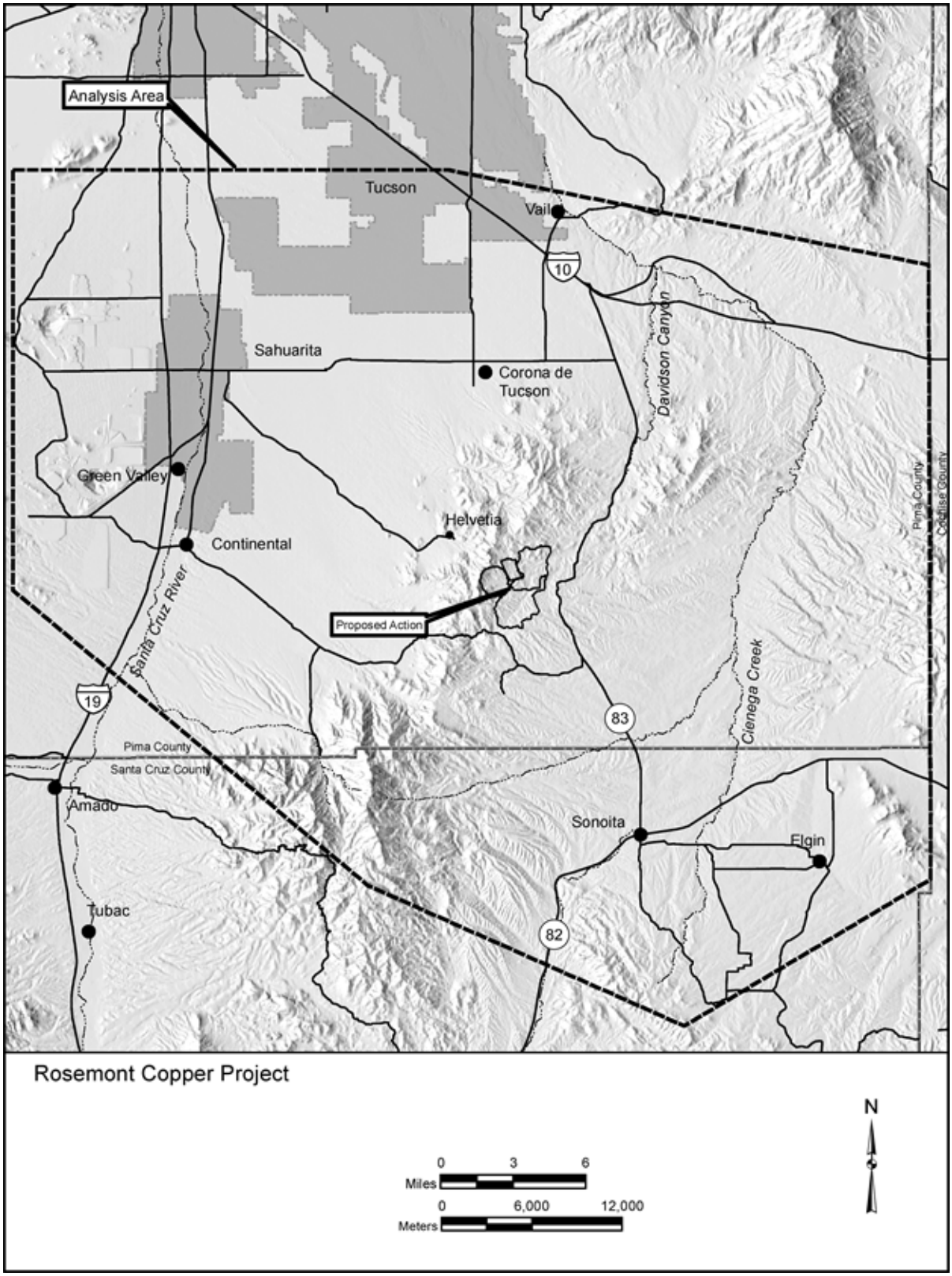


Figure 29. Analysis area for groundwater quantity

Issue 3B: West Side Groundwater Availability

Water needed to run the mine facility could reduce groundwater availability to private and public wells in the Santa Cruz Valley, specifically the communities of Sahuarita and Green Valley, Arizona. Household water availability may be reduced.

Issue 3B Factors for Alternative Comparison

- Water needed for operations from the Santa Cruz Valley and comparison with other water uses and basin water balance, measured in acre-feet
- Change in water table level (feet), including annual average and range, compared with background
- Locations in which water resources may be impacted (geographic extent)
- Duration of the effect (in years)
- Potential for subsidence to occur as a result of groundwater withdrawal
- Approximate number of wells within the geographic extent of the impact

Issue 3D: Surface Water Availability

Construction and operation of the mine pit, tailings, waste rock, and leach facilities may result in changes in surface water discharge to Davidson Canyon and Cienega Creek, portions of which are designated an Outstanding Arizona Water by the Arizona Department of Environmental Quality. Additionally, the availability of water for stock water tanks may be reduced.

Issue 3D Factors for Alternative Comparison

- Quantitative assessment of water released and available for beneficial uses
- Determination/estimation of number of stream miles changed from intermittent flow status to ephemeral flow status as a result of the project
- Quantitative assessment of potential lowering of the water table/reduced groundwater flow to Davidson Canyon and Cienega Creek that results in permanent changes in flow patterns and that may affect their Outstanding Arizona Water designations and current designated uses
- Stock watering tanks that will be unavailable (number)
- Change in volume, frequency, and magnitude of runoff from the project area
- Change in recharge of the aquifer by runoff
- Number of seeps and springs lost or impaired

Issue 4: Impact on Springs, Seeps, and Riparian Habitats

This issue relates to the potential impacts on riparian and wetland habitat that would result from the alteration of surface and subsurface hydrology from the pit and other operations. Potential impacts may include loss of riparian habitat and fragmentation of riparian habitat and corridors, including Cienega Creek.

Issue 4 Factors for alternative comparison

- Riparian habitat disturbed, unique or uncommon riparian habitat disturbed, and wildlife corridors disturbed (acres)
- Riparian habitat lost and unique or uncommon riparian habitat lost (acres)
- Seeps and springs degraded or lost (number)

- Qualitative assessment of ability to meet legal and regulatory requirements for riparian areas

Analysis Methodology, Assumptions, Uncertain and Unknown Information

Temporal Bounds of Analysis and Analysis Area

Temporally, the bounds of analysis for the mine water supply well field in the Upper Santa Cruz Sub-Basin has been selected to extend to 140 years after initiation of pumping, in order to allow the cone of depression resulting from 20 years of groundwater pumping to stabilize. While 20 years represents the maximum amount of drawdown in the vicinity of the Rosemont water supply wells, the lateral extent of the cone of depression will continue to expand after pumping stops. The temporal bounds of analysis for the area in the Davidson Canyon/Cienega Basin extends to 1,000 years after completion of mining. Specific snapshots of groundwater conditions for the analysis area are considered at the end of mining and 20, 50, 150, and 1,000 years after mine closure. It is recognized that predicting conditions 1,000 years in the future is speculative; however, this long time frame was selected in order to allow the bedrock aquifer impacted by the mine pit to come close to equilibrium. The analysis area shown in figure 29 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 pit, and encompasses the areas included in the groundwater models conducted for the analysis.

Methodology for Impacts Analysis

The following methodologies were used to analyze the specific issue assessment factors identified above.

Groundwater in the Davidson Canyon/Cienega Basin

Based on the issues presented above, the assessment factors for the Davidson Canyon/Cienega Basin are as follows:

- Direction and degree of change in water table level (feet), including annual average, range, and rate, compared with background (Issue 3A)
- Locations in which water resources may be impacted (geographic extent) (Issue 3A)
- Relative impairment of mountain-front groundwater recharge function (Issue 3A)
- Duration of the effect (in years) (Issue 3A)
- Determination/estimation of number of stream miles changed from intermittent flow status to ephemeral flow status as a result of the project (Issue 3D)
- Potential lowering of the water table/reduced groundwater flow to Davidson Canyon and Cienega Creek that results in permanent changes in flow patterns may affect their designations as Outstanding Arizona Waters and current designated uses (Issue 3D)
- Number of seeps and springs lost or impaired (Issue 3D and Issue 4)
- Comparison with basin water balance (Issue 3A)
- Reduction in groundwater outflow from Davidson Canyon (Issue 3A)

These factors are based on expected changes in the groundwater flow regime, including groundwater levels, flow direction, and recharge. In order to determine the predicted impacts to groundwater levels in the Davidson Canyon/Cienega Basin, results from three groundwater flow models were used to give a range of possible impacts. The groundwater models used in this analysis are more fully discussed in the “Methodologies” part of this section.

Impacts to springs and seeps and on perennial or intermittent streams are based on model results but also are based on the expected footprint of the area disturbed by mine activities and on assumptions regarding the source of the water and nature of the surface water/groundwater interaction. These assumptions are drawn from various technical reports and are explicitly cited in the analysis.

Groundwater in the Upper Santa Cruz Sub-Basin

Based on the issues presented above, the assessment factors for the Upper Santa Cruz Sub-Basin are as follows:

- Water needed for operations from the Santa Cruz Valley, measured in acre-feet (Issue 3B)
- Change in water table level (feet), including annual average and range, compared with background (Issue 3B)
- Locations in which water resources may be impacted (geographic extent) (Issue 3B)
- Duration of the effect (in years) (Issue 3B)
- Comparison with basin water balance (Issue 3B)

These factors are based on expected changes in the groundwater flow regime, including groundwater levels, flow direction, and recharge. In order to determine the predicted impacts to groundwater levels in the Upper Santa Cruz Sub-Basin, results from a groundwater flow model were used. The groundwater models used in this analysis are discussed further in the “Methodologies” part of this section.

Thresholds of Concern

The threshold of concern with respect to impacts to water wells in the Santa Cruz Valley is a drop in water levels greater than 10 feet over any period. Note that under Arizona water law, in general there is no regulatory mechanism that prescribes such a threshold. However, the 10-foot threshold is commonly used in other nonapplicable Arizona regulatory programs, such as well spacing requirements (Arizona Administrative Code R12-15-1302).

Springs, seeps, and perennial and intermittent stream reaches, on the other hand, can be sensitive to very small changes in groundwater levels; theoretically, the threshold of concern for these resources is any predicted change in water levels at all. However, in reality such small changes are unrealistic to either model or observe with any reliability. In addition, for many of the seeps and springs, the exact source of groundwater is unknown. For springs, seeps, and perennial and intermittent stream reaches, the following qualitative thresholds were established to reflect this uncertainty:

- Major – Reduction in flow can be estimated with high certainty and would impact resource function
- Minor – Reduction in flow can be estimated with high certainty but is not likely to impact resource function
- Possible – Reduction in flow could occur, but uncertainty exists regarding the source of the water
- Unlikely – Reduction in flow is unlikely to occur

The area of impact for springs, seeps, and wells in the Davidson Canyon/Cienega Basin is defined by the 5-foot contour of expected decrease in groundwater levels, which was the common threshold used for reporting expected water level impacts in the groundwater models described below.

Overview of Modeling Process

The methodology for determining impacts to groundwater for the above issues involves developing numerical groundwater flow models to predict the effect of the proposed mine water supply pumping on the groundwater system in the Upper Santa Cruz Sub-Basin and to predict the effect of the mine pit on the groundwater system in the Davidson Canyon/Cienega Basin.

Groundwater flow models are tools that attempt to mathematically simulate a real-world groundwater system. All models begin by analyzing and incorporating any available geological and hydrologic data that have been observed in the field, such as water-level measurements, aquifer test results, and the results of geological mapping and drilling. Using these data as a starting point, modelers then make a series of assumptions about how the groundwater system operates and choose appropriate techniques for simulating the real-world system mathematically. Although there is never any one single way to construct a groundwater flow model, there is an accepted process for constructing these models (American Society for Testing and Materials 2006).

Groundwater flow models are sophisticated tools, but they are only an approximation of reality, and the modeler has to constantly assess whether the model results are accurate and realistic. The modeling process is meant to ensure that this assessment occurs in a systematic and objective way. Three primary methods are built into the standard modeling process to ensure the accuracy of the model:

- Calibration. Calibration is a process through which various model parameters are systematically changed, within reasonable bounds, in order to get the model results to match real-world conditions (the calibration target). In groundwater flow modeling, the calibration target often consists of historic measured water levels or water level trends.
- Sensitivity Analysis. Sensitivity analysis is a systematic evaluation of which model parameters have the largest effect on the model results and an evaluation of how uncertainty about each parameter will affect the accuracy and reliability of the model.
- Verification. Verification is a step beyond calibration that is desirable but is not always able to be performed. In verification, once a model is believed to be calibrated to best match the calibration target, the model is then compared with a completely different set of known real-world conditions. This comparison ensures that the model is flexible, simulates the real-world environment under many conditions, and has not been “hard-wired” to only match the calibration target.

However, conducting both calibration and verification requires having two entirely separate targets; often, it is challenging to just find a single calibration target. Note that for this reason, verification was not conducted for any of the models discussed below. Lack of verification is not considered a fatal flaw to a model and does not suggest that the models are not accurate or usable: “A calibrated but unverified model may still be used to perform predictive simulations when coupled with a careful sensitivity analysis” (American Society for Testing and Materials 2006).

A fourth step in the modeling process known as validation takes place in the future. During this process, the past predictions of the model are compared with the reality as measured in the field to identify whether the model accurately estimated future impacts. Model validation is proposed as one aspect of future monitoring for the project.

In the case of the proposed project, it was recognized that groundwater flow models were the only tools that could reasonably be used to assess future impacts from the proposed project. Because of their critical importance, two additional steps were intentionally built into the modeling process.

- A system for independent peer review of the models was implemented. Under this system, modeling reports (from Errol L. Montgomery and Associates and Tetra Tech) were reviewed independently by third-party consultants recognized as being experts in the field of groundwater modeling (MWH or SRK Consulting). The third-party consultant prepared itemized critiques of the modeling reports, including the assumptions made, interpretation of data, and modeling techniques used. Face-to-face meetings were conducted, allowing the modeling experts among the consultants to come to consensus on various points of contention. Based on the peer review, revised models were prepared as described below. Additional peer review and criticism was also provided by Coronado specialists and at least one cooperating agency (Pima County).
- The original model for the mine site groundwater system was constructed by Errol L. Montgomery and Associates. Rosemont Copper recognized early in the process that the ultimate accuracy of the modeling depends strongly on the geological and hydrologic assumptions made in the model. To balance any possible subjectivity in the selection of assumptions, Rosemont Copper commissioned Tetra Tech to prepare a second, completely independent groundwater flow model of the mine site. The only original connection between the models was the underlying hydrologic data used as a basis for the models and the desire to model identical areas; other than this, the interpretation of these data and the design and operation of the models were conducted independently of one another.

For the purposes of analyzing groundwater impacts in this DEIS, the full range of modeling work has been assessed, not just a single report or model. For the mine site groundwater system, results from both independent models as well as a third model commissioned by Pima County have been used in order to offer a range of possible impacts. Any limitations in the modeling that may affect the impacts are clearly assessed and stated. The information presented below is based on the published reported results of the models. The original electronic modeling files have been provided to the Coronado and are currently being reviewed for consistency with the published reports.

Summary of Models Used

Mine Water Supply in Upper Santa Cruz Sub-Basin

Montgomery Mine Water Supply Model

The impacts to groundwater levels associated with the mine water supply well field near Sahuarita are predicted using a groundwater flow model constructed by Errol L. Montgomery and Associates (2009b; 2010), referred to hereafter as the Montgomery Mine Supply model. The proposed location for the mine water supply wells in the Santa Cruz Valley is within the Upper Santa Cruz Sub-Basin, which is a groundwater sub-basin within the Tucson Active Management Area. The Tucson Active Management Area is an administrative area that was created under the Arizona Groundwater Management Act of 1980; within the Tucson Active Management Area, groundwater resources are intensively managed by the Arizona Department of Water Resources. As part of the basin management, the Arizona Department of Water Resources has developed and maintains a groundwater model for the Tucson Active Management Area that covers 3,250 square miles (Mason and Bota 2006). The Tucson Active Management Area model was calibrated by the Arizona Department of Water Resources to match two data sets: water levels representing predevelopment

conditions in 1940, and changing water levels between 1941 and 1999. The model was then able to be used by the Arizona Department of Water Resources to predict future conditions from 2000 through 2024. The model is executed using the computer code MODFLOW 2000. Tucson Active Management Area boundaries and geographic features are shown in figure 30.

The Montgomery Mine Supply model is a modification of the Tucson Active Management Area model. The modifications made to the Tucson Active Management Area model primarily consist of refinements in the immediate vicinity of the mine water supply, based on the availability of more recent site-specific information. Modifications include changes in cell size, aquifer parameters, layer thickness, groundwater demands, and recharge.

This type of refinement of an existing model is a standard accepted practice for using a regional-scale model to analyze impacts from a specific project (Leake and Claar 1999). Use of the Tucson Active Management Area model as the basis for the mine water supply pumping prediction allows the predictive model to benefit from the long-term, area-wide data contained in the Tucson Active Management Area model. As such, the Montgomery Mine Supply model uses information recorded over the 66-year period from 1940 through 2006 as the basis for predicting groundwater behavior for a period lasting from 2007 through 2037. The predictive model incorporates the groundwater stresses, pumping withdrawals, and groundwater recharge facilities currently on file with the Arizona Department of Water Resources. The pumping withdrawal for the proposed project is then added into the model in order to predict the additional water table drawdown from the proposed project.

The Montgomery Mine Supply model was calibrated based on observed water level trends in various wells in the vicinity of the proposed well field from the period 1981 through 2005.

Status of Model and Peer Review

Independent peer review of the mine water supply model (Errol L. Montgomery and Associates Inc. 2009a) was conducted by MWH (Haws and Leeson 2010) to identify deficiencies in approach and execution of the modeling. A revised Montgomery Mine Supply model was prepared (Errol L. Montgomery and Associates Inc. 2010) and was reviewed again by MWH to identify whether deficiencies were addressed (Haws and Leeson 2011). MWH concluded the following:

- “After reviewing the Report Addendum and Additional Discussion memorandum, it is MWH’s opinion that the groundwater flow model developed by M&A meets industry standards for groundwater flow models and is adequate for predicting potential groundwater level changes caused by Rosemont mine supply pumping” (Haws and Leeson 2011:1).

Calibration of Model

A transient calibration analysis was completed (Barter and Odom 2011). Because of large seasonal fluctuations in groundwater levels in the Sahuarita area that are largely the result of agricultural pumping, the calibration was conducted on groundwater level trends, rather than on individual groundwater level measurements. Statistical assessment of the calibration was calculated using individual water level measurements corrected for the offset observed in the water level trends. The peer review process concluded that this technique was sufficient to demonstrate calibration (Haws and Leeson 2011). The calibration results were as follows:

- The residual mean of the transient calibration was 20.7 feet. The residual mean is the average of the residuals. A residual is the difference between an observed calibration target water level and a modeled water level at the same location. The residual mean for the model calibration is positive, which indicates a model bias towards over-predicting groundwater levels.

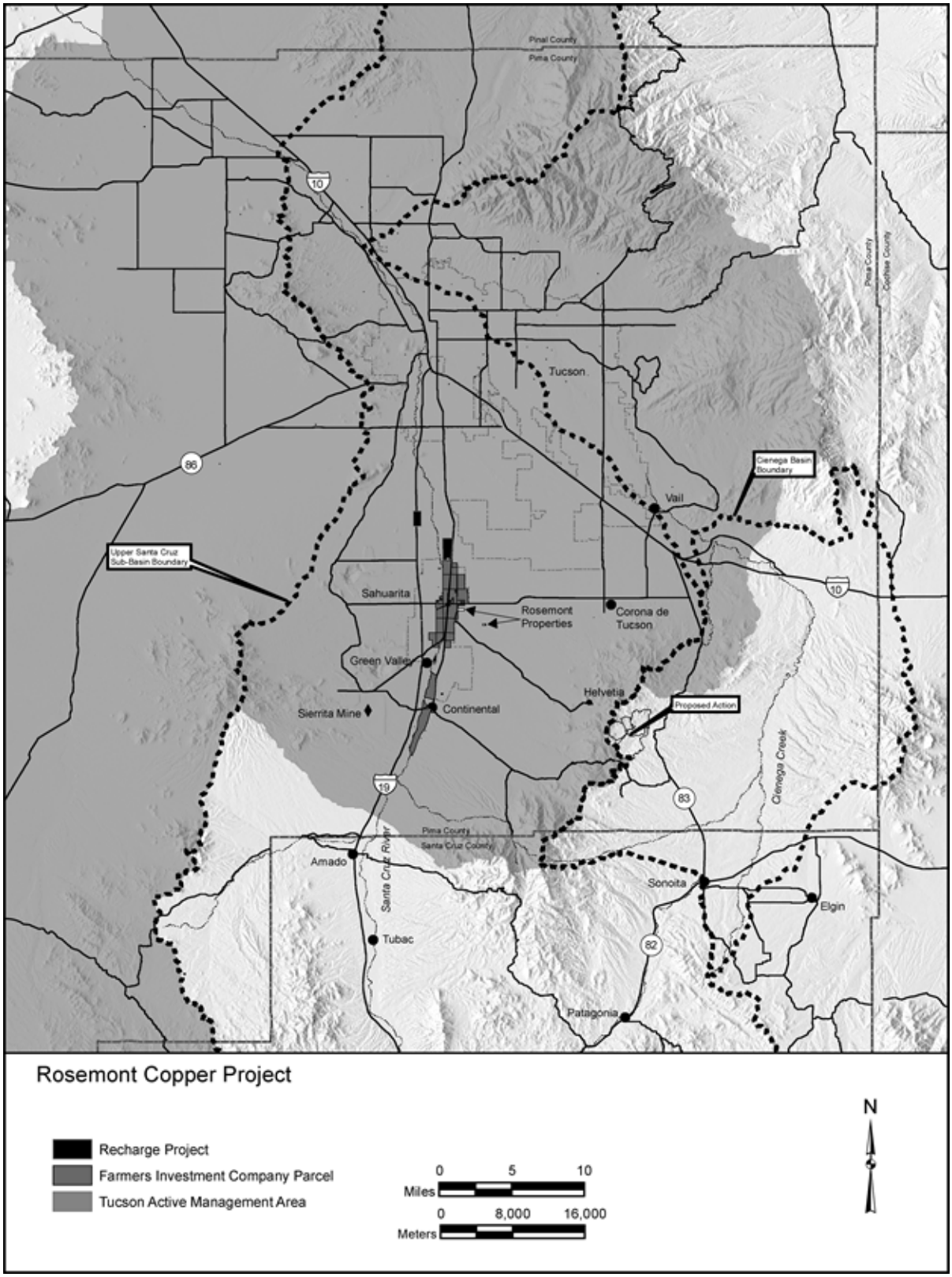


Figure 30. Tucson Active Management Area

- The absolute residual mean of the steady-state calibration was 21.66 feet. The absolute residual mean is the average of the absolute values of the residuals and represents the magnitude of differences seen between observed and modeled water levels.
- The residual standard deviation is 25.26 feet. One widely used standard for assessing the success of the calibration is the residual standard deviation divided by the range of observed values; values below 10 percent are generally considered to be acceptably calibrated. The residual standard deviation divided by the range of observed values was 10.6 percent.
- The calibration success (as measured by the residual standard deviation divided by the range of observed values) slightly exceeds the typical cutoff for acceptability of 10 percent. This appears to be largely to the result of the difficulties in finding acceptable calibration targets in the immediate vicinity of the project because of large seasonal fluctuations in groundwater levels. With respect to use of the model in the DEIS, the calibration was considered acceptable on the strength of MWH's final conclusions, subject to the limitations described in the next section.

Potential Limitations and Current Usability of Model

The Mine Water Supply model developed by Montgomery and Associates (2009a; 2010) has been used in order to analyze impacts in this DEIS, recognizing the following limitations:

- The calibration is considered acceptable by the peer reviewers (Haws and Leeson 2011); however, Montgomery and Associates (Barter and Odom 2011) provides one caution about the model results: "In this evaluation results indicate the model is showing a small bias to overpredict regional groundwater level decline during the calibration period. This bias does not render the model results invalid, but does indicate a potential that projected drawdown from Rosemont pumping could potentially be slightly smaller than simulated." In practice, this reflects a more conservative analysis in the DEIS and is therefore considered acceptable for analyzing impacts from pumping.
- Given the model cell size and uncertainties concerning connection of shallow wells to the regional aquifer, assessing impacts to local wells is not feasible. Using any large-scale model to predict the impacts to individual wells with any certainty is difficult at best. Furthermore, an inventory of all wells with the necessary information to assess impacts (depth, screened interval, pump setting, current water levels) does not exist and would be prohibitively costly and time consuming to create. It is unlikely that any modification to the model—or any model—would be able to fully analyze impacts to individual wells. The model is still used to assess impacts, with the understanding that impacts to individual wells are not considered, except in a qualitative manner.

Mine Site Models in the Davidson Canyon–Cienega Basin

Unlike for the Santa Cruz Valley, no regional groundwater models have been constructed that incorporate the project area; all modeling for the area has been conducted specifically for the proposed project. For the purposes of this analysis, three models are considered.

Also in contrast to the modeling for the mine water supply, the area of the proposed mine pit does not benefit from a lengthy period of historical data regarding groundwater levels, groundwater response to pumping, or the overall knowledge of area-wide hydrologic parameters. In addition, the geology of the project area is substantially more complex than that of the Santa Cruz Valley. In order to balance possible subjectivity when selecting modeling assumptions, two independent groundwater flow

models were commissioned by Rosemont Copper from Errol L. Montgomery and Associates and Tetra Tech to analyze the effect of the proposed mine pit on groundwater in Davidson Canyon and the Cienega Basin. Both models use the same model domain, pump test data, and fundamental geological data, but each model takes a different approach to developing the model cells and assigning geological and hydrologic properties to each cell. Each modeler conducted unique sensitivity and calibration computations and reached similar but not identical predictions regarding the response of the groundwater system to the stress imposed by the mine pit.

Outside the two independent models commissioned by Rosemont Copper, Pima County commissioned another independent model by Dr. Tom Myers, which has been presented to the Coronado as an alternative model for analyzing impacts to groundwater.

Each of these three models is discussed separately below. For the purposes of the impacts analysis in this DEIS, the predictive results from all three models were considered in order to develop a range of potential impacts, subject to the limitations listed for each model.

Montgomery Mine Site Model

The impacts to groundwater levels resulting from active pumping of groundwater from the proposed mine pit during mine operations, as well as long-term removal of groundwater from the aquifer by evaporation from the mine pit lake, are predicted using a groundwater flow model constructed by Errol L. Montgomery and Associates (2010), referred to hereafter as the Montgomery Mine Site model.

The framework for the Montgomery Mine Site groundwater model is based in part on a hydrogeologic data collection program implemented in 2008, which included well drilling, water-level monitoring, aquifer testing, and water quality sampling. These observed hydrogeologic data were incorporated into a groundwater flow model that covers 457 square miles and consists of 10 layers, with the base of the model at an elevation of 1,000 feet above mean sea level.

The modeling process for Errol L. Montgomery and Associates consisted of first constructing a steady-state model; a steady-state model assumes that the basin being modeled is in equilibrium, with no significant changes in water inflow, outflow, or storage over time. The steady-state model was constructed and then calibrated to the observed present-day water levels. Once calibrated, the model was modified to include the removal of groundwater caused by the proposed mine pit, and the resulting changes in groundwater levels are simulated over time (1,022 years in this case). The model is executed using the computer code MODFLOW-SURFACT.

Errol L. Montgomery and Associates made several important assumptions in order to construct their model:

- Perennial stream reaches are modeled using a stream-aquifer interaction package (STR).
- Evaporation losses from the mine pit lake are modeled using a lake modeling package (LAK2).
- Boundary conditions at the edges of the model domain are a combination of constant-head boundaries and general-head boundaries. Constant-head boundaries assume that water levels remain constant at the model edges and calculate the amount of water needed flow in or out of the model to maintain those water levels. General-head boundaries allow both water levels and groundwater flow to change at the edges of the model. Both constant-head and general-head boundaries can allow an unlimited amount of water to enter or leave the model; for this

reason it is necessary to consider the modeled groundwater flows through constant-head or general-head boundaries when assessing the validity of a groundwater model.

- It was assumed that any groundwater pumpage within the model area was negligible. Groundwater pumpage within the basin was estimated between 400 and 500 acre-feet per year.

Although it is recognized that flow with the aquifer occurs almost exclusively through fractures and faults, the model treats the aquifer as if it were porous media (similar to the mine water supply model). This is a standard approach for modeling large regional fractured bedrock systems, provided that the results are analyzed at an appropriate scale. There are other methods of modeling groundwater flow in fractured aquifers; however, for the most part such modeling methods require extensive data on either individual fractures or homogeneous fracture zones. Collection of this level of data is not feasible for a model of this size (457 square miles), and from a logistical standpoint there is limited ability to determine the hydraulic characteristics of individual faulting and fracturing features. Further, the hydraulic characteristics of faulted systems over the study area are not typically dominated by individual faults. Rather, the hydraulic extensiveness of individual faults is typically limited over the larger study area. Instead, on average the system of finite but connected individual faults and fractures behave equivalent to a porous medium. Use of an equivalent porous media to model fractured flow is widely recognized by as being acceptable to analyze groundwater flow at regional scales, as is modeled here. Such models are less acceptable for analyzing fate and transport over shorter distances, as individual fractures play an increasingly important role in contaminant movement.

- Three fault zones were modeled: the Davidson Canyon Fault Zone, Backbone Fault, and Flat Fault (figure 31).

Status of Model and Peer Review

Independent peer review of the first draft of the Montgomery Mine Site model (Montgomery and Associates Inc. 2009) was conducted by SRK Consulting to identify deficiencies in approach and execution of the modeling. A revised Montgomery Mine Site Model was prepared (Montgomery and Associates Inc. 2010) and was reviewed again by SRK Consulting to identify whether deficiencies were addressed. SRK Consulting (Ugorets and Cope 2010) concluded the following:

- “The ground water model presented in the revised report addresses the comments and recommendations made by SRK in its review of the original report. SRK finds the revised model and report to represent hydrogeological conditions that are appropriate to the model that was developed and to the data that were available. The predictive model is based on a good steady-state calibration and a reasonable transient-state calibration.”
- “Model predictions for both mining and post-mining conditions are reasonable, are based on the results of a completed comprehensive analysis, and provide a possible range of potential impacts to the ground water system and to surface-water bodies.”
- “The model was conceptualized, constructed, and presented to standard industry practices. Though there remain and will always remain uncertainties with a simulation of complex natural systems, the revised model is judged to be sufficient in concept and execution such that the resulting predictions of impacts are reasonably supported and defended by the available data.”

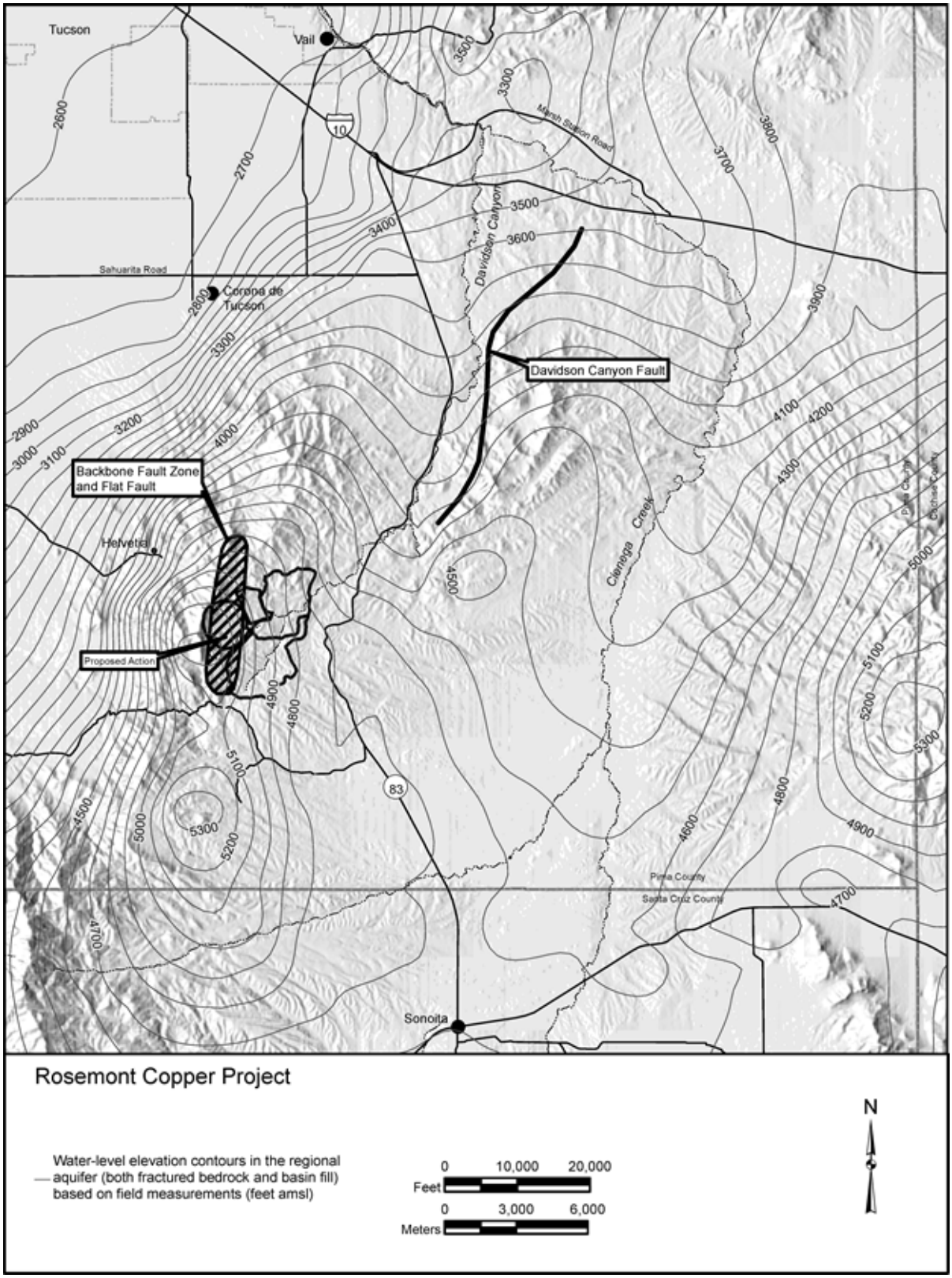


Figure 31. Groundwater levels in the Cienega Basin

Calibration of Model

A calibration was conducted on both the steady-state and transient models.

- Horizontal conductivity, vertical conductivity, and recharge were varied during the calibration.
- Observed groundwater levels were used as calibration targets, including water level responses during pump testing of five wells in order to calibrate the transient model.
- The residual mean of the steady-state calibration was 26.2 feet. The residual mean for the model calibration is positive, which indicates a model bias toward overpredicting groundwater levels. The absolute residual mean of the steady-state calibration was 58.0 feet. The residual standard deviation is 80.6 feet. The residual standard deviation divided by the range of observed values was 2.8 percent; values below 10 percent are generally considered to be acceptably calibrated.
- Difficulties in calibrating water levels on the west side of the model, nearest the mine pit, were identified. This means that the predicted groundwater levels in the immediate vicinity of the mine pit should be used with caution. This has not impacted the overall analysis of impacts; the expected changes in water levels in the immediate vicinity of the mine pit are very large, and impacts to springs and wells in this area are not in question, even if some error exists in the exact predicted amount of water level change. Overall, the difficulties in calibrating the model in this area result from the use of a porous media model to model fracture flow conditions. On a regional scale the porous media model is reliable for predicting water level impacts, but on the scale of individual wells the model may not fully reflect the individual fractures that supply water to that well.
- The Montgomery Mine Site model steady-state water balance is as follows. Inflows to the model area consisted of recharge (6,500 acre-feet per year) and inflow to the Cienega basin from general-head and constant-head boundaries (2,509 acre-feet per year). Outflows from the model area consisted of evapotranspiration (5,007 acre-feet per year), streamflow out of the model area from Cienega Creek (1,715 acre-feet per year), and outflow from general-head and constant-head boundaries into the Tucson Basin (2,282 acre-feet per year).

Sensitivity Analysis of Model

A sensitivity analysis was conducted on both the steady-state and transient models. The model parameters analyzed during the sensitivity analysis included horizontal and vertical hydraulic conductivity, hydraulic conductivity of the various fault zones, and recharge. Additional model parameters concerning the water balance for the mine pit lake were also analyzed. Montgomery and Associates Inc. (:figures 117–119) concluded the following:

- Overall, Montgomery and Associates found that varying model parameters by an order of magnitude higher or lower did not improve on the model calibration.
- The greatest changes due to sensitivity analysis occur in the first several hundred years of the simulation. Changes in hydraulic conductivity cause drawdown contours to advance or recede up to 3 miles in some directions, particularly along Davidson Canyon.
- However, by 1,000 years, changes in hydraulic conductivity do not result in a shift in drawdown contours more than 1 mile.

Potential Limitations and Current Usability of Model

The Montgomery Mine Site model (Montgomery and Associates Inc. 2010) has been used in order to analyze impacts in this DEIS, based on the following:

- The calibration appears to be within acceptable range. Although it was not entirely successful on the west side of the model, errors in predicted water levels at this location are not expected to change the overall impact assessment.
- Full peer review and revisions have been completed and have found the model to be acceptable (Ugorets and Cope 2010).
- It is recognized that the record of historic water level data used as a basis for the model is largely limited to the period since 2008. It is also recognized that the spatial distribution of detailed geological data is limited to the immediate project area.
- It is recognized that predicting conditions 1,000 years in the future is speculative; however, this long time frame was selected in order to allow the bedrock aquifer impacted by the mine pit to come close to equilibrium.
- It is recognized that while pumpage in the basin is relatively minor, compared with the overall basin water balance, pumpage in the basin is increasing and lack of modeling of this pumpage may affect future predictions.
- It is recognized that while much of the Cienega Basin was included in the model domain, the purpose of this model was to analyze impacts in the vicinity of the mine, and therefore the model may not be appropriate for use elsewhere in the basin without additional revision.
- The model has been used for the impact analysis in this DEIS as one out of three models that have been prepared for the project area, and it is not presented as the sole prediction of impacts.

Tetra Tech Mine Site Model

The impacts to groundwater levels resulting from active pumping of groundwater from the proposed mine pit during mine operations, as well as long-term removal of groundwater by evaporation from the mine pit lake, are also predicted using a second, independent groundwater flow model constructed by Tetra Tech (2010g), referred to hereafter as the Tetra Tech Mine Site model.

The Tetra Tech Mine Site model covers the same model domain of 457 square miles as the Montgomery Mine Site model and relies on the same underlying hydrogeologic data. However, the Tetra Tech model consists of 20 layers, versus 10 layers in the Montgomery Mine Site model, and the model domain has been divided into smaller grid sizes overall. The base of the model still lies at an elevation of 1,000 feet below mean sea level, like the Montgomery Mine Site model.

Tetra Tech's modeling process was similar to that of Errol L. Montgomery and Associates and also consisted of constructing a steady-state model and calibration of that model. Tetra Tech then ran two additional models over time, based on the steady-state model, in order to simulate the active pumping of groundwater from the pit and then the subsequent loss of water to evaporation from the pit lake after mine closure. The first transient model covers 22 years of pit dewatering associated with construction and active mining. The second transient model covers the next 1,000 years following closure of the mine. The model is executed using the computer code MODFLOW-SURFACT.

Like Errol L. Montgomery and Associates, Tetra Tech made several important assumptions in order to construct their model, as follows:

- Perennial reaches of Cienega Creek and Davidson Canyon are included in the model. The perennial reaches were modeled using a streamflow routing package (SFR1).
- Evaporation losses from the mine pit lake are modeled using a lake modeling package (LAK2).
- Boundary conditions at the edges of the model domain are constant-head boundaries. General-head boundaries were not used in the model.
- Tetra Tech assumed that any groundwater pumpage within the model area was negligible; no estimate of pumpage in the area was made.
- A possible barrier to groundwater flow from an intrusive dike across Davidson Canyon was modeled, as was the Backbone Fault. Davidson Canyon Fault and Flat Fault were not explicitly incorporated into the Tetra Tech model.
- Although it is recognized that flow with the aquifer occurs almost exclusively through fractures and faults, the model also treats the aquifer as if it were porous media.

Status of Model and Peer Review

Documentation of the Tetra Tech Mine Site model was produced in separate technical memoranda as each part of the model was constructed (O'Brien 2010a, 2010b, 2010c, 2010d). Independent peer review of each of the Tetra Tech Mine Site model technical memoranda was conducted by SRK Consulting. A complete Tetra Tech Mine Site model report was produced that incorporated changes agreed to during peer review and face-to-face meetings (Tetra Tech 2010g). SRK Consulting completed peer review of the complete Tetra Tech Mine Site model report. After making several additional recommendations, SRK Consulting (Ugorets 2011) concluded the following:

- "Despite those uncertainties, SRK concludes that the ground water model presented in the final version of the report was conceptualized, constructed, and presented to standard industry practices. The model addresses the comments and recommendations made by SRK in its review of the individual sections of the report. Further, SRK finds that the model generally represents hydrogeological conditions that are appropriate to the available data, is robust, and well calibrated to the pre-mining steady-state conditions. Model predictions for both mining and post-mining conditions are reasonable, are based on the results of comprehensive sensitivity analyses, and provide a range of potential impacts to the groundwater system and to surface-water bodies."

Calibration of Model

A calibration was conducted on the steady-state model. Unlike the Montgomery Mine Site model, no transient calibration was conducted.

- Horizontal conductivity, vertical conductivity, recharge, stream bed conductivity, and conductivity of a modeled groundwater flow barrier were varied during the calibration.
- Observed groundwater levels were used as calibration targets, and results were given with calibration targets both weighted for reliability and unweighted.
- The residual mean of the calibration was −1.18 to −4.47 feet. The residual mean for the model calibration is slightly negative, which indicates a slight model bias toward underpredicting groundwater levels.

- The absolute residual mean of the calibration was 55.05 to 97.61 feet.
- The residual standard deviation is 90.17 to 133.12 feet. The residual standard deviation divided by the range of observed values was 3.1 to 4.6 percent.
- Difficulties in calibrating water levels on the west side of the model, nearest the mine pit, were identified. This means that the predicted groundwater levels in the immediate vicinity of the mine pit should be used with caution. This has not impacted the overall analysis of impacts; the expected changes in water levels in the immediate vicinity of the mine pit are very large, and impacts to springs and wells in this area are not in question, even if some error exists in the exact predicted amount of water level change. Overall, the difficulties in calibrating the model in this area result from the use of a porous media model to model fracture flow conditions. On a regional scale the porous media model is reliable for predicting water level impacts, but on the scale of individual wells, seeps, springs, or other hydrologic features, the model may not fully reflect the individual fractures that supply water to those features.
- The Tetra Tech Mine Site model steady-state water balance is as follows. Inflows to the model area consisted of recharge (9,900 acre-feet per year) and inflow from constant-head boundaries (24,465 acre-feet per year). Outflows from the model area consisted of evapotranspiration (5,633 acre-feet per year), streamflow out of the model area from Cienega Creek (2,616 acre-feet per year as calculated from stream package inflows and outflows), and outflow from constant-head boundaries (26,116 acre-feet per year).

Sensitivity Analysis of Model

A sensitivity analysis was conducted on both the steady-state and transient models. The model parameters analyzed during the sensitivity analysis included horizontal and vertical hydraulic conductivity, hydraulic conductivity of the intrusive dike, specific storage, specific yield, and recharge. Additional model parameters concerning the water balance for the mine pit lake were also analyzed. Tetra Tech concluded the following:

- A range of aquifer storage parameters was analyzed. Aquifer storage parameters had a large effect on the extent of drawdown over the first 200 years of modeling. Higher storage values resulted in drawdown receding 3 miles toward the mine pit, while lower storage values resulted in drawdown advancing an additional mile beyond the mine pit.
- A reduction in evapotranspiration was analyzed. Lower evapotranspiration resulted in drawdown receding over 1 mile toward the mine pit, along with increased modeled flow in streams.
- A change in the amount of postmining mountain-front recharge was analyzed. The Tetra Tech Mine Site model assumed that recharge would actually increase slightly (about 2 percent), from a premining recharge of 9,900 acre-feet per year to a postmining recharge of 10,092 acre-feet per year. The Montgomery Mine Site model assumed that postmining mountain-front recharge would decrease by about 1 percent. Because of this difference in approach, Tetra Tech conducted a sensitivity analysis by modeling an unchanged recharge after construction of the mine. The reduction in recharge resulted in greater modeled reductions in streamflow in Cienega Creek and Davidson Canyon, drawdown advancing up to an additional 3 miles beyond the mine pit, and greater reduction in evapotranspiration.
- The choice of boundary conditions for the western boundary of the model (constant-head boundaries) was analyzed by modeling different kinds of boundary conditions, including no-flow and general-head boundaries. Variance in boundary conditions from constant-head to

general-head did not change the direction of flow out of the model boundary, nor did it significantly change the amount of flow or water levels. The no-flow boundary was found to cause conditions that could not be feasibly modeled.

- The intrusive dike was analyzed by varying the hydraulic conductivity by an order of magnitude. Results indicated that the intrusive dike does act to minimize propagation of impacts down Davidson Canyon. One recommendation by SRK during their final review was for additional sensitivity analysis to be conducted, as the simulation of the dike is "less than fully supported by the analyses and conclusions" (Ugorets 2011).

Potential Limitations and Current Usability of Model

The mine site model developed by Tetra Tech (2010g) has been used in order to analyze impacts in this DEIS, based on the following:

- The calibration appears to be within acceptable range. Although it was not entirely successful on the west side of the model, errors in predicted water levels at this location are not expected to change the overall impact assessment.
- Full peer review and revisions have been completed and have found the model to be acceptable (Ugorets 2011).
- The record of historic water level data used as a basis for the model is largely limited to the period since 2008. It is also recognized that the spatial distribution of detailed geological data is limited to the immediate project area.
- It is recognized that predicting conditions 1,000 years in the future is speculative; however, this long time frame was selected in order to allow the bedrock aquifer impacted by the mine pit to come close to equilibrium.
- It is recognized that while pumpage in the basin is relatively minor, compared with the overall basin water balance, pumpage in the basin is increasing, and lack of modeling of this pumpage may affect future predictions.
- It is recognized that while much of the Cienega Basin was included in the model domain, the purpose of this model was to analyze impacts in the vicinity of the mine; therefore, the model may not be appropriate for use elsewhere in the basin without additional revision.
- Overall, the peer review process determined that the model predictions are reasonable; however, one specific concern remaining with the Tetra Tech Mine Site model was the inclusion of the intrusive dike across Davidson Canyon, which acts as a barrier to groundwater flow and may therefore underestimate impacts along Davidson Canyon. The peer review suggested that additional sensitivity analyses be conducted to analyze the impacts of including the intrusive dike. This sensitivity analysis has been conducted and is currently being reviewed. The model has been used for the impact analysis in this DEIS as one out of three models that have been prepared for the project area, and it is not presented as the sole prediction of impacts.

The Dr. Myers Mine Site Model

Dr. Tom Myers was contracted by Pima County to conduct an independent modeling effort, as well as review modeling conducted by Errol L. Montgomery and Associates (Myers 2008, 2010a), referred to hereafter as the Dr. Myers Mine Site model. The approach of Dr. Myers is similar in nature to both the Tetra Tech and Montgomery Mine Site models. First, he calibrated a steady-state model. Then, he ran various transient models to simulate stresses associated with actively pumping groundwater from

the pit and from the loss of water from the formation of the pit lake. Unlike Errol L. Montgomery and Associates and Tetra Tech, Dr. Myers ran the transient model for a period of 7,500 years.

Construction of the Dr. Myers Mine Site model is fundamentally different from the other two models: it uses a smaller model area that is more reflective of natural topographic boundaries, and it uses very different boundary conditions. Both the Errol L. Montgomery and Associates and Tetra Tech Mine Site models extend the model beyond the topographic boundaries and use conditions that allow groundwater to flow in and out of the model domain in order to maintain the model water balance. Dr. Myers allows no groundwater to flow in and out of the model domain, except where Davidson Canyon and Cienega Creek leave the project area. Dr. Myers also specifies drain cells along Cienega Creek that model discharge to the creek. The model also differs with respect to how water loss from the pit is handled. The model is constructed using the computer code MODFLOW-2000.

It should be noted that although the model domain and approach are different, as with the other models, the fundamental output from the model is similar: it predicted water levels in the bedrock aquifer.

Status of Model and Peer Review

The Dr. Myers Mine Site model has not undergone any peer review, although it has undergone one revision (Myers 2010b) from the original version prepared (Myers 2008).

Calibration of Model

A calibration was conducted on the steady-state model.

- Horizontal conductivity and vertical conductivity appear to have been varied during the calibration.
- Observed groundwater levels were used as calibration targets, weighted for reliability.
- The residual mean of the calibration was −13.1 to 37.1 feet, depending on the layer.
- The absolute residual mean of the calibration was not presented.
- The residual standard deviation is 39.8 to 64.4 feet. The residual standard deviation divided by the range of observed values was not presented, nor is the range of values presented. Assuming a similar range of observed values as used by Errol L. Montgomery and Associates, the residual standard deviation divided by the range of observed values would be 1.2 to 2.0 percent.
- Any difficulties with model calibration on the west side of the model were not discussed, nor were figures presented to allow this assessment.
- A sensitivity analysis was presented in graphical form.

Potential Limitations and Current Usability of Model

The mine site model developed by Dr. Myers (Myers 2010b) also been used for the impact analysis in this DEIS, recognizing the following limitations:

- The calibration appeared to be within acceptable range, based on data presented and some further assumptions.
- No peer review has been conducted on this model.

- The model has been used for the impact analysis in this DEIS as one out of three models that have been prepared for the project area, and it is not presented as the sole prediction of impacts.

Summary of Effects by Issue Measures by Alternative

Table 47 presents the summary comparison of impacts from each alternative.

Table 47. Summary of effects

Issue Category	No Action	Proposed Action	Phased Tailings	Barrel	Barrel Trail	Scholefield-McCleary
Davidson Canyon/ Cienega Basin						
3A: Direction and degree of change in water table level (feet) 3A: Locations in which water resources may be impacted (geographic extent)	None	More than 100-foot drawdown near mine pit; 10- to 100-foot drawdown near residential areas along Singing Rock Road and Hilton Ranch Road, with impacts beginning by end of active mining; no drawdown above threshold of 5 feet at Corona del Tucson residences, along Cienega Creek, or at Davidson Canyon/Cienega confluence; 1- to 10-foot drawdown at Upper Empire Gulch, with impacts beginning approximately 50 years after end of active mining.	Same as proposed action	Same as proposed action	Same as proposed action	Same as proposed action
3A: Duration of effect (in years)	None	Perpetuity	Perpetuity	Perpetuity	Perpetuity	Perpetuity
3A: Relative impairment of mountain-front groundwater recharge function	None	1%	1%	1%	1%	1%
3D: Potential lowering of the water table/reduced groundwater flow to Davidson Canyon and Cienega Creek that results in permanent changes in flow patterns may affect their designations as Outstanding Arizona Waters and current designated uses						

Issue Category	No Action	Proposed Action	Phased Tailings	Barrel	Barrel Trail	Scholefield-McCleary
Subcomponent 1: Reduction in flow along Cienega Creek (percentage)	None	1 to 3% of average annual flow; critical low-flow periods (May through June) would see greater impacts; impacts modeled to potentially start 50 years after end of active mine life	Same as proposed action	Same as proposed action	Same as proposed action	Same as proposed action
Subcomponent 2: Miles of perennial stream length lost along Cienega Creek	None	0.16 (based on average flow)	0.16 (based on average flow)	0.16 (based on average flow)	0.16 (based on average flow)	0.16 (based on average flow)
Subcomponent 3: Reduction in flow along Davidson Canyon (percentage)*	None	10%; impacts expected to start immediately after construction of mine	10%	10%	10%	10%
Subcomponent 4: Miles of perennial stream length lost along Davidson Canyon*	None	0.29	0.29	0.29	0.29	0.29
3A: Comparison of mine pit water loss with overall basin water balance	None	1.7 to 5.3% (at equilibrium; during active mine dewatering this percentage would be greater)	1.7 to 5.3% (at equilibrium; during active mine dewatering this percentage would be greater)	1.7 to 5.3% (at equilibrium; during active mine dewatering this percentage would be greater)	1.7 to 5.3% (at equilibrium ; during active mine dewatering this percentage would be greater)	1.7 to 5.3% (at equilibrium; during active mine dewatering this percentage would be greater)
3D: Number of springs or seeps lost or impaired	None	63	63	63	63	67
3A: Potential reduction in groundwater outflow from Davidson Canyon	None	6.4%	6.4%	6.4%	6.4%	6.4%
3A: Approximate number of wells within geographic extent of impact	None	500 to 550	500 to 550	500 to 550	500 to 550	500 to 550
Upper Santa Cruz Sub-Basin						
3B: Water needed for operations from Santa Cruz Valley and comparison with other water uses and basin water balance, measured in acre-feet						
Subcomponent 1: Amount of groundwater pumped (acre-feet per year)	None	5,400	5,400	5,400	5,400	5,400

Issue Category	No Action	Proposed Action	Phased Tailings	Barrel	Barrel Trail	Scholefield-McCleary
Subcomponent 2: Groundwater pumped as percent increase in current pumping	None	6.7%	6.7%	6.7%	6.7%	6.7%
3B: Change in water table level (feet)						
Subcomponent 1: Approximate total drawdown attributable to pumping (feet)	None	Up to 70	Up to 70 feet	Up to 70 feet	Up to 70 feet	Up to 70 feet
Subcomponent 2: Annual rate of drawdown attributed to pumping (feet per year)	None	Up to 3.5	Up to 3.5	Up to 3.5	Up to 3.5	Up to 3.5
3B: Locations where water resources may be impacted (geographic extent), in miles from pumping center	None	3 to 4	3 to 4	3 to 4	3 to 4	3 to 4
3B: Duration of effect (in years)	None	100 to 140 years	100 to 140 years	100 to 140 years	100 to 140 years	100 to 140 years
3B: Approximate number of wells within geographic extent of impact	None	400 to 450	400 to 450	400 to 450	400 to 450	400 to 450

Note: Any ranges shown reflect the range of impacts from multiple models.

* Impacts to Davidson Canyon vary, depending on whether the Reach 2 and Escondido Springs are supplied by regional groundwater or ephemeral stormwater stored in the shallow alluvial aquifer. Multiple lines of evidence indicate that the latter is most likely. The potential reduction in perennial stream length assumes the springs that are supplied by the regional groundwater but is provided as a potential scenario.

Affected Environment

Relevant Laws, Regulations, Policies and Plans

Table 48 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 48. Summary of the Federal, State, and local regulatory requirements applicable to the project with respect to groundwater quantity

Law/Regulation	Regulates
Federal	
Forest Service Manuals 2520, 2530, and 2880 and FS-881 Technical Guide	Watershed protection and management, water resource management, geological resources, and groundwater management
State	
Well permits and well construction standards	Drilling and completion of wells or borings
Groundwater rights/water transfer	Pumping of groundwater from within an active management area; transfer of water outside an active management area
Recharge permits (water storage permit)	Storage of water in a permitted underground storage facility

Law/Regulation	Regulates
Local	
Town of Sahuarita General Plan	Comprehensive plan intended to guide Town decisionmakers and staff

Well Permits/Well Construction Standards (Arizona Administrative Code R12-15, Article 8)

All wells drilled within Arizona, as well as borings greater than 100 feet deep, must comply with well construction standards, as administered by the Arizona Department of Water Resources. Authorization is obtained by filing of a Notice of Intent with the Arizona Department of Water Resources. Well construction standards also apply to proper capping and abandonment of wells and borings when no longer needed.

The well field located in the Upper Santa Cruz Sub-Basin would require Arizona Department of Water Resources approval prior to construction; these permits must be granted, provided that all regulatory requirements are met.

Groundwater Rights/Water Transfer

The water supply for the mine would be withdrawn from wells located within the Tucson Active Management Area. As established under the Arizona Groundwater Management Act of 1980, within an active management area almost all pumping of groundwater requires some form of groundwater right or groundwater withdrawal permit (Arizona Revised Statutes 45-451). In the case of the mine water supply, the Arizona Department of Water Resources has issued a Mineral Extraction and Metallurgical Processing Permit to Rosemont (Arizona Revised Statutes 45-514). The Arizona Department of Water Resources is required to grant this permit, provided that all conditions under the statute are met, including the condition that no other alternative water supplies are available.

The groundwater pumped from the well field within the Tucson Active Management Area would be transferred outside the active management area for use at the mine. There are provisions within the Groundwater Management Act that restrict the transfer of water from within an active management area; however, the code provides for transfer of water pumped under a groundwater withdrawal permit, subject to payment of damages (Arizona Revised Statutes 45-543).

Groundwater Recharge

Recharge of water to the aquifer requires issuance of a water storage permit by the Arizona Department of Water Resources. This permit allows the holder to recharge water in an existing permitted underground storage facility. Contracting for available Central Arizona Project water is a separate process executed through the Central Arizona Water Conservation District.

Forest Service Guidance

Forest Service Manual 2520 (U.S. Forest Service 1992a) provides guidance for watershed protection and management. Specific areas of responsibility include planning, implementing, and monitoring watershed improvements (including abandoned mine lands); managing riparian areas for long-term conservation, productivity, biological diversity, and ecosystem integrity; and managing wetlands and floodplains.

Forest Service Manual 2530 (U.S. Forest Service 1992b) provides guidance for water resource management. Specific areas of responsibility include integrating water resource management with land management plans, coordinating with other agencies, conducting water resource investigations and collecting hydrologic data, and managing and monitoring water quality. Water quality management and monitoring have the specific objective of protecting and improving water quality to allow beneficial uses on Forest Service land.

Forest Service Manual 2880 (U.S. Forest Service 2008b) provides guidance for analysis of geological resources, hazards, and services. With respect to water resources, Forest Service Manual 2880 provides guidance for the inventory and analysis of groundwater dependent ecosystems. Hydrologic investigation techniques are further elaborated in FS-881, "Technical Guide to Ground Water Resource Management" (Glasser et al. 2007).

Forest Service guidance is nonprescriptive in nature. It does not provide absolute requirements for managing water quality or water resources but assigns responsibilities to Forest Service personnel for data collection and decisions and provides general objectives to be considered when making resource decisions.

Town of Sahuarita General Plan

The Town of Sahuarita has indicated that he continued pumping of groundwater from region that serves Sahuarita residents does not meet the Town of Sahuarita objective of encouraging water providers to evaluate water demand within the Town of Sahuarita to ensure the rate of use does not exceed a potential future supply. The Town of Sahuarita has also indicated that the planned pumping conflicts with a Town objective of encouraging water providers to use alternative water sources and water conservation methods and strategies by all users requiring large quantities of water.

Existing Conditions

The proposed project is in two groundwater basins located south of Tucson, Arizona. The mine water supply wells are in the Upper Santa Cruz Sub-Basin of the Tucson groundwater basin, which is geographically in the Santa Cruz Valley west of the Santa Rita Mountains. The mine is located in the Davidson Canyon drainage, which is technically part of the Tucson Basin. However, it is immediately adjacent to the Cienega Basin, which is located east of the Santa Rita Mountains and which for the purposes of the DEIS is considered part of the Cienega Basin. It is therefore referred to here as the Davidson Canyon/Cienega Basin (see figure 30).

Mine Water Supply (Upper Santa Cruz Sub-Basin)

The proposed project anticipates using up to 5,400 acre-feet per year of fresh water over the approximate 20-year life of the active mine operation. No pumping is expected to occur during construction and closure periods. The limited groundwater resources at the mine preclude developing the mine water supply at that location; therefore, Rosemont Copper has obtained two properties in the Upper Santa Cruz Sub-Basin on which to locate the mine water supply wells. These locations, shown in figure 30, are in the Sahuarita Heights area near the intersection of Sahuarita and Santa Rita Roads.

The right to extract and use up to 6,000 acre-feet of groundwater from the Tucson Active Management Area was granted to Rosemont Copper by the Arizona Department of Water Resources on January 18, 2008, under Mineral Extraction and Metallurgical Processing Groundwater Withdrawal Permit Number 59-215979.0000. This type of permit is a "shall issue" permit that must

be granted unless reliable alternative water supplies (uncommitted municipal and industrial Central Arizona Project water, surface water, or effluent) are available at comparable cost at the point where the mine's wellhead or distribution system would otherwise exist (Arizona Revised Statutes 45-514(A)(2) and (3)).

Total groundwater use from the Upper Santa Cruz Sub-Basin is expected to be 108,000 acre-feet. Additional process water will be obtained through pit dewatering at the mine site, which will reduce the amount needed to be transported to the mine site; the dewatering amount is estimated to total 16,000 to 27,000 acre-feet (Montgomery and Associates Inc. 2010; Tetra Tech 2010g).

Once transported, process water is expected to be fully consumed; no wastewater discharge is expected to be generated at the mine site. Some water will be lost to evaporation or incidental seepage or spillage, but most of the water will be entrained as pore water in the processed tailings facility and the heap leach pad.

General Hydrogeologic Framework

The Upper Santa Cruz Sub-Basin is a broad, north-south-trending alluvial valley drained by the Santa Cruz River and its tributaries. The Upper Santa Cruz Sub-Basin is bounded on the east by the Santa Rita Mountains and on the west by the Sierrita Mountains. At the deepest points, the Upper Santa Cruz Sub-Basin contains several thousand feet of alluvial materials. The principal hydrologic units in the analysis area, in descending order, are as follows: recent alluvium consisting of unconsolidated modern stream channel and floodplain sediments; the Fort Lowell Formation of Quaternary age; the Tinaja beds of Tertiary age; the Pantano Formation and the Helmet Fanglomerate of Tertiary age; and a bedrock complex of Precambrian to Tertiary age.

The recent alluvium comprises stream channel, floodplain alluvium, and terrace deposits that occur chiefly beneath the channel and floodplain of the Santa Cruz River and tributary washes. Thickness of recent alluvium ranges from zero at the contact with older rocks to probably no more than 100 feet. The Fort Lowell Formation and Tinaja Beds are collectively referred to as basin-fill deposits. Thickness ranges from a few feet at the margins of the basin to more than 1,200 feet, generally increasing with distance from the mountain areas. The Fort Lowell Formation and Tinaja beds form the principal aquifer in most parts of the analysis area. Tertiary age sediments lying below the Tinaja beds include the Pantano Formation and the Helmet Fanglomerate. The Pantano Formation is generally poorly permeable; however, the Helmet Fanglomerate is the principal aquifer for the Mission well field (located west of the Pima Mine Road recharge project). Except where abundantly fractured or weathered, the rocks that form the bedrock complex below the Pantano Formation are poorly permeable and yield only small quantities of groundwater to wells. In the analysis area, the bedrock complex is believed to function as a relatively impermeable basal unit below the regional aquifer.

Sources of Recharge

Within the analysis area groundwater recharge includes natural recharge from infiltration of precipitation and surface runoff; incidental recharge from agricultural irrigation and mine tailing seepage from the Sierrita mine; and artificial recharge at permitted underground storage facilities, including wastewater treatment facilities.

The principal source of recharge in the area is from infiltration of streamflow along the Santa Cruz River channel and tributary washes (estimated to be approximately 12,300 acre-feet within the analysis area). Another important source of natural recharge occurs along the mountain fronts as a

result of infiltration of runoff originating in the mountain areas near the basin margins (estimated to be approximately 9,700 acre-feet from the Sierrita and Santa Rita Mountains within the analysis area). These two sources are the principal components of natural groundwater recharge in the analysis area. Incidental recharge from agricultural irrigation primarily comes from irrigation of pecan groves by Farmers Investment Company, located along the Santa Cruz River west and south of the Rosemont Copper properties (see figure 30), and accounts for about 5,900 acre-feet of recharge. Seepage from mine tailing impoundments at Sierrita account for about 7,500 acre-feet of recharge; the mine tailings at Esperanza and Twin Buttes are no longer considered to be discharging.

Artificial recharge is attributable to four underground storage facilities in the analysis area: Pima Mine Road Recharge Project, Robson Ranch Quail Creek, San Xavier Arroyos Project, and Sahuarita Wastewater Treatment Plant (permit pending). Green Valley Wastewater Treatment Plant was historically recharging the aquifer and continues to do so; however, a large portion of the effluent from the plant is now recharged at Robson Ranch Quail Creek. All four underground storage facilities are currently artificially recharging the aquifer; these recharge locations are shown in figure 30. Artificial recharge rates reported in 2007 were used for flow modeling and totaled approximately 24,300 acre-feet. Total recharge in the analysis area, both natural and artificial, is approximately 60,000 acre-feet.

Groundwater Withdrawals

Groundwater withdrawals for agricultural irrigation, mining, public water supplies, domestic uses, and recreational uses have resulted in groundwater level declines in the area. These historic and present groundwater withdrawals are one of the principal factors influencing the direction of groundwater movement in the area. Based on data published by the Arizona Department of Water Resources, in 2006 groundwater withdrawals in the analysis area were approximately 82,000 acre-feet. Major water users include pecan grove irrigation by Farmers Investment Company (30,000 acre-feet), mining pumping associated with the ASARCO Mission and Freeport-McMoRan Sierrita Mines (33,400 acre-feet), and pumping by public water providers in the area, including recreational uses such as golf course irrigation (18,700 acre-feet). Major water providers include Community Water Company of Green Valley, Green Valley Domestic Water Improvement District, Las Quintas Serenas Water Company, Farmers Water Company, Rancho Sahuarita Water Company, and Quail Creek Water Company.

Major sources of recharge and groundwater withdrawal in the analysis area are summarized in figure 32. Overall, groundwater withdrawals exceed sources of recharge by approximately 22,000 acre-feet per year, not including mine water supply pumping.

Groundwater Levels and Conditions

Overall groundwater levels in the analysis area have declined as more groundwater has been withdrawn from the regional aquifer over the past several decades than has been replenished by recharge, although the rate of groundwater level decline has decreased since 1980, compared with the rate of decline from the previous four decades. Trends in groundwater level changes vary by location; measured groundwater levels during the past 10 years for wells nearest the Rosemont Copper properties are generally declining at a rate of 1 to 2 feet per year.

Groundwater recharge at Pima Mine Road Recharge Project and flood recharge along the Santa Cruz River have mitigated or reversed groundwater level declines in the central and northern portion of the area. However, relatively larger groundwater level declines associated with pumping in the Green Valley area still exist to the south.

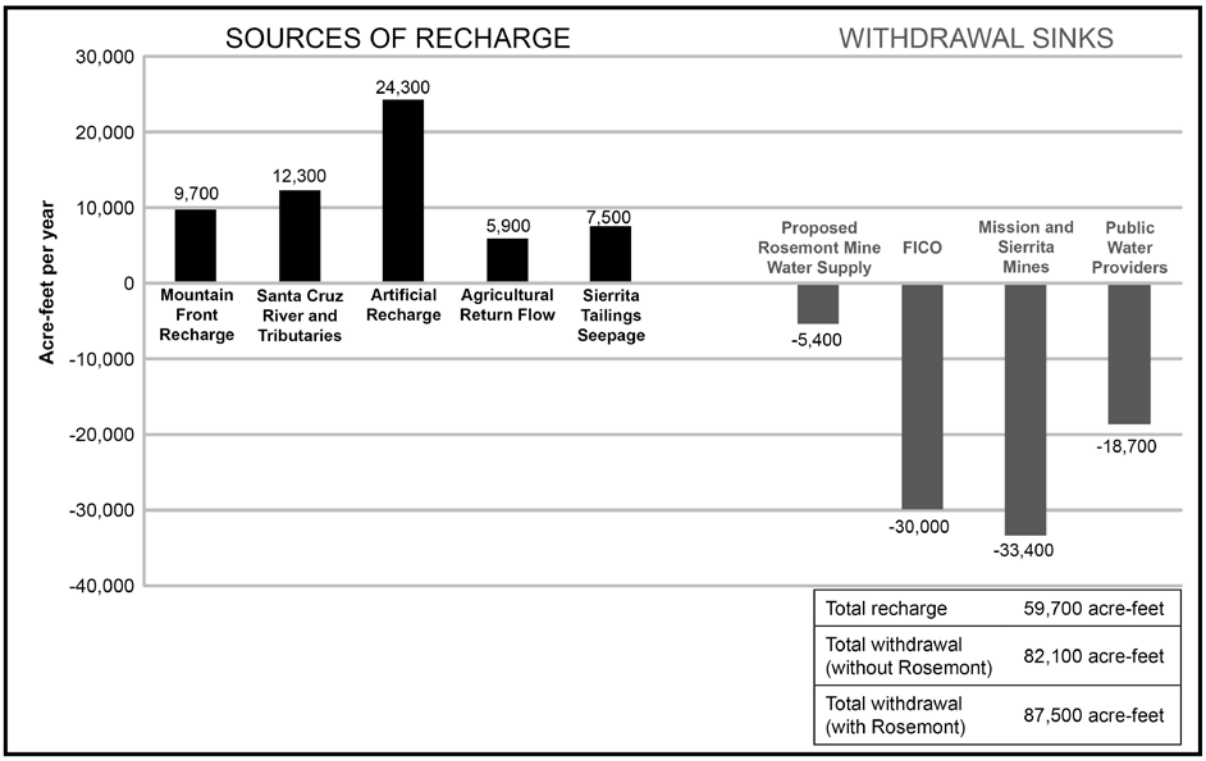


Figure 32. Comparison of sources of recharge and withdrawal sinks in mine water supply analysis area in the Upper Santa Cruz Sub-Basin

The groundwater withdrawals previously described are those associated with large water users; additional groundwater is drawn by what are known as “exempt” wells. Exempt wells are typically residential or stock wells that must be designed to pump less than 35 gallons per minute and irrigate no more than 2 acres. Groundwater use from exempt wells is difficult to track; other than when drilled, there are no reporting requirements to the Arizona Department of Water Resources associated with exempt wells. Groundwater levels in shallow residential wells located near the western Rosemont Copper property are higher than groundwater levels measured deeper in the aquifer and appear to vary less in response to seasonal agricultural pumping than deeper groundwater levels.

The average annual groundwater elevation in the shallow residential wells is approximately 60 feet higher in the area on the west of the Rosemont Copper property, a difference that decreases to a negligible amount on the east of the Rosemont Copper property.

There is no indication of a perched shallow groundwater system in the vicinity of the Rosemont Copper property, or that the shallow residential wells are disconnected from pumping in the regional aquifer, although some may be. Rather, the variation in water levels likely reflects complex subsurface aquifer units and a dynamic aquifer system. Patterns of groundwater movement in the area are controlled by location and quantity of groundwater recharge and discharge, including groundwater pumped from wells, and by aquifer properties. Groundwater level contours based on field measurements collected in late 2004 through early 2005 are shown in figure 33. The direction of groundwater movement is generally parallel to the Santa Cruz River, from south to north. In general, groundwater movement west of the river is toward the northeast, and groundwater movement east of the river is toward the northwest. Groundwater level contours in the vicinity of the two Rosemont Copper properties indicate that groundwater flow gradient is toward the northwest.

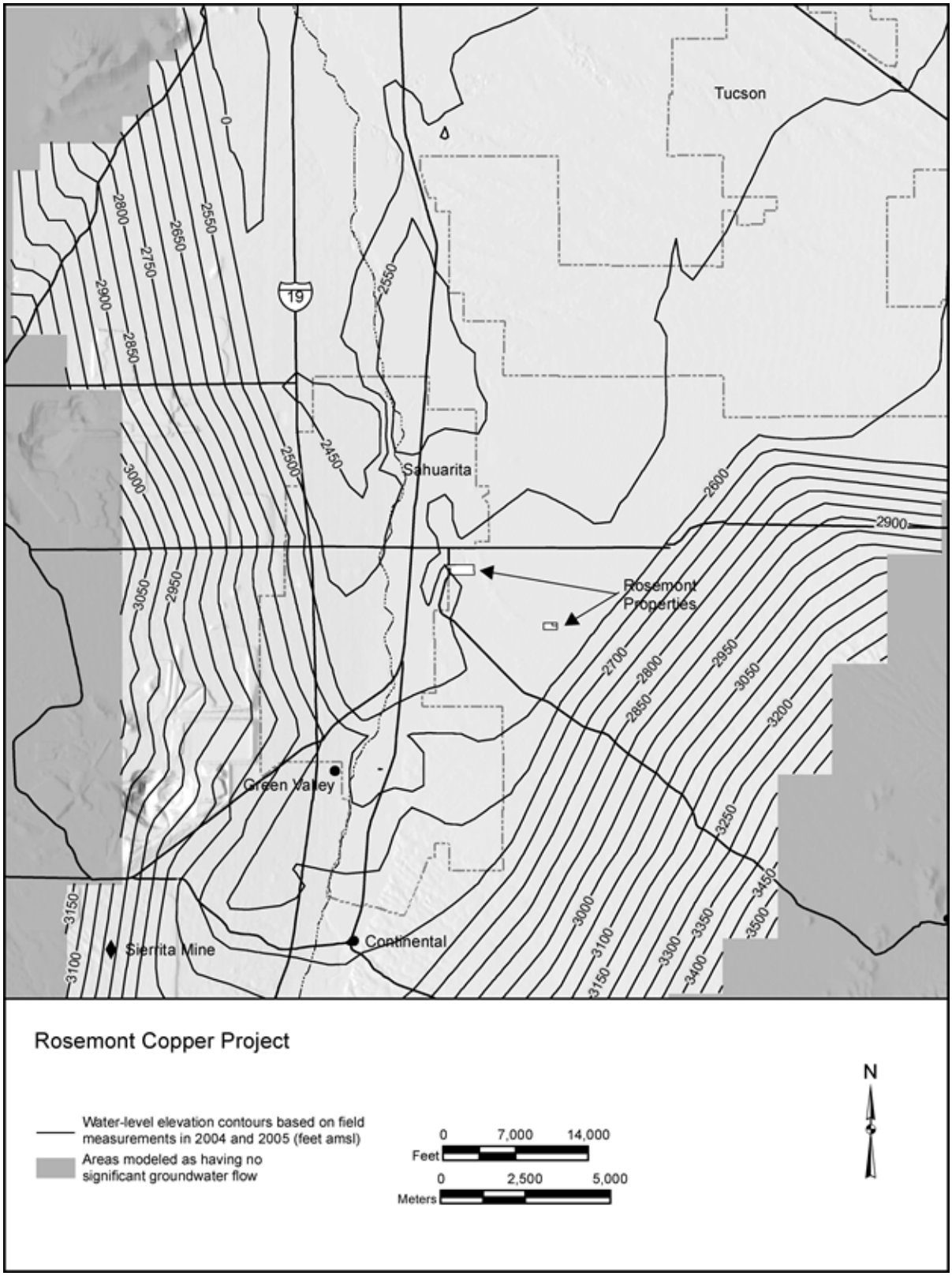


Figure 33. Groundwater levels in the Upper Santa Cruz Sub-Basin in 2004 and 2005

Pumping tests were conducted at two Rosemont Copper test wells 2007. Based on the results of pumping tests, the sustainable long-term pumping rates for production wells installed at these two locations were estimated to be approximately 1,500 and 500 gallons per minute.

Land Subsidence

Most subsidence in Arizona occurs as a result of pumping groundwater from aquifers, an activity that removes support for alluvial particles and allows the material to compact. Sources and quantities of past and current groundwater pumping and recharge were documented by Errol L. Montgomery and Associates (2009c) in an update to the Arizona Department of Water Resources model for the Sahuarita area. Recharge of Central Arizona Project water into the basin-fill formations occurs near Sahuarita.

Historic land subsidence resulting from groundwater withdrawal has been recorded in the Green Valley area of the Santa Cruz Basin (figure 34). Data from 2006 indicate that the groundwater withdrawals by nonexempt well owners in the Green Valley area totaled approximately 82,100 acre-feet. That total encompasses 30,000 acre-feet by the Farmers Investment Company for irrigating pecan groves, 33,400 acre-feet by the ASARCO Mission and Freeport-McMoRan Sierrita operations, and 18,700 acre-feet for public water supply, including golf course irrigation (Errol L. Montgomery and Associates Inc. 2009c). During the first eight years, Rosemont Copper will use approximately 5,400 acre-feet per year from water supply wells located near Sahuarita; this quantity will diminish to approximately 4,700 acre-feet per year for the remaining 12 years of the operation (Errol L. Montgomery and Associates Inc. 2009a).

The Arizona Department of Water Resources publishes annual maps showing land subsidence in the Sahuarita and Green Valley area. The most recent map for the period from February 2009 through January 2010 is shown in figure 34; the map shows that subsidence of less than 0.2 inch occurred in a broad area north of East Sahuarita Road (west of Interstate 19) southward to near Whitehouse Canyon Road (Arizona Department of Water Resources 2010). Over that period, two limited areas near major supply wells subsided by 0.7 to 1.4 inches. Incremental additional subsidence is expected on an annual basis owing to future committed groundwater withdrawals in the area, including groundwater withdrawals associated with the mine water supply.

Mine Site (Davidson Canyon/Cienega Basin)

General Hydrogeologic Framework and Conditions

Hydrogeology in the project area, within Davidson Canyon and the Cienega Basin on the east side of the Santa Rita Mountains, is fundamentally different from that at the proposed well field in the Santa Cruz Valley. Although geology had been well characterized in the area, prior to the proposed project, almost no hydrogeologic information such as well logs, groundwater quality samples, or groundwater hydrographs existed in the project area. Beginning in 2008, an intensive hydrogeologic investigation was undertaken, including the installation of 30 wells and piezometers at 17 locations in the vicinity of the mine. The wells were designed to characterize the near-pit hydrogeology, monitor groundwater levels at multiple depths, characterize the hydrogeology throughout the upper Davidson Canyon watershed, including bedrock and alluvium, and install long-term monitoring wells between 1 and 5 miles away from the proposed mine pit. Monitoring has continued in these wells, as well as springs and seeps, including aquifer testing, water level and flow monitoring, and water quality sampling (Errol L. Montgomery and Associates Inc. 2009b).

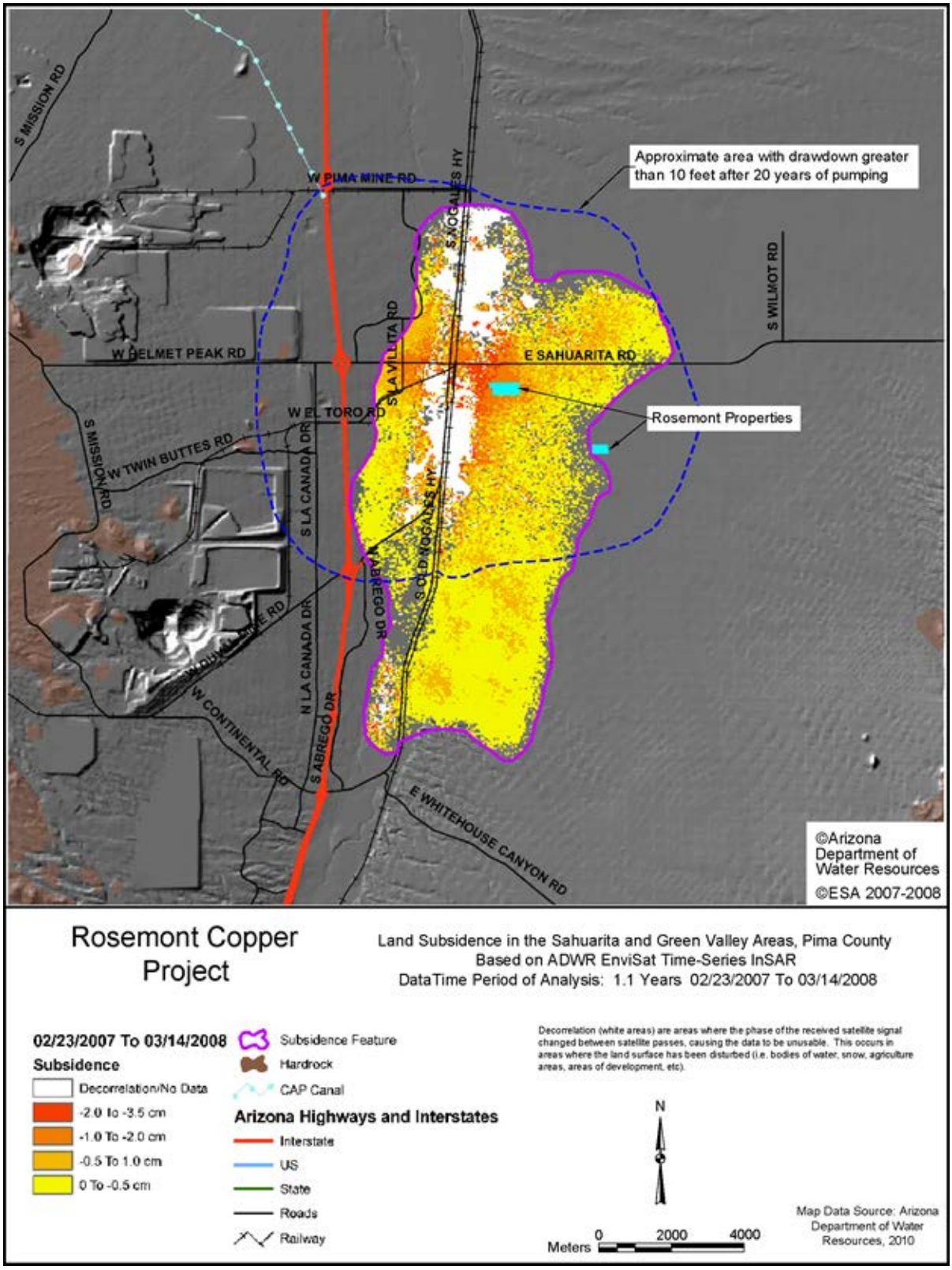


Figure 34. Subsidence in the Sahuarita and Green Valley areas, Pima County, February 2009 through January 2010. Adapted from Arizona Department of Water Resources (2010).

Hydrogeology in the project area is characterized by fractured and faulted Paleozoic age sedimentary and Mesozoic age sedimentary and volcanic rocks, bounded on the west by competent Precambrian intrusive rocks that form the core of the Santa Rita Mountains and bounded on the southeast by unfractured, strongly cemented basin-fill deposits (see figure 20 in the "Geology, Minerals, and Paleontology" section). Groundwater in the vicinity of the mine exists in three general areas. Limited quantities of groundwater occur in the faults and fractures of the consolidated Mesozoic and Paleozoic basement rocks of the Santa Rita Mountains. Moderate quantities of groundwater occur in the basin-fill deposits in upper Cienega Basin to the southeast of the project. Groundwater also exists in the shallow recent alluvium along the ephemeral wash channels. This alluvial groundwater is recharged during substantial storm events and may then infiltrate into underlying bedrock fractures, evaporate or be transpired by plants, or move as subsurface flow downstream. Groundwater in the alluvial stream deposits is believed to discharge in several springs in lower Davidson Canyon (Reach 2 Spring and Escondido Spring), as well as to eventually discharge subsurface from Davidson Canyon at the confluence with Cienega Creek (Tetra Tech 2010a). The majority of the proposed mine pit would be completed in faulted and fractured bedrock.

Groundwater in the project area is found in relatively limited quantities in the bedrock complex. Regionally in the Cienega Basin, the majority of the groundwater is stored in the basin-fill deposits and in the shallow alluvium occurring along the principal surface water drainage channels. Based on measurements obtained in approximately 70 wells, piezometers, and drill holes during the period from 1975 through 2008, the measured groundwater levels in the immediate vicinity of the proposed pit ranged from artesian conditions of about 34 feet above to more than 400 feet below land surface. Contours of groundwater elevation for the region are shown in figure 31. The direction of groundwater movement in the bedrock appears to be strongly influenced by topography, with the basin generally draining to the north toward Tucson. The general direction of groundwater movement in the project area is toward the east but transitions with distance to the northeast.

Groundwater enters the basin as recharge originating from precipitation and exits the basin through evapotranspiration, groundwater outflow, groundwater pumping, and discharge to surface streams. Assumptions for the exact proportion of each component of the water balance differ between the three models prepared for the project area, as shown in table 49. It should be noted that the Dr. Myers Mine Site model covers a different area than the Tetra Tech Mine Site and Montgomery Mine Site models.

Table 49. Estimate of water balance for the Davidson Canyon/Cienega Basin

Component of Steady-State Model Water Balance	Montgomery and Associates (2010)	Tetra Tech (2010g)	Myers (2010a)*
Recharge from Precipitation (acre-feet)	6,500	9,909	Estimated 7,000
Evapotranspiration (acre-feet)	5,007	4,240	Estimated 1,200
Pumping† (acre-feet)	400 to 500	Not estimated	Not estimated

* Model domain differs from Montgomery and Associates and Tetra Tech model domains.

† Value was estimated but not used in any of the three models.

Wells in the project area are primarily used for domestic and stock water uses and have sustainable well yields from less than 1 to 3 gallons per minute. Estimates of groundwater use within the Davidson Canyon/Cienega Basin are approximately 400 to 500 acre-feet per year; most of this occurs in the vicinity of Sonoita-Elgin, while a smaller proportion may occur in the lower part of the Cienega Basin, including the vicinity of the project (Montgomery and Associates Inc. 2010).

Water use by domestic and stock wells has steadily increased in the basin. In 1980, approximately 630 domestic or stock wells were known to be in the Cienega Basin. By 1990, the number of domestic and stock wells had increased to more than 1,000, and by 2010, the number of domestic and stock wells had increased to more than 1,800 (Arizona Department of Water Resources 2011c).

Seeps and Springs

Seeps and springs represent an interface between groundwater and surface water systems.

Flow from seeps and springs in the Rosemont and Davidson Canyon areas can be attributed to the following: (1) discharge of shallow subsurface fracture flow that is directly dependent on storm and runoff events and that may or may not be in direct hydraulic connection with the groundwater flow system; (2) discharge of groundwater via fractures that intersect land surface and that are in connection with the regional groundwater flow system; (3) discharge from the recent stream channel alluvium or other shallow aquifer, where it is forced to flow to land surface at bedrock constrictions; and/or (4) discharge of groundwater along low-permeability fault zones that force groundwater to flow to land surface.

A springs inventory was compiled from multiple data sources within 12 miles of the mine pit; this distance was selected in order to identify all potential springs that may be affected by groundwater level drawdown. Data sources included detailed springs inventories conducted for the project in the immediate vicinity of the mine site (Errol L. Montgomery and Associates Inc. 2009b; Tetra Tech 2010a; WestLand Resources Inc. 2007b), springs identified from Arizona Department of Water Resources water rights data (Pearce 2007), springs identified on U.S. Geological Survey 1:24,000-scale topographic maps, and several springs requested to be added by the Bureau of Land Management. Several additional springs down Davidson Canyon (Escondido, Reach 2, and Davidson Springs) are included in the inventory beyond the 12-mile radius owing to their identification as areas of critical importance during scoping.

Detailed flow data exist only for those springs investigated specifically for the project in the immediate vicinity of the mine site. The remainder of the springs, particularly those identified off of topographic maps, may or may not actually be present. Further, the source of these springs is largely entirely unknown. For the purposes of this analysis, all identified springs were assumed to exist and have the potential to be impacted by groundwater drawdown.

Within the larger vicinity of the project area, 132 seeps and springs have been observed or referenced in the available data sources (figure 35). Detailed seep and spring observation data obtained during the period 2006 through 2011 are shown in table 50 where available.

Environmental Consequences

Direct and Indirect Effects of Each Alternative

No Action Alternative

Under the no action alternative, groundwater conditions in both the Upper Santa Cruz Sub-Basin and the Davidson Canyon/Cienega Basin would remain unchanged, with no impact to water availability. Groundwater levels in the Upper Santa Cruz Sub-Basin would continue to decline because of existing groundwater withdrawals, as shown in table 51. In the Davidson Canyon/Cienega Basin, no springs or seeps or perennial or intermittent streams would be impacted either by surface disturbance or by changes in groundwater levels beyond those currently observed.

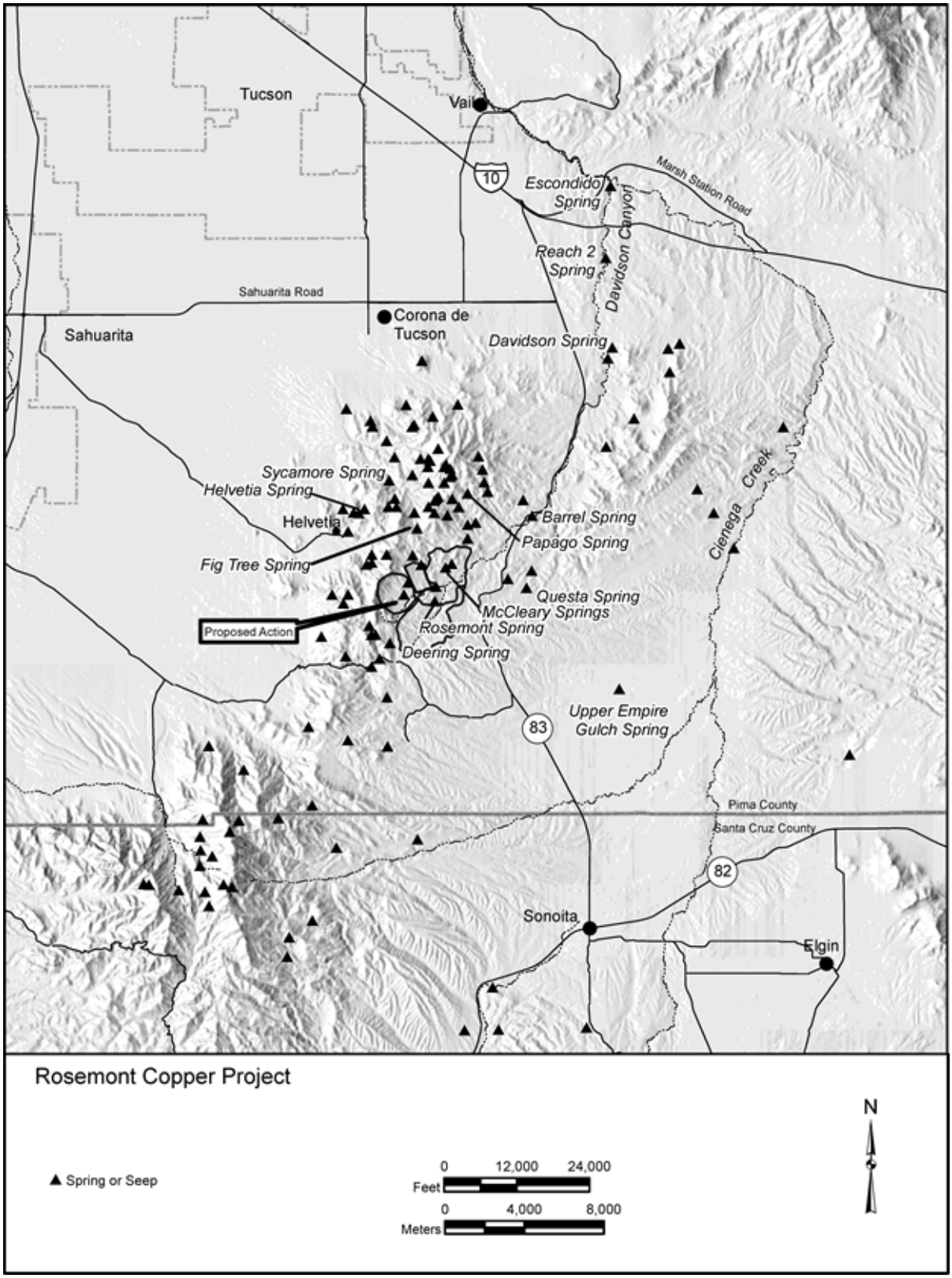


Figure 35. Seeps and springs

Table 50. Springs and seeps within 12 miles of the mine pit

Name of Spring	Cadastral Location	Observed Flow Rate and Characteristics*	Data Source
Alamo Spring	D-21-16 1dda	Unknown	U.S. Geological Survey (USGS) topographic map
Aliso Spring	D-19-15 34cd	Unknown	USGS Geographical Name Information System database
Apache Spring	D-20-16 6dc	Unknown	USGS Geographical Name Information System database
Armour Spring	D-20-15 6db	Unknown	USGS Geographical Name Information System database
Baldy Spring	D-20-15 18ab	Unknown	USGS Geographical Name Information System database
Barrel Spring	D-18-16 14cab	Small seep; <1 gallon per minute (gpm)	WestLand Resources, Inc. (2007b); Errol L. Montgomery and Associates (2009b)
Basin Spring	D-19-15 11bab	Spring not located and no riparian vegetation present (summer 2011)	USGS topographic map; Westland Resources, Inc. (2011c)
Batamout Spring	D-18-16 8ba	Spring not located and no riparian vegetation present (summer 2011)	Arizona Department of Water Resources (ADWR) Statement of Claimant; Westland Resources, Inc. (2011c)
Bear Spring	C-20-15 22b	Unknown	USGS Geographical Name Information System database
Bee Spring	D-18-16 31bb	Improved; no riparian vegetation present. Small seep, <1 gpm	ADWR Statement of Claimant; Westland Resources, Inc. (2011c)
Bellows Spring	D-20-15 18ba	Unknown	USGS Geographical Name Information System database
Big Spring	D-18-16 18caa	Spring not located and no riparian vegetation present (summer 2011)	USGS Geographical Name Information System database; Westland Resources, Inc. (2011c)
Bobo Spring	D-17-17 21b	Unknown	USGS Geographical Name Information System database
Bog Spring	D-20-14 1ac	Unknown	USGS Geographical Name Information System database
Bootlegger Spring	D-17-18 31cc	Unknown	USGS topographic map
Bowman Spring	D-19-15 13ac	Improved; no riparian vegetation present.	USGS topographic map; Westland Resources, Inc. (2011c)
Box Canyon Spring	D-19-15 12ba	Spring not located and no riparian vegetation present (summer 2011)	ADWR Statement of Claimant; Westland Resources, Inc. (2011c)
California Mine Spring	D-17-17 19db	Unknown	USGS topographic map
Chavez Spring	D-18-15 14dbb	Unknown	Bureau of Land Management (BLM)
Chet Spring	D-21-16 4cc	Unknown	USGS topographic map
Cold Water Spring	D-18-17 23dbc	Unknown	ADWR Statement of Claimant
Cottonwood Spring	D-20-16 33ad	Unknown	USGS topographic map
Cow Spring	D-17-16 19dca	Unknown	ADWR Statement of Claimant
Crucero Spring	D-18-16 9cbd	Dry, up to <1 gpm	Errol L. Montgomery and Associates (2009b)
Dam Spring	D-17-16 32aac	Unknown	ADWR Statement of Claimant
Davidson Spring†	D-17-17 19ac	Unknown	Tetra Tech (2010a)
Deering Spring	D-19-15 1dbd	~1 gpm	Errol L. Montgomery and Associates (2009b)

Name of Spring	Cadastral Location	Observed Flow Rate and Characteristics*	Data Source
Develop Spring	D-20-15 13ab	Unknown	ADWR Statement of Claimant
Diesler Spring	D-18-15 24cc	Unknown	ADWR Statement of Claimant
Double Spring	D-18-16 8baa	Spring not located and no riparian vegetation present (summer 2011)	ADWR Statement of Claimant; Westland Resources, Inc. (2011c)
Dutch John Spring	D-19-14 36dc	Unknown	USGS Geographical Name Information System database
Escondido†	D-16-17 30a	Unknown	Tetra Tech (2010a)
Faber Spring	D-19-14 24da	Unknown	USGS Geographical Name Information System database
Feliz Spring	D-18-15 35ba	Unknown	ADWR Statement of Claimant
Fence Spring	D-17-15 35bdb	Unknown	ADWR Statement of Claimant
Fig Tree Spring	D-18-16 19abb	<0.1 gpm; supports riparian area of approximately 0.5 acres	Errol L. Montgomery and Associates (2009b); Westland Resources, Inc. (2010d)
Florida Spring	D-20-15 6aa	Unknown	USGS Geographical Name Information System database
Grader Spring	D-18-16 27ca	Spring not located and no riparian vegetation present (summer 2011)	ADWR Statement of Claimant; Westland Resources, Inc. (2011c)
Heiter Spring	D-18-15 1ddb	Spring not located and no riparian vegetation present (summer 2011)	ADWR Statement of Claimant; Westland Resources, Inc. (2011c)
Helvetia Spring	D-18-15 14DBA	~0.2 to 1.6 gpm	BLM
Hilton Spring	D-17-17 32caa	Unknown	ADWR Statement of Claimant
Hole Seep Spring	D-19-15 1bc	Unknown	ADWR Statement of Claimant
Horse Pasture Spring	D-18-16 15aa	Spring not located and no riparian vegetation present (summer 2011)	Pearce (2007); Westland Resources, Inc. (2011c)
HQ Water Spring	D-18-16 16cd	Spring not located and no riparian vegetation present (summer 2011)	ADWR Statement of Claimant; Westland Resources, Inc. (2011c)
Indian Spring	D-17-15 36cbc	Unknown	ADWR Statement of Claimant
Kent Spring	D-20-14 12aa	Unknown	USGS Graphical Name Information System database
La Cholla Spring	D-18-16 5cba	Unknown	ADWR Statement of Claimant
Lazy Boy spring	D-18-16 18ad	Spring not located and no riparian vegetation present (summer 2011)	ADWR Statement of Claimant; Westland Resources, Inc. (2011c)
Little Indian Spring	D-17-15 36cbc	Unknown	ADWR Statement of Claimant
Locust Spring	D-19-15 1bdb	Dry, occasional damp	Errol L. Montgomery and Associates (2009b)
Lower Mulberry Spring	D-18-16 9dbb	Moist, up to <0.1 gpm	Errol L. Montgomery and Associates (2009b)
Lower Spring	D-18-16 8abc	Spring not located and no riparian vegetation present (summer 2011)	ADWR Statement of Claimant; Westland Resources, Inc. (2011c)
McBeth Spring	D-20-14 13da	Unknown	USGS Geographic Name Information System database
McCleary Dam	D-18-16 29bda	Flow under dam, 2 to 3 gpm	Errol L. Montgomery and Associates (2009b)

Name of Spring	Cadastral Location	Observed Flow Rate and Characteristics*	Data Source
McCleary No. 1	D-18-16 30abc	Varies from dry to small seep; ~1 gpm	WestLand Resources Inc. (2007b); Errol L. Montgomery and Associates (2009b); Pearce (2007)
McCleary No. 2	D-18-16 19cdd	No flow, ground moist; <1 gpm	WestLand Resources Inc. (2007b); Errol L. Montgomery and Associates (2009b)
Melon Spring	D-18-16 17bba	Spring not located and no riparian vegetation present (summer 2011)	ADWR Statement of Claimant; Westland Resources, Inc. (2011c)
Mescal Spring	D-17-17 21a	Unknown	USGS Geographical Name Information System database
Mesquite Flat Spring	D-18-16 7aaa	Unknown	USGS Topographic Map
Mine Water Spring	D-19-15 24dc	Improved; no flow or riparian vegetation present	ADWR Statement of Claimant; Westland Resources, Inc. (2011c)
Monkey Spring	D-21-16 3cb	Unknown	USGS Topographic Map
Mud Spring	D-19-18 28bc	Unknown	USGS Topographic Map
Mudhole Spring	D-18-16 17bb	No flow, ground moist; some riparian vegetation present	ADWR Statement of Claimant; Westland Resources, Inc. (2011c)
Mueller Spring	D-18-16 29cc	Improved; no flow or riparian vegetation present	ADWR Statement of Claimant; Westland Resources, Inc. (2011c)
Mulberry Spring	D-18-16 9abc	Dry, up to <0.1 gpm	Errol L. Montgomery and Associates (2009b)
Oak Spring	D-18-16 17bbc	Standing pool; limited riparian vegetation present	ADWR Statement of Claimant; Westland Resources, Inc. (2011c)
Ojo Blanco Spring	D-18-16 4cd	Improved; limited riparian vegetation present	USGS Geographical Name Information System database; Westland Resources, Inc. (2011c)
Paja Verde Spring	D-19-15 23ca	Spring not located and no riparian vegetation present (summer 2011)	USGS Geographical Name Information System database; Westland Resources, Inc. (2011c)
Papago Spring	D-21-17 17da	Unknown	USGS Topographic Map
Papago Spring (No. 2)	D-18-16 16bba	Dry, up to 1.7 gpm	Errol L. Montgomery and Associates (2009b)
Peligro Adit	D-18-15 24dcc	Seep	Errol L. Montgomery and Associates (2009b)
Pole Cat Spring	D-18-16 7bd	Spring not located and no riparian vegetation present (summer 2011)	ADWR Statement of Claimant; Westland Resources, Inc. (2011c)
Proctor Box Spring	D-19-15 12bc	Spring not located and no riparian vegetation present (summer 2011)	ADWR Statement of Claimant; Westland Resources, Inc. (2011c)
Proctor Spring	D-19-15 3acc	Unknown	USGS Topographic Map
Questa Spring	D-18-16 27ddd	Small pond present; <1 gpm	WestLand Resources Inc. (2007b); Errol L. Montgomery and Associates (2009b); Pearce (2007)
Robinson Spring	D-19-15 29cb	Unknown	USGS Geographical Name Information System database
Rock Spring	D-18-16 6ddd	Unknown	ADWR Statement of Claimant
Rockhouse Spring	D-18-17 10cda	Unknown	ADWR Statement of Claimant

Name of Spring	Cadastral Location	Observed Flow Rate and Characteristics*	Data Source
Rosemont Spring	D-18-16 32bbc	~1 to 2 gpm	WestLand Resources Inc. (2007b); Errol L. Montgomery and Associates (2009b); Pearce (2007)
Ruelas Spring	D-18-15 35bdc	Dry, occasional damp	Errol L. Montgomery and Associates (2009b)
Ruelas Spring Number Two and Three	D-18-15 26aa	Unknown	USGS Geographical Name Information System database
Rust Spring	D-18-15 1acb	Unknown	ADWR Statement of Claimant
Sanford Spring	D-18-17 15daa	Unknown	ADWR Statement of Claimant
Sawmill Spring	D-20-15 4bb	Unknown	USGS Geographical Name Information System database
Scholefield No. 1	D-18-16 16ccc	No flow, ground dry; supports riparian area of approximately 0.3 acre	WestLand Resources Inc. (2007b); Errol L. Montgomery and Associates (2009b); WestLand Resources, Inc. (2010d)
Scholefield No. 2	D-18-16 17adb	No flow, ground moist	WestLand Resources Inc. (2007b); Errol L. Montgomery and Associates (2009b)
Scholefield No. 3	D-18-16 17caa	Most recent observations show flow <1 gpm, ground moist. No riparian vegetation present	WestLand Resources Inc. (2007b); Westland Resources, Inc. (2011c)
Shamrod Spring	D-18-15 14BCD	Unknown	BLM
Siphon Spring	D-17-16 31cda	Unknown	ADWR Statement of Claimant
Soldier Spring	D-18-15 25bb	Unknown	ADWR Statement of Claimant
Sprung Spring	D-20-14 13ab	Unknown	USGS Geographical Name Information System database
SS-2	D-18-15 13aab	Dry	Errol L. Montgomery and Associates (2009b)
Sulfur Spring		Spring not located and no riparian vegetation present (summer 2011)	USGS Geographical Name Information System database; Westland Resources, Inc. (2011c)
SW	D-19-15 1bbb	Dry, occasional damp	Errol L. Montgomery and Associates (2009b)
Sweetwater Spring	D-20-15 11bbb	Unknown	USGS Geographical Name Information System database
Sycamore Spring	D-18-15 12dba	Dry, to 1 gpm	Errol L. Montgomery and Associates (2009b)
Sylvester Spring	D-20-14 1dc	Unknown	USGS Geographical Name Information System database
Tree Spring	D-18-16 8acc	Dry, some riparian vegetation	ADWR Statement of Claimant; Westland Resources, Inc. (2011c)
Tub Spring	D-1816 6dd	Unknown	ADWR Statement of Claimant
Tunnel Spring	D-17-16 32cb	Unknown	USGS Topographic Map
Tunnel Spring #2	D-17-16 31bbd	Unknown	ADWR Statement of Claimant
Unnamed Spring (Reach 2)†	D-17-17 06bd	Unknown	Tetra Tech (2010a)
Unnamed Spring No. 1	D-18-15 23ba	Unknown	Pearce (2007)
Unnamed Spring No. 2	D-18-16 30cd	Standing pool; no riparian vegetation present	Pearce (2007); Westland Resources, Inc. (2011c)
Unnamed Spring No. 3	D-18-16 30cd	Unknown	Pearce (2007)

Name of Spring	Cadastral Location	Observed Flow Rate and Characteristics*	Data Source
Unnamed Spring No. 4	D-18-16 26bc	Spring not located and no riparian vegetation present (summer 2011)	Pearce (2007); Westland Resources, Inc. (2011c)
Unnamed Spring No. 5	D-18-16 29ab	Spring not located and no riparian vegetation present (summer 2011)	Pearce (2007); Westland Resources, Inc. (2011c)
Unnamed Spring No. 6 (Possibly same as McCleary No. 2)	D-18-16 19cd	Unknown	Pearce (2007)
Unnamed Spring No.7	D-17-17 28b	Unknown	USGS Topographic Map
Unnamed Spring No.8	D-20-14 12ac	Unknown	USGS Topographic Map
Unnamed Spring No.9	D-20-14 14aa	Unknown	USGS Topographic Map
Unnamed Spring No.10	D-20-15 21cd	Unknown	USGS Topographic Map
Unnamed Spring No. 11	D-20-15 27bb	Unknown	USGS Topographic Map
Unnamed Spring No.12	D-18-17 6ac	Unknown	USGS Topographic Map
Unnamed Spring No. 13	D-18-15 34aa	Unknown	ADWR Statement of Claimant
Unnamed spring No. 14	D18-16 21bc	Spring not located; limited riparian vegetation present (summer 2011)	ADWR Statement of Claimant; Westland Resources, Inc. (2011c)
Unnamed Spring No. 15	D-20-14 10ddc	Unknown	USGS Geographical Name Information System database
Unnamed Spring No. 16	D-17-15 36cc	Spring not located and no riparian vegetation present (summer 2011)	ADWR Statement of Claimant; Westland Resources, Inc. (2011c)
Unnamed Spring No. 17	D-18-16 8ac	Unknown	ADWR Statement of Claimant
Unnamed Spring No. 18	D-18-15 13ac	Unknown	ADWR Statement of Claimant
Unnamed Spring No. 19	D-18-15 13ad	Unknown	ADWR Statement of Claimant
Unnamed Spring No. 20	D-17-16 31cd	Unknown	ADWR Statement of Claimant
Unnamed Spring No. 21	D-18-16 6dc	Unknown	ADWR Statement of Claimant
Unnamed Spring No. 22	D-18-16 7da	Spring not located and no riparian vegetation present (summer 2011)	ADWR Statement of Claimant; Westland Resources, Inc. (2011c)
Unnamed Spring No. 23	D-18-16 8ba	Unknown	ADWR Statement of Claimant
Unnamed Spring No. 24	D-18-16 8ca	Spring not located and no riparian vegetation present (summer 2011)	ADWR Statement of Claimant; Westland Resources, Inc. (2011c)
Upper Empire Gulch Spring	D-19-17 18AAD	Unknown	BLM
Walnut Spring	D-20-14 11ccc	Unknown	USGS Geographical Name Information System database
Willow Spring	D-19-15 22bc	Unknown	USGS Geographical Name Information System database
Wood Spring	D-18-16 17cbb	Spring not located and no riparian vegetation present (summer 2011)	ADWR Statement of Claimant; Westland Resources, Inc. (2011c)
Water Develop Spring	D-18-16 17ab	Standing pool; limited riparian vegetation present	ADWR Statement of Claimant; Westland Resources, Inc. (2011c)
Zackendorf Spring	D-18-15 14ADA	Unknown	BLM

* Flow rate as observed in 2008 and 2009 by WestLand Resources Inc., Montgomery and Associates, or Tetra Tech, or in 2011 by WestLand Resources Inc.

† Located in lower Davidson Canyon outside the 12-mile radius of the mine pit.

Table 51. Modeled groundwater level drawdown for selected wells

Well Cadastral Location, Name, and Proximity to Pumping	Time Period	Estimated Drawdown without Mine Water Supply Pumping (feet)	Estimated Drawdown with Mine Water Supply Pumping (feet)	Estimated Additional Drawdown from Mine Water Supply Pumping (feet)
D-17-14 07DDD (FICO S-12) Located ~2,000 feet north of northern parcel	Year 10	10	50	40
D-17-14 07DDD (FICO S-12) Located ~2,000 feet north of northern parcel	Year 20	90	150	60
D-17-14 21ACD Located immediately adjacent to west side of southern parcel	Year 10	25	60	35
D-17-14 21ACD Located immediately adjacent to west side of southern parcel	Year 20	70	120	50
D-17-14 17DCC Located between the two parcels, ~3,000 feet south of northern parcel and ~7,000 feet northwest of southern parcel	Year 10	15	60	45
D-17-14 17DCC Located between the two parcels, ~3,000 feet south of northern parcel and ~7,000 feet northwest of southern parcel	Year 20	80	150	70
D-17-14 04BCB (City of Tucson SC-023A) Located ~2 miles northeast of northern parcel	Year 10	25	35	10
D-17-14 04BCB (City of Tucson SC-023A) Located ~2 miles northeast of northern parcel	Year 20	130	160	30
D-17-14 30BBB (FICO S-33) Located ~2 miles southwest of northern parcel	Year 10	5	20	15
D-17-14 30BBB (FICO S-33) Located ~2 miles southwest of northern parcel	Year 20	70	100	30

Impacts Common to All Action Alternatives

Impacts to groundwater quantity are associated with the mine water supply pumping in the Upper Santa Cruz Sub-Basin and the drawdown from the mine pit, located east of the Santa Rita Mountains. Both the mine water supply pumping and the mine pit are actions common to all action alternatives. Therefore, with respect to groundwater level changes, groundwater availability, impacts to wells, and impacts to perennial flows the impacts from these activities are common to all action alternatives.

Impacts to springs and seeps are affected not only by groundwater level changes but by the footprint of the various alternatives as well. These impacts are assessed by individual alternative.

Impacts Resulting from Mine Water Supply Pumping in Upper Santa Cruz Sub-Basin

The specific factors to be considered in assessing impacts resulting from mine water supply pumping are as follows:

- Amount of water to be pumped from the Upper Santa Cruz Sub-Basin for mine operations (acre-feet), compared with the basin water balance (percent increase in basin pumping)
- The change in water table level (total drawdown from pumping as well as annual rate of drawdown from pumping), compared with background changes (total drawdown unrelated to pumping as well as annual rate of drawdown unrelated to pumping), and the geographic extent in which water resources may be impacted
- Duration of the effects of pumping in the Upper Santa Cruz Sub-Basin
- Number of wells within the geographic extent of impact

Predicted Change in Groundwater Levels and Geographic Area of Impact

The water table in the Upper Santa Cruz Sub-Basin is in decline as a result of existing municipal, residential, agricultural, and mining withdrawals. Results of the mine water supply model (Barter and Odom 2011; Errol L. Montgomery and Associates Inc. 2009a) indicate that additional drawdown of the water table would occur as a result of both existing and future public and private pumping and the proposed mine water supply withdrawal (see table 51).

The threshold of significance for impacts to wells was selected as being 10 feet. The geographic area within which water supply, domestic, stock, and irrigation wells would be impacted above this threshold of significance is shown in figure 36. After 10 years, this represents an area up to 3 miles from the Rosemont well field. After 20 years, this represents an area up to 4 miles from the Rosemont well field.

In order to compare the estimated impacts with background changes in water levels, five wells were selected that represent a variety of distances and directions from the two Rosemont Copper properties where pumping will occur. Note that these do not represent the only wells in the analysis area. These wells have been selected for their record of historic water levels and because they were specifically assessed in the Errol L. Montgomery and Associates Inc. (2009a) modeling report. Locations of these wells are shown in figure 36. The modeled drawdown in water levels at each well without mine water supply pumping and with mine water supply pumping at two points in time (10 and 20 years after pumping commences) are shown in table 51.

The contours shown in figure 36 represent the drawdown expected to occur over 20 years that is solely owing to the mine water supply pumping; however, significant drawdown is expected in the area owing to other groundwater pumping. Drawdown expected to occur over 20 years owing to both mine water supply pumping and other estimated groundwater pumping is shown in figure 37. Drawdown expected to occur over 20 years owing solely to other groundwater pumping (without the mine water supply pumping) is shown in figure 38.

In addition to drawdown, potential changes in groundwater flow direction are a potential impact from mine water supply pumping. Water level elevation contours, which indicate the direction of groundwater flow, after 20 years are shown in figure 39 (with both mine water supply pumping and other groundwater pumping) and figure 40 (without mine water supply pumping, only other groundwater pumping). No significant changes in flow direction are expected to occur owing to mine water supply pumping. The gradient of the water table will change slightly, from 8.1 feet per thousand feet without mine water supply pumping, to 9.4 feet per thousand feet with mine water supply pumping.

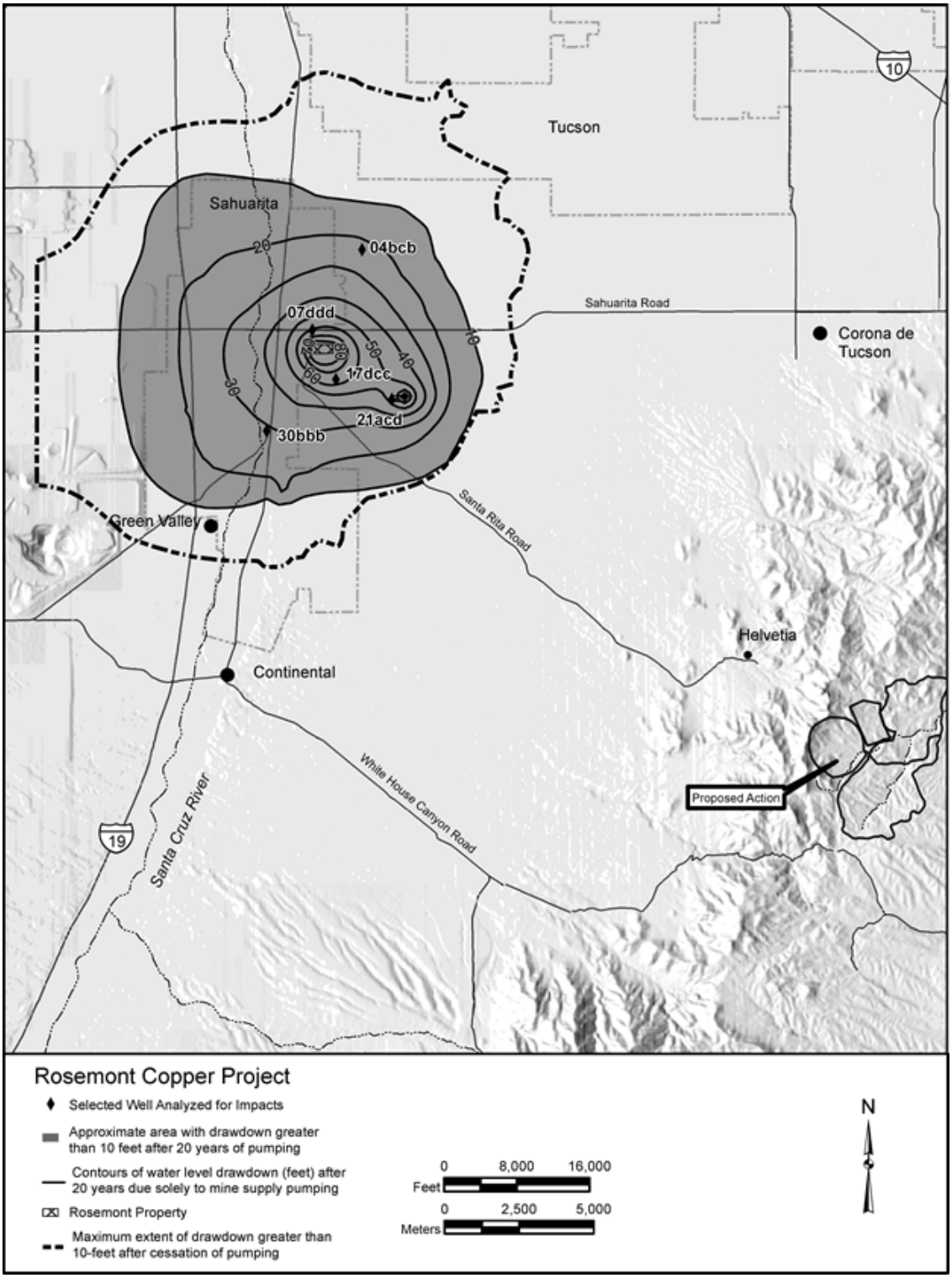


Figure 36. Geographic area of impact from mine water supply pumping after 20 years of pumping (Errol L. Montgomery and Associates Inc. 2009a)

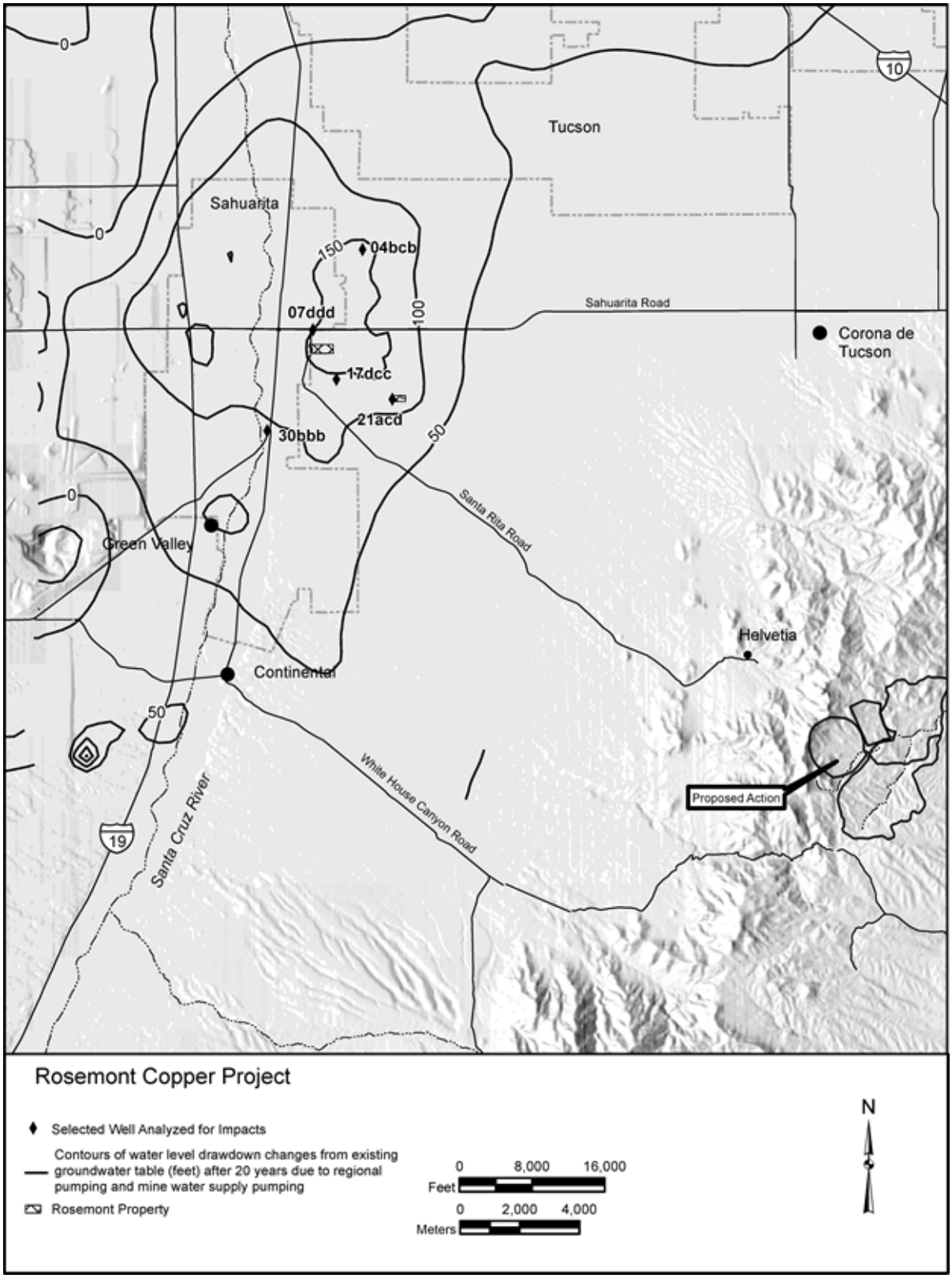


Figure 37. Regional water-level drawdown after 20 years, including mine supply pumping

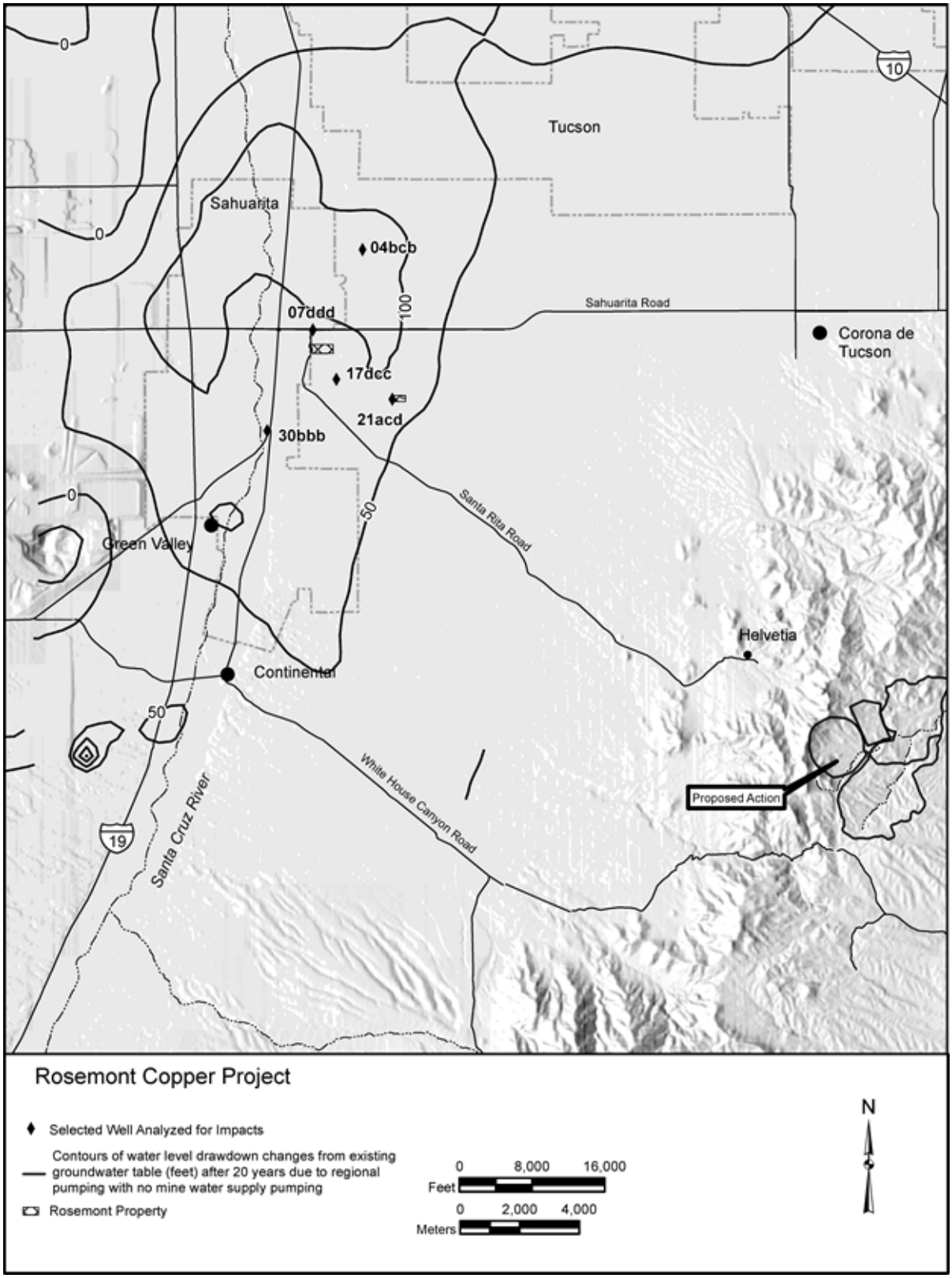


Figure 38. Regional water-level drawdown after 20 years without mine supply pumping

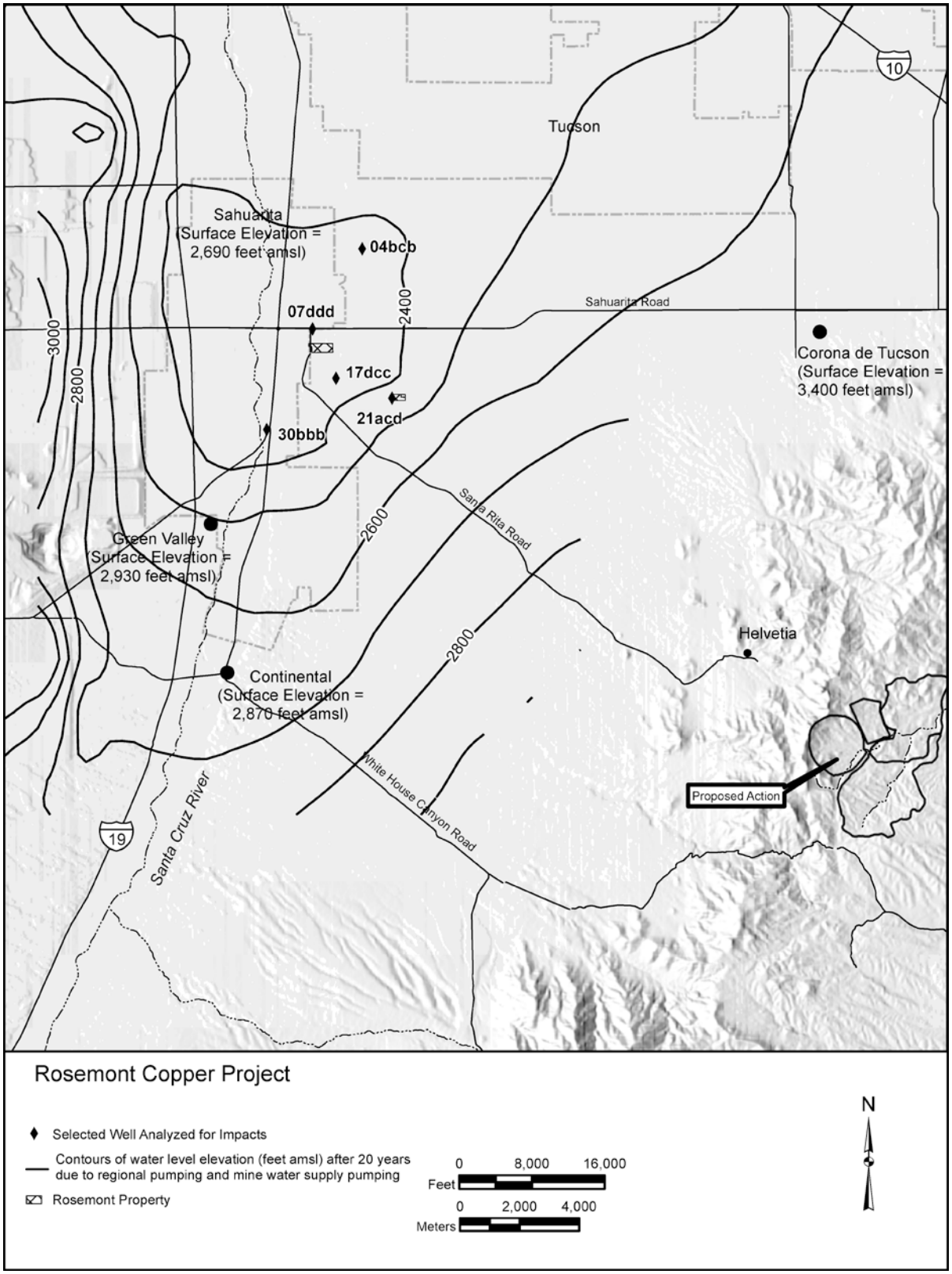


Figure 39. Regional water elevations after 20 years, including mine supply pumping

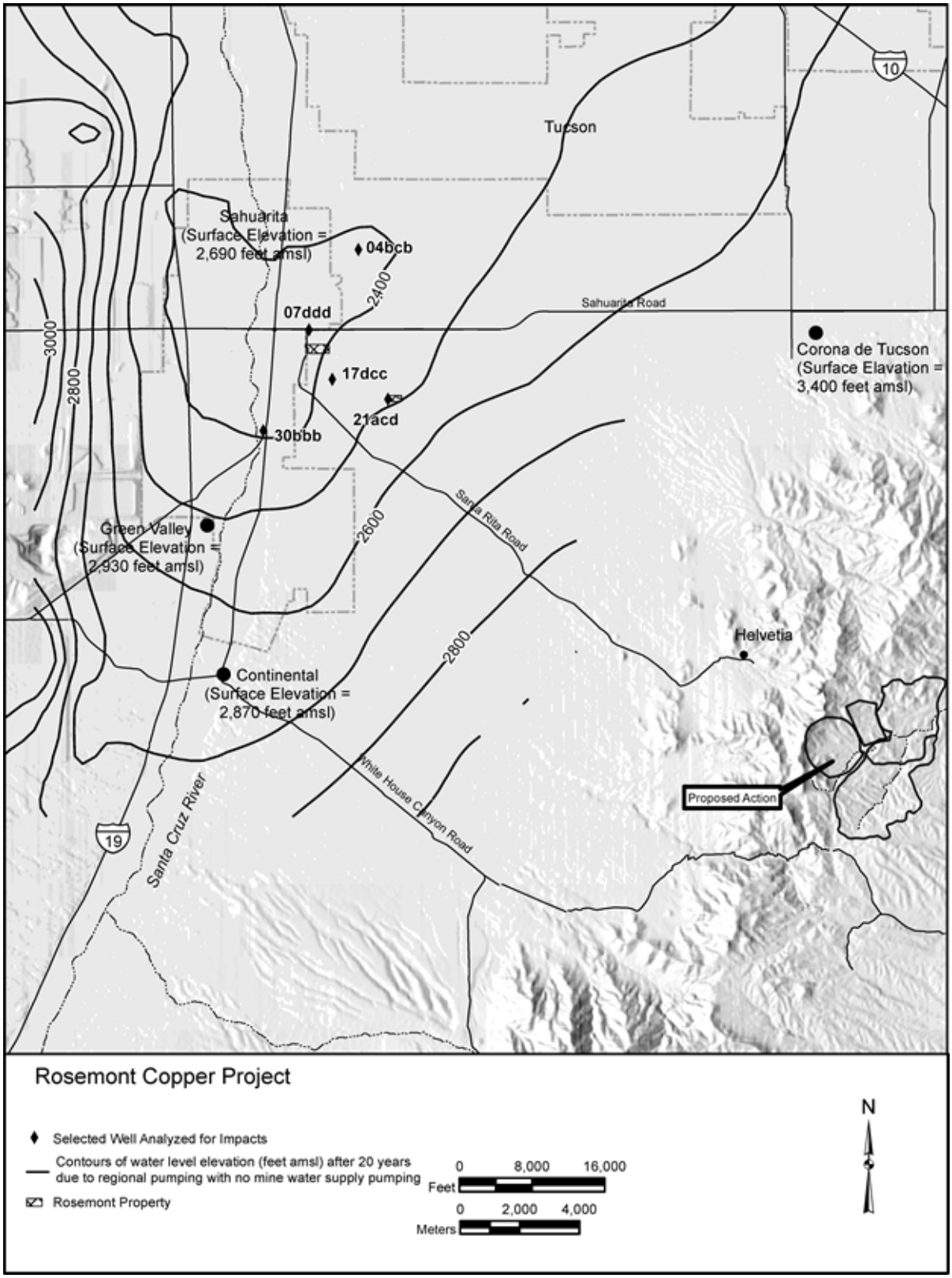


Figure 40. Regional water-level elevations after 20 years without mine supply pumping

Groundwater level drawdown resulting from pumping for the mine water supply are estimated to be as great as 70 feet immediately adjacent to the Rosemont Copper properties and 10 to 15 feet approximately 3 to 4 miles from the Rosemont Copper properties. The annual drawdown rate with and without mine water supply pumping, along with the historic annual drawdown rate for each well, are shown in table 52. The increased rate of decline would persist for the 20-year expected duration of pumping. When pumping ceases, some recovery of water levels may be seen in the immediate vicinity of the Rosemont Copper properties; however, in general, the overall drop in water levels caused by the mine supply pumping would not recover unless water levels in the regional aquifer began increasing as a whole.

The Montgomery Mine Water Supply model was originally conducted only for 20 years, ending at the point that mine water supply pumping ceases (Errol L. Montgomery and Associates Inc. 2009a, 2010). While this represents the point of maximum drawdown in the immediate vicinity of the Rosemont wells, the Forest Service requested that the model be extended until the cone of depression reaches approximate equilibrium and stops expanding. The extended modeling concluded that the cone of depression would keep expanding between 100 and 140 years after pumping stops. During this time, the cone of depression reaches approximate equilibrium and stops expanding. The 10-foot drawdown contour is projected to expand an additional 1 to 2 miles laterally before reaching equilibrium (Barter and Whittier 2011).

Table 52. Modeled and historic rates of water level change for selected wells

Well Cadastral Location, Name, and Proximity to Pumping	Without Mine Water Supply Pumping Annual Rate of Change (feet per year)	With Mine Water Supply Pumping Annual Rate of Change (feet per year)	Attributable to Mine Water Supply Pumping Annual Rate of Change (feet per year)	Historic Annual Rate of Change (feet per year) (date range)
D-17-14 07DDD (FICO S-12) Located ~2,000 feet north of northern parcel	4.5	7.5	3	1.7 (1947 to 2005)
D-17-14 21ACD Located immediately adjacent to west side of southern parcel	3.8	6	2.2	1 (1975 to 2006)
D-17-14 17DCC Located between the two parcels, ~3,000 feet south of northern parcel and ~7,000 feet northwest of southern parcel	4	7.5	3.5	3.2 (1953 to 1979)
D-17-14 04BCB (City of Tucson SC-023A) Located ~2 miles northeast of northern parcel	6.5	8	1.5	1.2 (1968 to 2007)
D-17-14 30BBB (FICO S-33) Located ~2 miles southwest of northern parcel	3.5	5	1.5	3.5 (1952 to 2005)

The values in tables 51 and 52 and in figure 37 represent predicted drawdown. However, a seasonal variation of 10 to 100 feet above and below the average annual level is expected as a result of agricultural pumping in the area, although the effect of seasonal agricultural withdrawal may decrease if the agricultural land is converted to residential use.

Approximately 400 to 450 domestic or other production wells registered with the Arizona Department of Water Resources would be impacted by drawdown in groundwater levels over 10 feet;

approximately 63 percent of these are smaller domestic or exempt wells. Note that this is not considered a comprehensive inventory of wells in the area, nor are there adequate well construction and operation details to determine whether this drawdown would impact well performance. Shallow wells in the analysis area are not specifically assessed by the model because of their possible disconnect with the regional aquifer and the general lack of information about the construction and operation of small domestic supply wells. However, in general, similar drawdowns could also occur in shallow wells, although the model is not able to predict these specific impacts.

In addition to the representative wells analyzed in tables 51 and 52, several specific wells associated with water companies, municipalities, or other government entities have been assessed. These wells are summarized in table 53.

Table 53. Modeled groundwater level drawdown for selected public supply, municipal, or government wells

Cadastral Location	Well Owner	Well Depth (feet)	Expected Drawdown in Regional Aquifer due to Rosemont Pumping after 20 years (feet)
D-18-13 02BAB	Community Water Company of Green Valley	700	<10
D-18-13 02BDD	Community Water Company of Green Valley	1000	<10
D-17-13 26BCC	Las Quintas Serenas Water Company	807	20-30
D-17-13 26CCD	Las Quintas Serenas Water Company	922	20-30
D-17-13 25DAB	Pima County	300	20-30
D-17-14 08ADD	Pima County Parks and Recreation	500	30-40
D-17-13 14CAB	Pima County Solid Waste Management	40	20-30
D-17-13 01CDD	Sahuarita Water Company	905	20-30
D-17-13 01BAC	Sahuarita Water Company	990	20-30
D-17-13 01ABB	Sahuarita Water Company	982	20-30
D-16-13 36CBC	Sahuarita Water Company	1053	<10
D-17-13 11BAA	Sahuarita Water Company	1080	20-30
D-17-13 01ACC	Town of Sahuarita	1135	20-30
D-17-14 04BCB	City of Tucson	600	20-30
D-17-14 02BAA	City of Tucson	624	<10
D-16-14 26CCC	City of Tucson	700	<10
D-16-14 21DDC	City of Tucson	600	<10
D-16-14 21CCB	City of Tucson	600	<10
D-17-13 26AAB	Valle Verde Water	677	20-30
D-18-13 02BCC	Community Water Company of Green Valley	515	<10
D-17-14 04ACA	City of Tucson	602	20-30
D-16-14 28CCB	City of Tucson	500	<10
D-16-14 21DBB	City of Tucson	650	<10
D-16-14 20ACB	City of Tucson	535	<10
D-16-14 20ADA	City of Tucson	540	<10
D-16-14 20BBB	City of Tucson	403	<10
D-17-13 26A	Valle Verde Water	507	10-20
D-17-13 36CDD	Pima County Wastewater (water supply)	400	10-20
D-17-13 36DAC	Pima County Wastewater (monitoring wells)	30 - 60	10-20

Effect on Overall Groundwater Availability

In addition to impacts to specific wells from groundwater drawdown, there is the potential to affect overall groundwater availability within the Upper Santa Cruz Sub-Basin and within the Tucson Active Management Area as a whole. Within the Upper Santa Cruz Basin Sub-Basin, the 5,400 acre-feet per year represents a 6 to 7 percent increase over the current estimated pumpage demand of 82,000 acre-feet; within the entire Tucson Active Management Area, it represents a 2 percent increase over the estimated pumpage demand of 252,000 acre-feet.

Effect on Land Subsidence — Land subsidence associated with groundwater withdrawal in the Santa Cruz Valley is expected to continue in association with the degree of pumping in excess of recharge. This subsidence is being monitored by the Arizona Department of Water Resources.

Impacts Resulting from the Mine in the Davidson Canyon/Cienega Basin

The results of the groundwater modeling in the Davidson Canyon/Cienega Basin indicate that the mine pit would create a permanent drawdown of the water table. Groundwater would flow toward the mine pit in perpetuity from the time the excavation intersects the water table. At first, while the mine is operational, groundwater would be pumped directly from the mine pit. After closure of the mine, the pit is expected to gradually fill with groundwater, forming a mine pit lake. The mine pit lake would lose water through evaporation, and this water would be perpetually replenished by groundwater from the regional aquifer. In this way, the mine pit lake is expected to act as a permanent regional hydraulic sink.

Pumping of the mine pit would draw down the level of groundwater in the regional aquifer, forming what is known as a cone of depression (figures 41 through 44). Because the mine pit lake would act to remove groundwater in perpetuity from the system, this cone of depression is expected to persist in perpetuity. The boundaries of the cone of depression would migrate outward for a very long period of time until they eventually reach equilibrium. The various models estimate equilibrium will be reached between 1,000 and 7,000 years after closure of the mine. The cone of depression would stop expanding, but the flow of groundwater toward the mine pit would be a permanent feature of the regional aquifer.

The specific factors to be considered to assess impacts resulting from mine water supply pumping are as follows:

- The amount of water lost to the mine pit by evaporation (acre-feet), compared with the basin water balance (as percent of natural recharge, evapotranspiration, and exempt well pumpage)
- Direction and degree of change in water table level (feet) and the geographic extent in which water resources may be impacted
- Impairment of mountain-front groundwater recharge function
- Duration of the effect of mine pit drawdown (in years)
- Estimation of the number of stream miles changed from intermittent flow status to ephemeral flow status as a result of the project, along with the potential impacts to Davidson Canyon and Cienega Creek, which may affect their designations as Outstanding Arizona Waters and current designated uses
- Number of seeps and springs lost or impaired
- Reduction in groundwater outflow from Davidson Canyon (acre-feet)
- Number of wells within the geographic extent

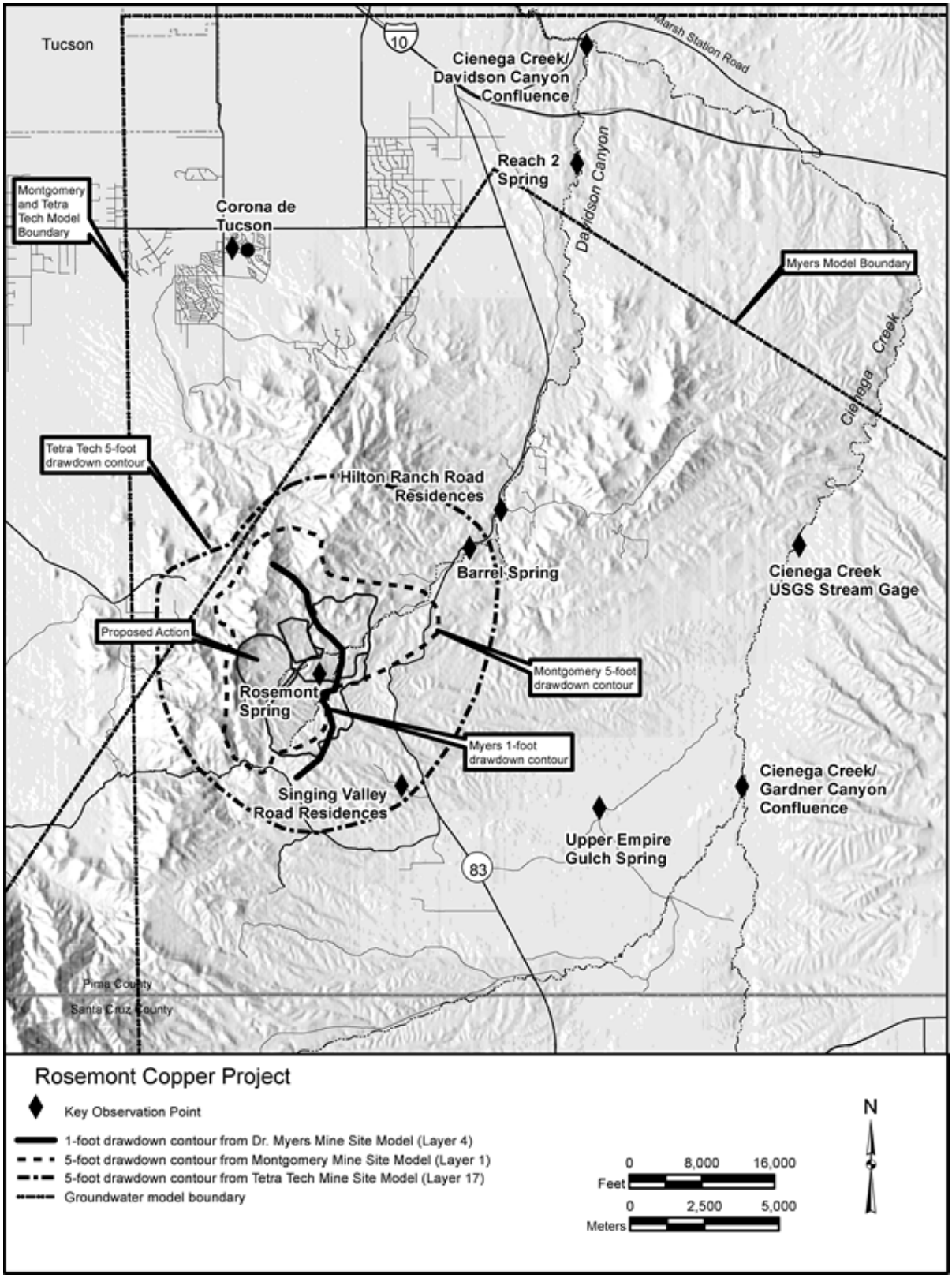


Figure 41. Water-level drawdown in the vicinity of mine at end of active mining

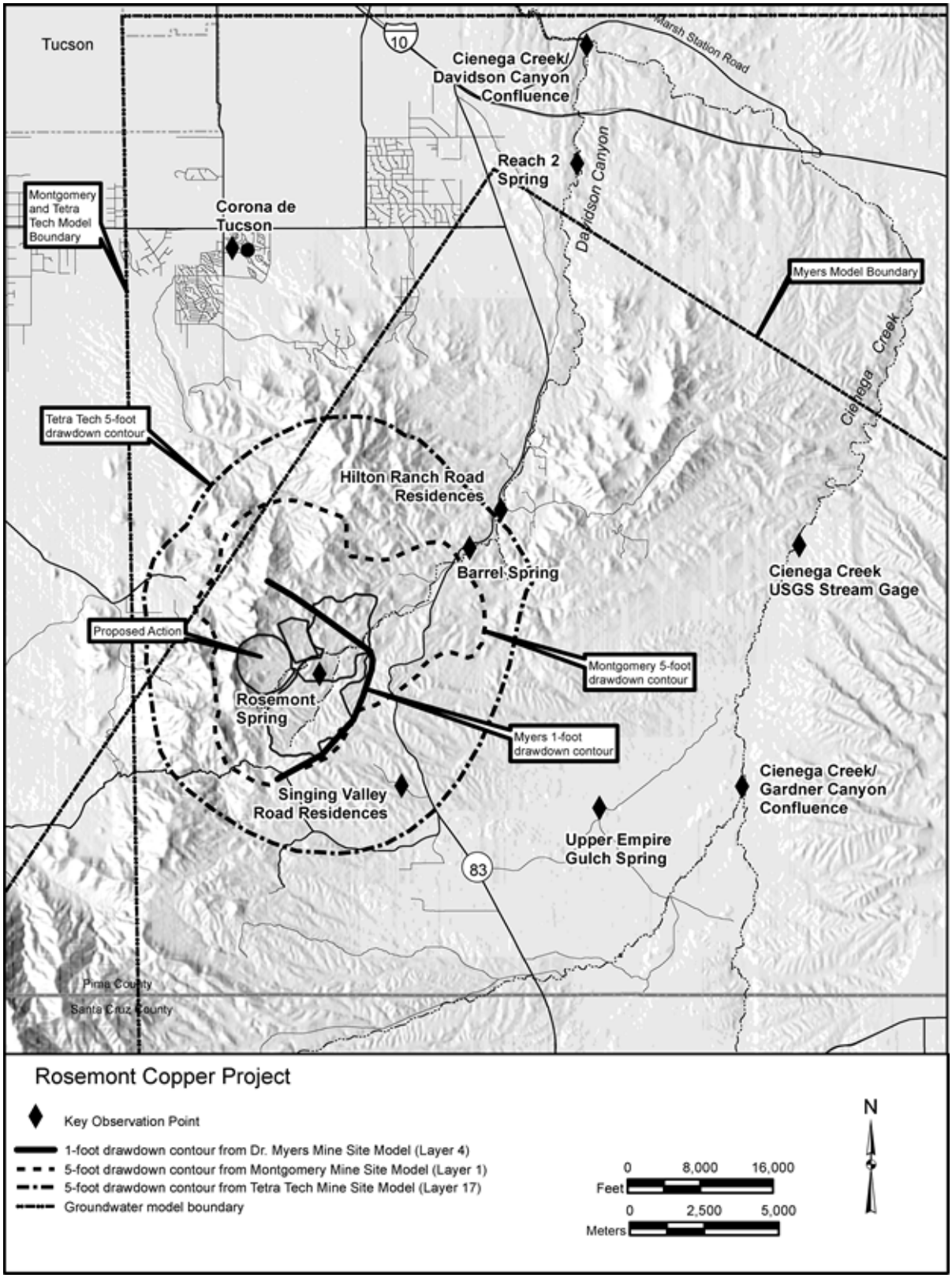


Figure 42. Water-level drawdown in the vicinity of mine 20 years after active mining

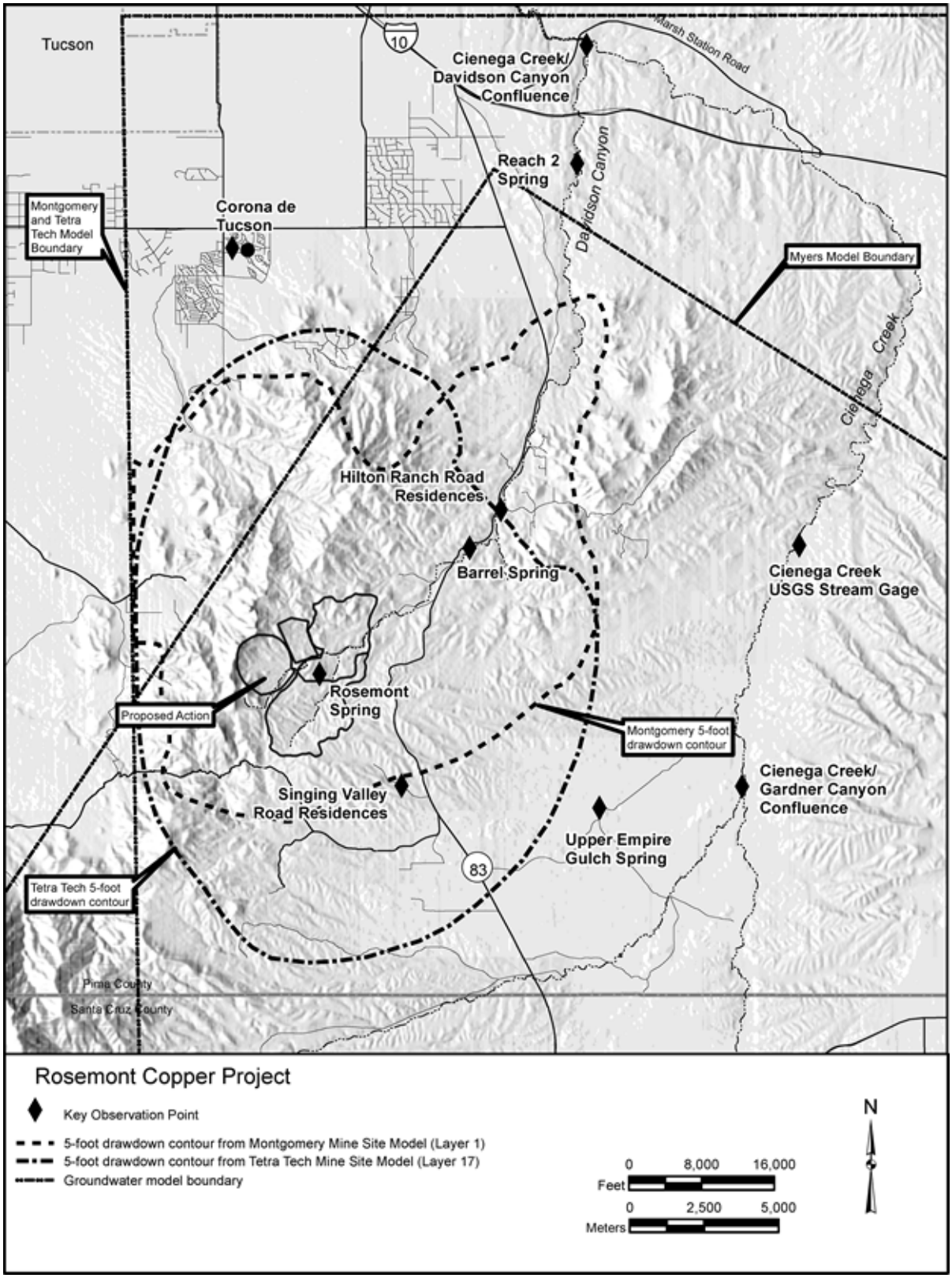


Figure 43. Water-level drawdown in the vicinity of mine 150 years after active mining

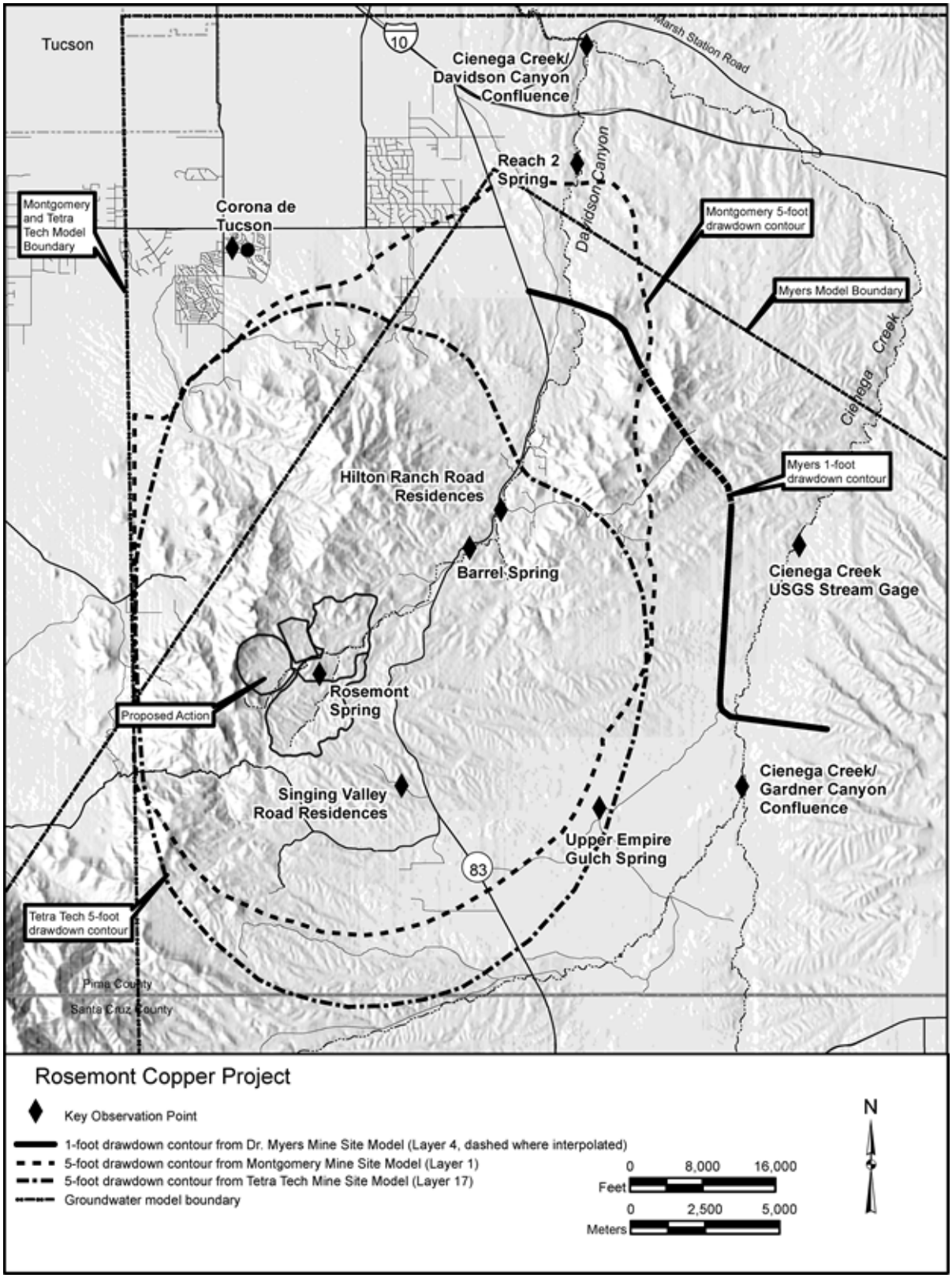


Figure 44. Water-level drawdown in the vicinity of mine 1,000 years after active mining

Predicted Change in Groundwater Levels as a Result of the Mine Pit

The temporal bounds of analysis extends to 1,000 years after mine closure. In order to assess the progression of impacts, snapshots of groundwater conditions are assessed at the end of active mining and at 20, 50, 150, and 1,000 years after mine closure. The modeled areas of impact, as defined by the 5-foot drawdown contours of the Montgomery and Tetra Tech Mine Site models and the 1-foot drawdown contour of the Myers model, are shown for selected time periods in figures 41 through 44.

Within the analysis area, impacts are further assessed at selected geographic locations, chosen because they represent important areas of potential surface water/groundwater interaction throughout the Davidson Canyon/Cienega Basin, as well as to represent a range of distance and direction from the mine pit. These selected locations are shown in figures 41 through 44 and listed below:

- Rosemont Spring. This spring is located approximately 0.7 mile southeast of the mine pit and was selected to represent groundwater conditions near the pit.
- Barrel Spring. This spring is located approximately 4.5 miles down Barrel Canyon from the mine pit and was selected to represent groundwater conditions as they may migrate toward Davidson Canyon.
- Reach 2 Spring. This spring is located approximately 12 miles down Davidson Canyon from the mine pit and was selected not only to represent a point this distance from the mine pit but because Reach 2 Spring is the point at which a perennial reach of Davidson Canyon begins.
- Upper Empire Gulch springs near Empire Ranch. These springs are located approximately 3.5 miles east of State Route 83 in Empire Gulch.
- Confluence of Davidson Canyon and Cienega Creek. This confluence is located approximately 14 miles down Davidson Canyon from the mine pit.
- Perennial portion of Cienega Creek. This portion is located approximately 9 miles east-southeast of the mine pit, near the confluence with Gardner Canyon.
- Perennial portion of Cienega Creek. This portion is located approximately 11 miles east-northeast of the mine pit, near U.S. Geological Survey stream gage no. 09484550.
- Corona de Tucson residential area. This is located approximately 9 miles north of the mine pit, within the Santa Cruz Valley, on the other side of Santa Rita Mountains.
- Nearest residences (and likely domestic wells) along Singing Valley Road. These are approximately 2 miles southeast of mine pit.
- Nearest residences (and likely domestic wells) along Hilton Ranch Road. These are approximately 6 miles northeast of mine pit.

As indicated earlier, to the extent possible, all three groundwater flow models were used to assess groundwater impacts at these times and locations. Not all models were able to be used for all locations and times. The following tables summarize the estimated groundwater drawdown in the regional aquifer resulting from the mine pit at the end of active mining (table 54; see figure 41), 20 years after mine closure (table 55; see figure 42), 50 years after mine closure (table 56), 150 years after mine closure (table 57; see figure 43), and 1,000 years after mine closure (table 58; see figure 44).

Table 54. Modeled groundwater drawdown resulting from mine pit at end of active mining

Location	Predicted Drawdown (feet) from Specified Groundwater flow Model Montgomery and Associates Inc. (2010)	Predicted Drawdown (feet) from Specified Groundwater flow Model Tetra Tech (2010g)	Predicted Drawdown (feet) from Specified Groundwater flow Model Myers (2010b)
Rosemont Spring	100	100	1 to 10
Barrel Spring	<5	5 to 10	<1
Reach 2 Spring	<5	<5	<1
Upper Empire Gulch springs	<5	<5	<1
Davidson/Cienega Confluence	<5	<5	<1
Gardner/Cienega Confluence	<5	<5	<1
Cienega near Stream Gage	<5	<5	<1
Corona de Tucson	<5	<5	<1
Singing Valley Road Residences	<5	10	<1
Hilton Ranch Road Residences	<5	<5	<1

Notes: Values represent the following model layers: Montgomery (Layer 1), Tetra Tech (Layer 17), Myers (Layer 4).

Drawdown values taken from Montgomery and Associates Inc. (2010:figure 110); Tetra Tech (2010g:figure 8-5); Myers (2010b:figures A-1 and A-1a).

Table 55. Modeled groundwater drawdown resulting from mine pit 20 years after mine closure

Location	Predicted Drawdown (feet) from Specified Groundwater flow Model Montgomery and Associates Inc. (2010)	Predicted Drawdown (feet) from Specified Groundwater flow Model Tetra Tech (2010g)	Predicted Drawdown (feet) from Specified Groundwater flow Model Myers (2010b)
Rosemont Spring	>100	10 to 100	1 to 10
Barrel Spring	<5	5 to 10	<1
Reach 2 Spring	<5	<5	<1
Upper Empire Gulch Springs	<5	<5	<1
Davidson/Cienega Confluence	<5	<5	<1
Gardner/Cienega Confluence	<5	<5	<1
Cienega near Stream Gage	<5	<5	<1
Corona de Tucson	<5	<5	<1
Singing Valley Road Residences	<5	10 to 100	<1
Hilton Ranch Road Residences	<5	<5	<1

Notes: Values represent the following model layers: Montgomery (Layer 1), Tetra Tech (Layer 17), Myers (Layers 1 and 4).

Drawdown values taken from Montgomery and Associates Inc., (2010:figure 111); Tetra Tech (2010g:figure 8-10); Myers (2010b:figure A-2).

Table 56. Modeled groundwater drawdown resulting from mine pit 50 years after mine closure

Location	Predicted Drawdown (feet) from Specified Groundwater flow Model Montgomery and Associates Inc. (2010)	Predicted Drawdown (feet) from Specified Groundwater flow Model Tetra Tech (2010g)	Predicted Drawdown (feet) from Specified Groundwater flow Model Myers (2010b)
Rosemont Spring	–	10 to 100	10 to 50
Barrel Spring	–	5 to 10	1 to 10
Reach 2 Spring	–	<5	<1
Upper Empire Gulch Springs	–	<5	<1
Davidson/Cienega Confluence	–	<5	<1
Gardner/Cienega Confluence	–	<5	<1
Cienega near Stream Gage	–	<5	<1
Corona de Tucson	–	<5	<1
Singing Valley Road Residences	–	10 to 100	<1
Hilton Ranch Road Residences	–	<5	1 to 10

Notes: Values represent the following model layers: Montgomery (Layer 1), Tetra Tech (Layer 17), Myers (Layer 4).

– indicates that the modeling report did not analyze this time period.

Drawdown values taken from Tetra Tech (2010g:figure 8-11); Myers (2010b:figure A-2).

Table 57. Modeled groundwater drawdown resulting from mine pit 150 years after mine closure

Location	Predicted Drawdown (feet) from Specified Groundwater flow Model Montgomery and Associates Inc. (2010)	Predicted Drawdown (feet) from Specified Groundwater flow Model Tetra Tech (2010g)	Predicted Drawdown (feet) from Specified Groundwater flow Model Myers (2010b)
Rosemont Spring	>100	10 to 100	–
Barrel Spring	10 to 100	10 to 100	–
Reach 2 Spring	<5	<5	–
Upper Empire Gulch Springs	<5	<5	–
Davidson/Cienega Confluence	<5	<5	–
Gardner/Cienega Confluence	<5	<5	–
Cienega near Stream Gage	<5	<5	–
Corona de Tucson	<5	<5	–
Singing Valley Road Residences	10 to 100	10 to 100	–
Hilton Ranch Road Residences	5 to 10	<5	–

Notes: Values represent the following model layers: Montgomery (Layer 1), Tetra Tech (Layer 17).

– indicates that the modeling report did not analyze this time period.

Drawdown values taken from Montgomery and Associates Inc. (2010:figure 112); Tetra Tech (2010g:figure 8-12).

Table 58. Modeled groundwater drawdown resulting from mine pit 1,000 years after mine closure

Location	Predicted Drawdown (feet) from Specified Groundwater flow Model Montgomery and Associates Inc. (2010)	Predicted Drawdown (feet) from Specified Groundwater flow Model Tetra Tech (2010g)	Predicted Drawdown (feet) from Specified Groundwater flow Model Myers (2010b)
Rosemont Spring	>100	10 to 100	50 to 100*
Barrel Spring	10 to 100	10 to 100	10 to 50
Reach 2 Spring	<5	<5	<1
Upper Empire Gulch Springs	<5	5 to 10	1 to 10
Davidson/Cienega Confluence	<5	<5	<1
Gardner/Cienega Confluence	<5	<5	1 to 10
Cienega near Stream Gage	<5	<5	<1
Corona de Tucson	<5	<5	<1
Singing Valley Road Residences	10 to 100	10 to 100	10 to 50
Hilton Ranch Road Residences	10 to 100	<5	10 to 50

Notes: Values represent the following model layers: Montgomery (Layer 1), Tetra Tech (Layer 17), Myers (Layers 1 and 4).

Drawdown values taken from Montgomery and Associates Inc. (2010:figure 113); Tetra Tech (2010g:figure 8-13); Myers (2010b:figure A-4).

* Modeling report presents data, but interpretation is unclear on figures.

The impacts resulting from these predicted groundwater level drawdowns on domestic wells, perennial streams, and overall groundwater availability are assessed below. Impacts of these predicted groundwater level drawdowns on springs and seeps are assessed by individual alternative.

Effect on Perennial Streamflow

There are several perennial stream sections within the analysis area for which impacts from groundwater level changes are a concern, as follows:

- Cienega Creek near the confluence with Gardner Canyon
- Cienega Creek near stream gage no. 09484550
- Portions of Cienega Creek just upstream of Davidson Canyon confluence
- Portions of Davidson Canyon from Reach 2 Spring to confluence with Cienega Creek

As with springs, changes to perennial flows in streams are highly dependent on the geological conditions that bring about those perennial flows in the first place. Perennial flow can result from discharge of water from the regional aquifer into the streambed as a result of the intersection of fracture zones or upwelling from regional groundwater flow encountering a flow barrier. Perennial flow can also result from discharge of shallow groundwater that is stored, that is moving subsurface in alluvial stream sediments, and that is forced to the surface by geological conditions, such as bedrock constrictions of the stream channel. In the case of this shallow alluvial groundwater, changes in ephemeral surface flows are more likely to impact perennial flows than changes in regional groundwater levels.

Cienega Creek Streamflow — With respect to Cienega Creek, no surface disturbance from mining facilities is located within the Upper Cienega Creek watershed upstream of the confluence with

Davidson Canyon, so any contribution to perennial flows resulting from stormwater stored in shallow alluvial stream sediments will not be affected. Therefore, in assessing the potential changes to streamflow in Cienega Creek, only the possible interaction with the regional groundwater system is considered.

All three models make a specific analysis of potential changes in Cienega Creek perennial stream flow (Montgomery and Associates Inc. 2010; Myers 2008; Tetra Tech 2010g).

The Tetra Tech Mine Site model analyzed potential changes in Cienega Creek streamflow for 11 different reaches, from the confluence with Gardner Canyon downstream past the confluence with Davidson Canyon. Conceptually, the Tetra Tech model assumes that any stream reach has the potential to be perennial, depending on groundwater levels. Model results indicate that at 1,000 years after mine closure these reaches had the potential for reduction in perennial stream flow of up to 0.09 cubic feet per second, which represents less than 3 percent of simulated average annual base flow (Tetra Tech 2010g:75, figure 8-15).

An earlier version of the Dr. Myers Mine Site model also estimated changes in Cienega Creek streamflow (Myers 2008), although this same estimate was not conducted in the most recent and revised Myers model version. The earlier version of the Dr. Myers Mine Site model indicates that Cienega Creek streamflow could decrease by 1 percent of average annual base flow (Myers 2008:45, figure 31).

The Montgomery Mine Site model estimates not only the possible reduction in perennial base flow along Cienega Creek but also the potential reduction in the length of perennial stream segments. Model results indicate at 1,000 years after mine closure these reaches had the potential for reduction in perennial streamflow of up to 0.02 cubic feet per second, which represents 1 percent of simulated base flow (Montgomery and Associates Inc. 2010:104, table 7). Model results indicate that at 1,000 years after mine closure the perennial stream length could decrease by 0.16 mile, which represents 2.1 percent of the estimated 7.6 miles of observed stream length.

It should be noted that these impacts all assume that Cienega Creek streamflow arises from the regional aquifer and not from storm flow stored in the shallow alluvial aquifer. No specific literature or data were obtained regarding the likely source of Cienega Creek streamflow; however, the assumption that it arises from the regional aquifer is the most conservative approach.

The percent reductions in streamflow predicted by the groundwater flow models are based on estimates of median streamflow from various sources. The natural variation in streamflows will result in greater impacts. Certain times of the year have significantly less flow and therefore could be impacted more by decreases in groundwater levels. Low flows as a result of drought would also result in greater impacts from decreases in groundwater levels.

For example, based on mean monthly streamflows observed at the U.S. Geological Survey stream gage on Cienega Creek near Sonoita between 2001 and 2010, the overall average streamflow was 2 cubic feet per second (the value used to calculate the above percentages). However, the lowest observed streamflow during this period was 0.065 cubic feet per second (June 2010). Seasonally, the lowest mean monthly streamflows tend to occur in May and June, with the mean monthly June streamflow averaging 0.28 cubic feet per second (U.S. Geological Survey 2011). The potential impact during times of extremely low flow is depicted in figure 45. This figure depicts the minimum monthly flow at the U.S. Geological Survey stream gage (09484550) for the period of record from 2001 to 2010, compared with the modeled reduction in base flow from the Montgomery and Tetra Tech Mine

Site models (0.02 cubic feet per second and 0.09 cubic feet per second, respectively). Based on the period 2001 to 2010, the predicted reductions in base flow would have had the potential to remove base flow from some portions of the stream during May and June.

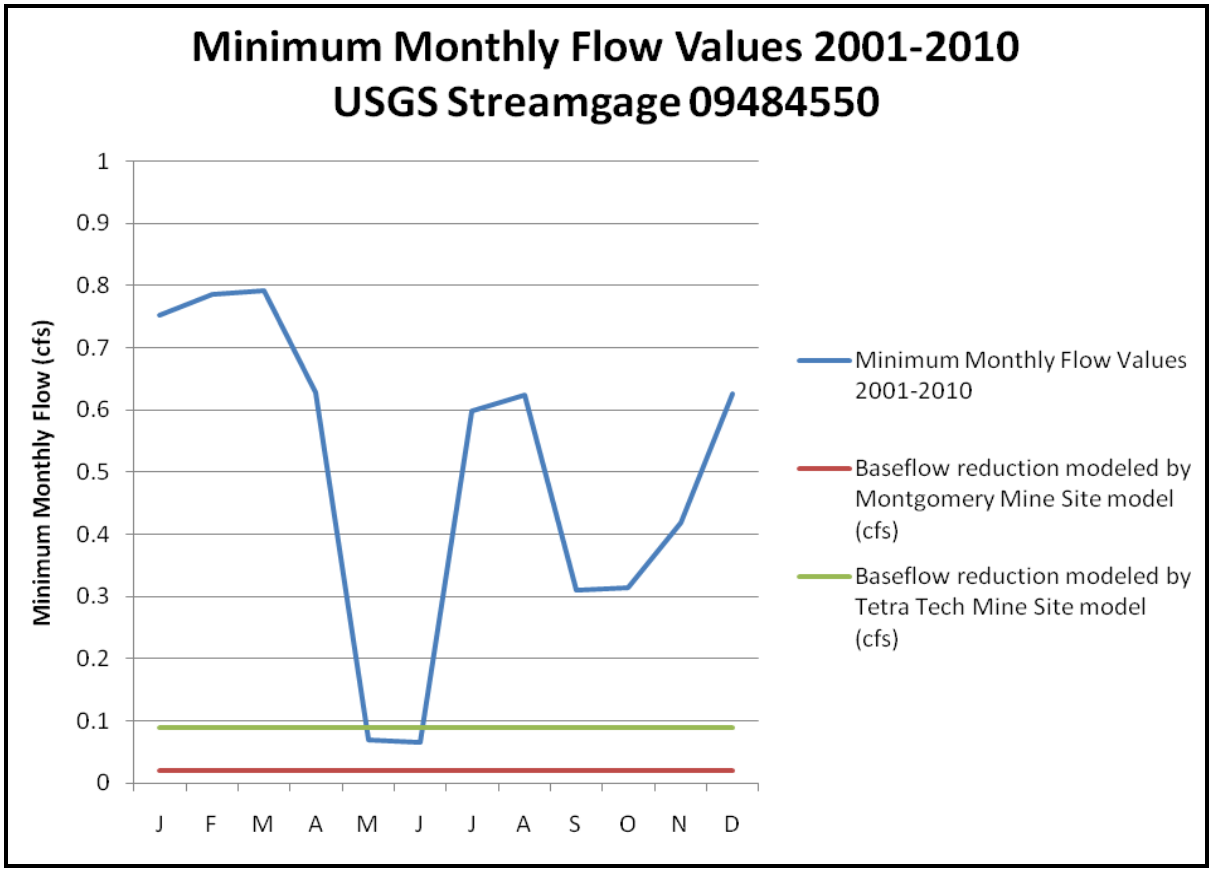


Figure 45. Modeled impact of drawdown on Cienega Creek

Davidson Canyon Streamflow — The Tetra Tech Mine Site model also estimated changes to streamflow in six reaches of Davidson Canyon, from approximately the confluence of Barrel Canyon downstream to the confluence with Cienega Creek. The model makes the assumption that streamflow could be fed from the regional aquifer and predicts a change in flow of up to 0.01 cubic feet per second (Tetra Tech 2010g:75, figure 8-15). This amount was considered to be within the margin of error of the model.

However, a more detailed hydrogeologic analysis of Davidson Canyon was conducted by Tetra Tech specifically to assess potential impacts to streamflow and springs within Davidson Canyon. Rather than modeling, this study focused on assessing observed field data in order to qualitatively determine likely impacts to perennial stream flow in lower Davidson Canyon (Tetra Tech 2010a). Based on water quality data, geological mapping and reconnaissance, observed groundwater levels, and observed flow data, Tetra Tech (2010a) drew several conclusions about the source of the perennial reach that begins at Reach 2 Spring and persists intermittently to the confluence of Cienega Creek. The Tetra Tech (2010a) report concludes that it is most likely that Reach 2 Spring (as well as Escondido Spring, which is closer to the confluence with Cienega Creek) derives its water from

ephemeral storm flows stored subsurface in the shallow alluvial stream sediments, which are then forced to the surface by bedrock constrictions of the stream channel.

These conclusions are based on several lines of evidence. Geological conditions were observed that would be conducive to forcing shallow alluvial water to the surface in the locations of Reach 2 and Escondido Springs. In addition, isotope signatures of water from Reach 2 Spring and Escondido Spring both reflect the influence of summer precipitation, in contrast to wells in the regional aquifer that reflect the influence of winter precipitation. Finally, this stretch of Davidson Canyon has actually been dry during the last few years, rather than being supported by perennial flow as would be expected from a more constant deep groundwater source.

Modeling of changes in ephemeral surface runoff as a result of the mine activities has been conducted (Krizek 2010a, 2010b, 2010c, 2010d), with an estimate that flows near the outflow of Barrel Canyon will decrease by approximately 23 to 46 percent, depending on the alternative, as a result of capture of runoff by mine facilities. This change in streamflow becomes less with distance downstream. Under the proposed action, the reduction in ephemeral stream flow in the reach of Davidson Canyon where Reach 2 Spring and Escondido Spring occur is predicted to be approximately 10 percent, based on modeling using regression equations (Zeller 2011).

This reduction in ephemeral flows would persist through mine closure and during the initial stages of reclamation when stormwater controls and retention ponds are still operations. Ephemeral flow would recover once natural surface flow is fully reestablished from reclaimed areas; however, the area of the mine pit would no longer contribute flow to the watershed, and some reduction in ephemeral flows would persist in perpetuity.

Owing to the uncertainty associated with the source of water to the Davidson Canyon springs, additional modeling was also conducted assuming the springs arise from the regional aquifer instead of ephemeral stream flow. Similar to the analysis of Cienega Creek, the Montgomery Mine Site model estimates the possible reduction in perennial base flow along Davidson Canyon as well as the potential reduction in the length of perennial stream segments and also assumes that perennial streamflow arises from the regional aquifer. Model results indicate that at 1,000 years after mine closure these reaches had the potential for reduction in perennial streamflow of up to 0.04 cubic feet per second (Montgomery and Associates Inc. 2010 :104, table 7). Model results indicate that at 1,000 years after mine closure the perennial stream length in Davidson Canyon could decrease by 0.29 mile, which represents 41 percent of the estimated 0.7 mile of observed stream length. Again, it should be noted that this assumes the flow in Davidson Canyon is directly connected to the regional aquifer.

Summary of Impacts to Streamflow

- Based on modeling by Montgomery and Associates Inc. (2010), Tetra Tech (2010g), and Myers (2008), at a point 1,000 years after closure of the mine, average annual perennial stream flow within Cienega Creek, if arising from the regional groundwater aquifer, could decrease by 1 to 3 percent. Based on modeling by Montgomery and Associates Inc. (2010), perennial stream length could decrease up to 2.1 percent of the observed 7.6-mile length of perennial stream. These impacts would persist in perpetuity. Impacts would be greater when consideration is given to seasonal lows or drought cycles.
- Based on field investigations by Tetra Tech (2010a), the source of water for lower Davidson Canyon, starting at Reach 2 Spring, is most likely ephemeral storm flow stored and moving subsurface in shallow alluvial stream sediments. These ephemeral flows, and by extension

the groundwater feeding Reach 2 Spring, have been modeled to decrease by 10 percent as a result of mine activities. These impacts would lessen following mine closure, but a portion of these impacts would persist in perpetuity.

- If the source of flow in Davidson Canyon instead is the regional aquifer, then flow in Davidson Canyon at a point 1,000 years after closure of the mine is estimated to decrease by 0.01 to 0.04 cubic feet per second (Montgomery and Associates Inc. 2010; Tetra Tech 2010g). Perennial stream length could decrease by up to 41 percent of the observed 0.7-mile length of the perennial stream. If the source of flow in Davidson Canyon is the regional aquifer, these impacts would persist in perpetuity.

These results can be used to estimate the effect of these flow reductions on the current uses of Cienega Creek and Davidson Canyon and their designation as Outstanding Arizona Waters. With respect to Cienega Creek, the average estimated reductions in flow (1 to 3 percent) and reduction in perennial stream length (2.1 percent) are minor and would not be expected to affect existing uses or its designation as an Outstanding Arizona Water. However, on a seasonal basis these impacts would be much greater. With respect to Davidson Canyon, the impacts are strongly dependent on where the source of water arises. The most comprehensive study available (Tetra Tech 2010a) uses multiple lines of evidence that suggest the streamflow arises not from interaction with the regional aquifer, but from storm flow stored and moving subsurface in shallow alluvial sediments. Under this scenario, the estimated reduction in flow would be 10 percent, which could have noticeable but minor impacts on current uses and designation as an Outstanding Arizona Water. If flow in Davidson Canyon arises instead from the regional aquifer, the estimated reduction in flow would be substantially greater, with a decrease of up to 41 percent of the observed 0.7-mile length of the perennial stream.

Uncertainty of Streamflow Modeling

There is significant uncertainty associated with the modeled impacts to both Cienega Creek and Davidson Canyon. This uncertainty is associated with the conceptual hydrologic framework, the time frame involved, and the magnitude of the modeled impact.

- Conceptual hydrologic framework. While modeled as one large regional aquifer, the hydrologic connection between the fractured bedrock aquifer that will be dewatered during mine operations and by evaporation from the mine pit lake, and the basin fill aquifer through which Cienega Creek flows, is poorly understood. Modeled impacts could be either less or more, depending on the nature of the hydrologic connection between these two aquifers, and the nature of the connection of Cienega Creek with the basin fill aquifer.
- Time frames. The modeled reductions in base flow described above are predicted to occur 1,000 years in the future. The farther into the future modeling is conducted, the greater the potential that small variations in modeling parameters can result in large errors in prediction. While modeling was conducted to 1,000 years in order to allow the aquifer to come to equilibrium, impacts predicted over this long time frame are speculative. Impacts to streamflow are less speculative for shorter modeled time frames. Impacts for shorter time frames are summarized in Table 59. No impacts are modeled to occur until approximately 50 years after closure of the mine. Impacts over this time frame are more reasonably predicted by the groundwater models. Impacts modeled at 150 years to 1,000 years into the future are much more uncertain.
- Magnitude of impact. The amounts of drawdown that would result in this reduction are extremely small, and in fact are smaller than the margin of error for the models. For instance, the Montgomery Mine Site model predicts a drawdown less than 0.01 foot; this same

threshold was used as the convergence criteria for the model. This means that changes in water level less than 0.01 foot were considered irrelevant to the model solution. The modeled results must be placed in context of the uncertainty associated with such small values.

Table 59. Modeled impacts to Cienega Creek over time

Modeled Time Frame	Reduction in Streamflow (cfs) Modeled by Montgomery Mine Site Model (Montgomery & Associates Inc. 2010)	Reduction in Streamflow (cfs) Modeled by Tetra Tech Mine Site Model (O'Brien 2011)
End of Mine Life	0	0
20 Years after Mine	0	0
50 Years after Mine	0	0.01
150 Years after Mine	0	0.04
1,000 Years after Mine	0.02	0.09

Effect on Riparian Vegetation

Riparian vegetation would be affected by reductions in both surface flow and groundwater levels. Effects on riparian vegetation are fully discussed in the “Biological Resources” section of the DEIS.

Effect on Well Owners

Groundwater drawdowns of 10 to 100 feet are modeled to occur in the vicinity of the residential neighborhood along Singing Valley Road west of State Route 83 and Hilton Ranch Road east of State Route 83. Little is known about the domestic wells in these areas, but groundwater availability is highly likely to be affected by the drawdown from the mine pit.

Approximately 500 to 550 domestic or other production wells registered with the Arizona Department of Water Resources could be impacted by drawdown in groundwater levels over 10 feet; approximately 95 percent of these are smaller domestic, stock, or exempt wells. Note that this is not considered a comprehensive inventory of wells in the area, nor are there adequate well construction and operation details to determine whether this drawdown would impact well performance.

Effect on Overall Groundwater Availability

The mine pit would be actively pumped during the active mining phase and then would act as a hydraulic sink to the regional aquifer in perpetuity. When equilibrium is reached, the loss of water from the aquifer as a result of the pit is estimated to be anywhere from 104 gallons per minute (Montgomery and Associates Inc. 2010) to 230 gallons per minute (Tetra Tech 2010g). This amount represents the maximum amount of water that would enter the mine pit, eventually evaporate, and be lost to the overall aquifer, thereby being unavailable to supply perennial flows and evapotranspiration, or being unavailable as groundwater outflow from the watershed. During active mining, the loss of water would be greater, approximately 300 to 550 gallons per minute.

During mining, these rates indicate that the loss of water from the groundwater basin forming the Davidson Canyon/Cienega Creek Basin as a result of active mining and dewatering would be approximately 480 to 900 acre-feet per year. At equilibrium, these rates indicate that the loss of water from the groundwater basin as a result of the mine pit lake would be approximately 170 to 370 acre-feet per year. During mining this amount would represent a loss equivalent to 5 to 14 percent of the

current basin recharge and would represent an increase in water loss from the aquifer of 9 to 75 percent. After closure, when the aquifer reaches equilibrium, this amount would represent a loss equivalent to 2 to 5 percent of the current basin recharge and would represent an increase in evaporative water loss from the aquifer of 3 to 31 percent, as shown in table 60.

Table 60. Comparison of equilibrium loss of water availability by pit lake

Component of Water Balance	Estimate Under Premining Conditions (acre-feet per year)*	Equilibrium Water Loss from Pit Lake (acre-feet per year)	Equilibrium Water Loss Percentage of Water Balance Component	Source
Recharge from Precipitation	6,500 to 9,900	170 to 370	2 to 5	Montgomery and Associates Inc. (2010), Tetra Tech (2010g); Myers (2010b)
Evapotranspiration	1,200 to 5,600	170 to 370	3 to 31	Montgomery and Associates Inc. (2010), Tetra Tech (2010g); Myers (2010b)
Pumpage	400 to 500	170 to 370		Montgomery and Associates Inc. (2010)

* Note that geographic areas differ for various estimates, as detailed in Table 49.

Effect on Mountain-Front Recharge

Mountain-front recharge is a component of the hydrologic system in which precipitation falling on relatively impermeable mountain ranges concentrates into stream channels, which then infiltrate into the ground and recharge aquifers when they reach permeable alluvial fans or basin fill deposits. Because the mine pit cuts off part of the mountain front, mountain-front recharge capabilities would be affected.

The reduction in mountain-front recharge owing to capture by the mine pit lake, as well as falling on the tailings and waste rock piles, which will have stormwater controls, was estimated to be approximately 73 acre-feet per year at the end of active mining; this represents an approximate 1 percent reduction in the estimated 1,102 acre-feet of mountain-front recharge (Montgomery and Associates Inc. 2010).

Effect on Groundwater Discharge from Davidson Canyon

Groundwater discharge from Davidson Canyon to the Cienega Creek drainage potentially supports downstream flow in Cienega Creek, although details of this hydrogeologic connection are not fully analyzed in any of the modeling reports. Two potential impacts to groundwater discharge could occur: (1) from reductions in flow as a result of drawdown in the regional aquifer; and (2) from reductions in shallow groundwater moving through the alluvial stream sediments.

Myers (2010b) estimates the potential reduction in Davidson Canyon discharge as a result of drawdown in the regional aquifer to be 6.4 percent. Reductions in shallow groundwater in alluvial stream sediments, as described above, could be between 4 and 8 percent, based on expected reductions in ephemeral flows from the Barrel Canyon drainage. However, portions of this groundwater are likely lost to evapotranspiration in the riparian areas of Davidson Canyon downstream of the Reach 2 Spring.

Proposed Action Alternative

Effect on Springs and Seeps

The specific impacts to springs and seeps depend on whether they obtain water from local recharged precipitation, water flowing through the regional aquifer intersecting or forced to the surface, or storm flows stored in alluvial sediments and forced to the surface by geological conditions. An assessment of the likely source of different springs is presented by Tetra Tech (2010a). The estimated impacts to springs and seeps, along with the rationale for this assessment, are presented in table 61. Direct impacts refer to springs that are within the footprint of an action alternative and would likely be disturbed, covered, or otherwise removed and would no longer function as a natural spring. Indirect impacts refer to springs that would not be physically disturbed but that may experience changes in hydrology as a result of groundwater level declines.

Table 61. Estimated impacts to springs and seeps as a result of proposed action alternative

Name of Spring	Directly Impacted	Likelihood of Indirect Impact	Rationale for Indirect Impact
Bee Spring	Yes	NA	NA
Deering Spring	Yes	NA	NA
McCleary Dam	Yes	NA	NA
McCleary No. 1	Yes	NA	NA
McCleary No. 2	Yes	NA	NA
Mueller Spring	Yes	NA	NA
Peligro Adit	Yes	NA	NA
Rosemont Spring	Yes	NA	NA
Unnamed Spring No. 2	Yes	NA	NA
Unnamed Spring No. 3	Yes	NA	NA
Unnamed Spring No. 5	Yes	NA	NA
Unnamed Spring No. 6 (Possibly same as McCleary No. 2)	Yes	NA	NA
Barrel Spring	No	Unlikely	Water source likely local and disconnected from regional aquifer (Tetra Tech 2010a); springs are not in proximity to pit
Basin Spring	No	Unlikely	Based on field reconnaissance, spring is likely not a perennial feature, and is more likely local and disconnected from the regional aquifer (WestLand Resources Inc. 2011c)
Batamout Spring	No	Unlikely	Based on field reconnaissance, spring is likely not a perennial feature, and is more likely local and disconnected from the regional aquifer (WestLand Resources Inc. 2011c)
Big Spring	No	Unlikely	Based on field reconnaissance, spring is likely not a perennial feature, and is more likely local and disconnected from the regional aquifer (WestLand Resources Inc. 2011c)
Bowman Spring	No	Possible	Water source unknown; if connected to regional aquifer, would experience drawdowns up to 10 to 100 feet (Montgomery and Associates Inc. 2010; Myers 2010b; Tetra Tech 2010g)
Box Canyon Spring	No	Unlikely	Based on field reconnaissance, spring is likely not a perennial feature, and is more likely local and disconnected from the regional aquifer (WestLand Resources Inc. 2011c)

Name of Spring	Directly Impacted	Likelihood of Indirect Impact	Rationale for Indirect Impact
California Mine Spring	No	Possible	Water source unknown; if connected to regional aquifer, would experience drawdowns up to <5 to 100 feet (Montgomery and Associates Inc. 2010; Myers 2010b; Tetra Tech 2010g)
Chavez Spring	No	Possible	Water source unknown; if connected to regional aquifer, would experience drawdowns up to 10 to 100 feet (Montgomery and Associates Inc. 2010; Myers 2010b; Tetra Tech 2010g)
Cow Spring	No	Possible	Water source unknown; if connected to regional aquifer, would experience drawdowns up to <5 to 10 feet (Montgomery and Associates Inc. 2010; Myers 2010b; Tetra Tech 2010g)
Crucero Spring	No	Unlikely	Water source likely local and disconnected from regional aquifer (Tetra Tech 2010a); springs are not in proximity to pit
Dam Spring	No	Possible	Water source unknown; if connected to regional aquifer, would experience drawdowns up to 10 to 100 feet (Montgomery and Associates Inc. 2010; Myers 2010b; Tetra Tech 2010g)
Davidson Spring†	No	Unlikely	Source of flow is likely from Empire Mountains and disconnected from Davidson Canyon (Tetra Tech 2010a)
Diesler Spring	No	Possible	Water source unknown; if connected to regional aquifer, would experience drawdowns >100 feet (Montgomery and Associates Inc. 2010; Myers 2010b; Tetra Tech 2010g)
Double Spring	No	Unlikely	Based on field reconnaissance, spring is likely not a perennial feature, and is more likely local and disconnected from the regional aquifer (WestLand Resources Inc. 2011c)
Escondido†	No	Minor	Source of flow is likely shallow stream bed alluvium (Tetra Tech 2010a), and 10 percent reduction in ephemeral flows is estimated in Davidson Canyon. If connected to regional aquifer, would experience drawdown <5 feet (Montgomery and Associates Inc. 2010; Myers 2010b; Tetra Tech 2010g)
Feliz Spring	No	Possible	Water source unknown; if connected to regional aquifer, would experience drawdowns >100 feet (Montgomery and Associates Inc. 2010; Myers 2010b; Tetra Tech 2010g)
Fence Spring	No	Possible	Water source unknown; if connected to regional aquifer, would experience drawdowns up to 5 to 10 feet (Montgomery and Associates Inc. 2010; Myers 2010b; Tetra Tech 2010g)
Fig Tree Spring	No	Major	Water source uncertain, but reduction in flow likely regardless of source because of proximity to pit (Tetra Tech 2010a)
Grader Spring	No	Unlikely	Based on field reconnaissance, spring is likely not a perennial feature, and is more likely local and disconnected from the regional aquifer (WestLand Resources Inc. 2011c)
Heiter Spring	No	Unlikely	Based on field reconnaissance, spring is likely not a perennial feature, and is more likely local and disconnected from the regional aquifer (WestLand Resources Inc. 2011c)
Helvetia Spring	No	Major	Water source is most likely from regional aquifer (Tetra Tech 2010a); drawdown in water level up to 10 to 100 feet likely (Montgomery and Associates Inc. 2010; Myers 2010b; Tetra Tech 2010g)

Name of Spring	Directly Impacted	Likelihood of Indirect Impact	Rationale for Indirect Impact
Hilton Spring	No	Possible	Water source unknown; if connected to regional aquifer, would experience drawdowns up to <5 to 100 feet (Montgomery and Associates Inc. 2010; Myers 2010b; Tetra Tech 2010g)
Hole Seep Spring	No	Possible	Water source unknown; if connected to regional aquifer, would experience drawdowns up to 10 to >100 feet (Montgomery and Associates Inc. 2010; Myers 2010b; Tetra Tech 2010g)
Horse Pasture Spring	No	Unlikely	Based on field reconnaissance, spring is likely not a perennial feature, and is more likely local and disconnected from the regional aquifer (WestLand Resources Inc. 2011c)
HQ Water Spring	No	Unlikely	Based on field reconnaissance, spring is likely not a perennial feature, and is more likely local and disconnected from the regional aquifer (WestLand Resources Inc. 2011c)
Indian Spring	No	Possible	Water source unknown; if connected to regional aquifer, would experience drawdowns up to 10 to 100 feet (Montgomery and Associates Inc. 2010; Myers 2010b; Tetra Tech 2010g)
La Cholla Spring	No	Possible	Water source unknown; if connected to regional aquifer, would experience drawdowns up to 10 to 100 feet (Montgomery and Associates Inc. 2010; Myers 2010b; Tetra Tech 2010g)
Lazy Boy Spring	No	Unlikely	Based on field reconnaissance, spring is likely not a perennial feature, and is more likely local and disconnected from the regional aquifer (WestLand Resources Inc. 2011c)
Little Indian Spring	No	Possible	Water source unknown; if connected to regional aquifer, would experience drawdowns up to 10 to 100 feet (Montgomery and Associates Inc. 2010; Myers 2010b; Tetra Tech 2010g)
Locust Spring	No	Major	Water source uncertain, but reduction in flow likely, regardless of source, because of proximity to pit (Tetra Tech 2010a)
Lower Mulberry Spring	No	Unlikely	Water source likely local and disconnected from regional aquifer (Tetra Tech 2010a); springs are not in proximity to pit
Lower Spring	No	Unlikely	Based on field reconnaissance, spring is likely not a perennial feature, and is more likely local and disconnected from the regional aquifer (WestLand Resources Inc. 2011c)
Melon Spring	No	Unlikely	Based on field reconnaissance, spring is likely not a perennial feature, and is more likely local and disconnected from the regional aquifer (WestLand Resources Inc. 2011c)
Mesquite Flat Spring	No	Possible	Water source unknown; if connected to regional aquifer, would experience drawdowns up to 10 to 100 feet (Montgomery and Associates Inc. 2010; Myers 2010b; Tetra Tech 2010g)
Mine Water Spring	No	Unlikely	Based on field reconnaissance, spring is likely not a perennial feature, and is more likely local and disconnected from the regional aquifer (WestLand Resources Inc. 2011c)
Mudhole Spring	No	Possible	Water source unknown; if connected to regional aquifer, would experience drawdowns up to 10 to >100 feet (Montgomery and Associates Inc. 2010; Myers 2010b; Tetra Tech 2010g)

Name of Spring	Directly Impacted	Likelihood of Indirect Impact	Rationale for Indirect Impact
Mulberry Spring	No	Unlikely	Water source likely local and disconnected from regional aquifer (Tetra Tech 2010a); springs are not in proximity to pit
Oak Spring	No	Possible	Water source unknown; if connected to regional aquifer, would experience drawdowns up to 10 to >100 feet (Montgomery and Associates Inc. 2010; Myers 2010b; Tetra Tech 2010g)
Ojo Blanco Spring	No	Possible	Water source unknown; if connected to regional aquifer, would experience drawdowns up to 10 to 100 feet (Montgomery and Associates Inc. 2010; Myers 2010b; Tetra Tech 2010g)
Papago Spring	No	Unlikely	Water source likely local and disconnected from regional aquifer (Tetra Tech 2010a); springs are not in proximity to pit
Papago Spring (No. 2)	No	Possible	Water source unknown; if connected to regional aquifer, would experience drawdowns up to 10 to 100 feet (Montgomery and Associates Inc. 2010; Myers 2010b; Tetra Tech 2010g)
Pole Cat Spring	No	Unlikely	Based on field reconnaissance, spring is likely not a perennial feature, and is more likely local and disconnected from the regional aquifer (WestLand Resources Inc. 2011c)
Proctor Box Spring	No	Unlikely	Based on field reconnaissance, spring is likely not a perennial feature, and is more likely local and disconnected from the regional aquifer (WestLand Resources Inc. 2011c)
Proctor Spring	No	Possible	Water source unknown; if connected to regional aquifer, would experience drawdowns up to 10 to 100 feet (Montgomery and Associates Inc. 2010; Myers 2010b; Tetra Tech 2010g)
Questa Spring	No	Major	Water source is most likely from regional aquifer (Tetra Tech 2010a); drawdown in water level up to 10 to 100 feet likely (Montgomery and Associates Inc. 2010; Myers 2010b; Tetra Tech 2010g)
Rock Spring	No	Possible	Water source unknown; if connected to regional aquifer, would experience drawdowns up to 10 to 100 feet (Montgomery and Associates Inc. 2010; Myers 2010b; Tetra Tech 2010g)
Ruelas Spring	No	Major	Water source uncertain, but reduction in flow likely regardless of source because of proximity to pit (Tetra Tech 2010a)
Ruelas Spring Number Two and Three	No	Possible	Water source unknown; if connected to regional aquifer, would experience drawdowns up to 10 to >100 feet (Montgomery and Associates Inc. 2010; Myers 2010b; Tetra Tech 2010g)
Rust Spring	No	Possible	Water source unknown; if connected to regional aquifer, would experience drawdowns up to 10 to 100 feet (Montgomery and Associates Inc. 2010; Myers 2010b; Tetra Tech 2010g)
Scholefield No. 1	No	Unlikely	Water source likely local and disconnected from regional aquifer (Tetra Tech 2010a); springs are not in proximity to pit
Scholefield No. 2	No	Unlikely	Water source likely local and disconnected from regional aquifer (Tetra Tech 2010a); springs are not in proximity to pit

Name of Spring	Directly Impacted	Likelihood of Indirect Impact	Rationale for Indirect Impact
Scholefield No. 3	No	Possible	Water source unknown; if connected to regional aquifer, would experience drawdowns up to 10 to 100 feet (Montgomery and Associates Inc. 2010; Myers 2010b; Tetra Tech 2010g)
Shamrod Spring	No	Possible	Water source unknown; if connected to regional aquifer, would experience drawdowns up to 10 to 100 feet (Montgomery and Associates Inc. 2010; Myers 2010b; Tetra Tech 2010g)
Siphon Spring	No	Possible	Water source unknown; if connected to regional aquifer, would experience drawdowns up to 10 to 100 feet (Montgomery and Associates Inc. 2010; Myers 2010b; Tetra Tech 2010g)
Soldier Spring	No	Possible	Water source unknown; if connected to regional aquifer, would experience drawdowns up to 10 to >100 feet (Montgomery and Associates Inc. 2010; Myers 2010b; Tetra Tech 2010g)
SS-2	No	Possible	Water source unknown; if connected to regional aquifer, would experience drawdowns up to 10 to 100 feet (Montgomery and Associates Inc. 2010; Myers 2010b; Tetra Tech 2010g)
Sulfur Spring	No	Unlikely	Based on field reconnaissance, spring is likely not a perennial feature, and is more likely local and disconnected from the regional aquifer (WestLand Resources Inc. 2011c)
SW	No	Major	Water source uncertain, but reduction in flow likely regardless of source because of proximity to pit (Tetra Tech 2010a)
Sycamore Spring	No	Possible	Water source unknown; if connected to regional aquifer, would experience drawdowns up to 10 to 100 feet (Montgomery and Associates Inc. 2010; Myers 2010b; Tetra Tech 2010g)
Tree Spring	No	Possible	Water source unknown; if connected to regional aquifer, would experience drawdowns up to 10 to 100 feet (Montgomery and Associates Inc. 2010; Myers 2010b; Tetra Tech 2010g)
Tub Spring	No	Possible	Water source unknown; if connected to regional aquifer, would experience drawdowns up to 10 to 100 feet (Montgomery and Associates Inc. 2010; Myers 2010b; Tetra Tech 2010g)
Tunnel Spring	No	Possible	Water source unknown; if connected to regional aquifer, would experience drawdowns up to 10 to 100 feet (Montgomery and Associates Inc. 2010; Myers 2010b; Tetra Tech 2010g)
Tunnel Spring #2	No	Possible	Water source unknown; if connected to regional aquifer, would experience drawdowns up to 5 to 100 feet (Montgomery and Associates Inc. 2010; Myers 2010b; Tetra Tech 2010g)
Unnamed Spring (Reach 2)[†]	No	Minor	Source of flow is likely shallow stream bed alluvium (Tetra Tech 2010a), and 10% reduction in ephemeral flows is estimated in Davidson Canyon. If connected to regional aquifer, would experience drawdown <5 feet (Montgomery and Associates Inc. 2010; Myers 2010b; Tetra Tech 2010g)
Unnamed Spring No. 1	No	Possible	Water source unknown; if connected to regional aquifer, would experience drawdowns up to 10 to 100 feet (Montgomery and Associates Inc. 2010; Myers 2010b; Tetra Tech 2010g)

Name of Spring	Directly Impacted	Likelihood of Indirect Impact	Rationale for Indirect Impact
Unnamed Spring No. 13	No	Possible	Water source unknown; if connected to regional aquifer, would experience drawdowns up to 10 to 100 feet (Montgomery and Associates Inc. 2010; Myers 2010b; Tetra Tech 2010g)
Unnamed Spring No. 14	No	Possible	Water source unknown; if connected to regional aquifer, would experience drawdowns up to 10 to >100 feet (Montgomery and Associates Inc. 2010; Myers 2010b; Tetra Tech 2010g)
Unnamed Spring No. 16	No	Unlikely	Based on field reconnaissance, spring is likely not a perennial feature, and is more likely local and disconnected from the regional aquifer (WestLand Resources Inc. 2011c)
Unnamed Spring No. 17	No	Possible	Water source unknown; if connected to regional aquifer, would experience drawdowns up to 10 to 100 feet (Montgomery and Associates Inc. 2010; Myers 2010b; Tetra Tech 2010g)
Unnamed Spring No. 18	No	Possible	Water source unknown; if connected to regional aquifer, would experience drawdowns up to 10 to >100 feet (Montgomery and Associates Inc. 2010; Myers 2010b; Tetra Tech 2010g)
Unnamed Spring No. 19	No	Possible	Water source unknown; if connected to regional aquifer, would experience drawdowns up to 10 to >100 feet (Montgomery and Associates Inc. 2010; Myers 2010b; Tetra Tech 2010g)
Unnamed Spring No. 20	No	Possible	Water source unknown; if connected to regional aquifer, would experience drawdowns up to 10 to 100 feet (Montgomery and Associates Inc. 2010; Myers 2010b; Tetra Tech 2010g)
Unnamed Spring No. 21	No	Possible	Water source unknown; if connected to regional aquifer, would experience drawdowns up to 10 to 100 feet (Montgomery and Associates Inc. 2010; Myers 2010b; Tetra Tech 2010g)
Unnamed Spring No. 22	No	Unlikely	Based on field reconnaissance, spring is likely not a perennial feature, and is more likely local and disconnected from the regional aquifer (WestLand Resources Inc. 2011c)
Unnamed Spring No. 23	No	Possible	Water source unknown; if connected to regional aquifer, would experience drawdowns up to 10 to 100 feet (Montgomery and Associates Inc. 2010; Myers 2010b; Tetra Tech 2010g)
Unnamed Spring No. 24	No	Unlikely	Based on field reconnaissance, spring is likely not a perennial feature, and is more likely local and disconnected from the regional aquifer (WestLand Resources Inc. 2011c)
Unnamed Spring No. 4	No	Unlikely	Based on field reconnaissance, spring is likely not a perennial feature, and is more likely local and disconnected from the regional aquifer (WestLand Resources Inc. 2011c)
Unnamed Spring No.12	No	Possible	Water source unknown; if connected to regional aquifer, would experience drawdowns up to <5 to 100 feet (Montgomery and Associates Inc. 2010; Myers 2010b; Tetra Tech 2010g)
Upper Empire Gulch Spring†	No	Possible	Water source unknown; if connected to regional aquifer, would experience drawdowns from <1 feet (Myers 2010b) to 5 feet (Montgomery and Associates Inc. 2010; Tetra Tech 2010g)

Name of Spring	Directly Impacted	Likelihood of Indirect Impact	Rationale for Indirect Impact
Water Develop Spring	No	Possible	Water source unknown; if connected to regional aquifer, would experience drawdowns up to 10 to 100 feet (Montgomery and Associates Inc. 2010; Myers 2010b; Tetra Tech 2010g)
Wood Spring	No	Unlikely	Based on field reconnaissance, spring is likely not a perennial feature, and is more likely local and disconnected from the regional aquifer (WestLand Resources Inc. 2011c)
Zackendorf Spring	No	Possible	Water source unknown; if connected to regional aquifer, would experience drawdowns up to 10 to 100 feet (Montgomery and Associates Inc. 2010; Myers 2010b; Tetra Tech 2010g)

Notes:
Major – Reduction in flow can be estimated with high certainty and would impact resource function.
Minor – Reduction in flow can be estimated with high certainty but may not impact resource function.
Possible – Reduction in flow could occur, but uncertainty exists as to source of water.
Unlikely – Reduction in flow is unlikely to occur.

Of the 132 springs or seeps listed in table 50, 18 are expected to have major impacts; these springs are likely to be directly impacted by the surface disturbance (12 springs) or have reduction in flow severe enough to impact their function as a resource as a result of predicted drawdown in the aquifer from the mine pit (6 springs). Two springs (Reach 2 and Escondido) are expected to have minor impacts, with expected 10 percent reductions in flow from reduced ephemeral stream flow, although if these springs are connected to the regional aquifer, greater impacts could occur. Another 45 springs or seeps possibly could be impacted by reductions in groundwater level if fed from the regional aquifer, but the source of water is unknown. Twenty-nine springs are unlikely to be impacted because of their distance from the pit and local sources of recharge. In all, 63 springs are likely to have impacts to their function as a resource (directly impacted, or indirect impacts categorized as major or possible).

Phased Tailings Alternative

The estimated impacts to springs and seeps for the Phased Tailings Alternative are identical to those for the proposed action alternative.

Barrel Alternative

The estimated impacts to springs and seeps for the Barrel Alternative are identical to those for the proposed action alternative.

Barrel Trail Alternative

The estimated impacts to springs and seeps for the Barrel Trail Alternative are identical to those for the proposed action alternative.

Scholefield-McCleary Alternative

The Scholefield-McCleary Alternative is estimated to be identical to the proposed action alternative, with the following exceptions: Deering Spring is not expected to be directly impacted but rather would be indirectly impacted, and there are six additional springs directly impacted. The indirect

impact to Deering Spring is categorized as major. The water source for this spring is uncertain, but reduction in flow is likely regardless of source because of proximity to the pit.

The six additional springs directly impacted by the Scholefield-McCleary Alternative are Papago Spring No.2, HQ Water Spring, Scholefield Nos. 1, 2, and 3, Water Develop Spring, Wood Spring and Unnamed Spring No. 14. Under the proposed action, Papago Spring No. 2, Scholefield No. 3, Water Develop Spring and Unnamed Spring No. 14 were considered to have a possible indirect impact, and HQ Water Spring, Scholefield No. 1, Scholefield No. 2, and Wood Spring were considered unlikely to be indirectly impacted from groundwater level declines. Overall, for the Scholefield-McCleary Alternative, 67 springs are likely to have impacts to their function as a resource (directly impacted, or indirect impacts categorized as major or possible).

Cumulative Effects

The Council on Environmental Quality defines a cumulative impact as “the impact on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable actions regardless of what agency (federal or nonfederal) or person undertakes such other actions” (40 Code of Federal Regulations 1508.7). As outlined in the chapter 3 introduction, cumulative impacts of past and present actions are identified and analyzed in the “Affected Environment” part of each resource section, including for “Groundwater Quantity.” 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 chapter 3 introduction. The following reasonably foreseeable actions from that list were determined to contribute to a cumulative impact to groundwater quantity:

- Delivery and recharge of groundwater with water from the Central Arizona Project in the Green Valley area by the Community Company of Green Valley
- Extension of Central Arizona Project water into Farmers Investment Company actively farmed pecan groves and activation of groundwater storage facility
- Anticipated increase in demand for groundwater in the Sahuarita area by 200 percent in year 2030
- Expansion of limestone quarries in the Davidson Canyon drainage system north and northeast of the Santa Rita Mountains

Community Water Company of Green Valley is currently planning potential Central Arizona Project water delivery and recharge in the Green Valley area. The amount and location of storage is unknown, although Community Water Company currently holds a Central Arizona Project subcontract for 2,858 acre-feet of water. Environmental documentation necessary to build the pipeline was completed by the U.S. Bureau of Reclamation in July 2010.

There is a new groundwater storage facility currently permitted by the Arizona Department of Water Resources that would involve the potential extension of Central Arizona Project water use into the Farmers Investment Company actively farmed pecan groves located east of Sahuarita.

By 2030 projected deliveries of groundwater in the Sahuarita area will almost double, and private wells will likewise double their groundwater withdrawal. Two specific large-scale projects have been identified and were used in the modeling. However, it should be noted that these projects are dependent on housing market conditions, which are currently poor. The status of these projects is therefore unknown at this time.

- Arizona State Land Department – Sahuarita Area Conceptual Plan. Arizona State Land Department has submitted an application for an Analysis of Assured Water Supply to the Arizona Department of Water Resources for a total committed demand of approximately 15,000 acre-feet per year on state lands that are in the immediate vicinity of the Rosemont Copper planned well field. When submitted, pumping was simulated to begin in 2012, with full build-out reached in 2031.
- Sahuarita Water Company has submitted an application for modification to the Arizona Department of Water Resources to increase their Designation of Assured Water Supply to approximately 11,000 acre-feet per year to accommodate new residential developments. When submitted, pumping was simulated to begin in 2010, with full build-out reached in 2037.

With respect to the projected increase in water use in the Upper Santa Cruz Sub-Basin, these projections were incorporated into the Montgomery Mine Supply model and are already accounted for in the analysis of direct and indirect effects. Specifically, even without mine water supply pumping, groundwater levels in the Upper Santa Cruz Sub-Basin have historically decreased by 1 to 3.5 feet per year and are projected to continue to decrease by 3.5 to 6.5 feet per year. Mine water supply pumping over a 20-year period is projected to increase this rate of drawdown to a total decrease of 5 to 8 feet in groundwater levels per year.

With respect to potential delivery of Central Arizona Project water and recharge of the aquifer, these projects were not incorporated into the Montgomery Mine Supply model, although four other active recharge projects were incorporated. The cumulative effect of these two potential projects would likely reduce the rate of decline in the Upper Santa Cruz Sub-Basin.

Expansion of limestone quarries within Davidson Canyon could result in additional water use in the area. If water were pumped from wells located within or near Davidson Canyon, this water use could increase the amount of drawdown in the regional aquifer and cause additional impacts to riparian vegetation and spring flow in the area.

The withdrawal of groundwater from the Santa Cruz Valley for the mine water supply will contribute to the overall groundwater withdrawal from the Sahuarita area that has resulted in the land subsidence observed in the area. This land subsidence is still active.

Mitigation Effectiveness

There are numerous mitigation measures with respect to groundwater quantity. These include the following.

To the extent possible, diversions to route stormwater efficiently through or around project facilities and to transport runoff water to downstream watersheds will be designed, located, and operated consistent with topography. This is pertinent because the springs downgradient of Davidson Canyon likely have their source from storm flow stored in shallow alluvial sediments.

Rosemont Copper will mitigate the potential effects of mine related pumping on residential water supply wells in the Sahuarita Heights neighborhood by entering into an agreement with the Rosemont United Sahuarita Well Owners. The agreement, which is currently in place, is a legally binding residential well protection plan that has been negotiated and implemented by the United Sahuarita Well Owners group and Rosemont Copper. This well protection plan addresses pump inspection, pump maintenance, pump replacement, well inspection, well maintenance, and well replacement to

ensure that residential water wells in the Sahuarita area remain productive throughout the life of minerals production operations.

Rosemont Copper will implement regional groundwater mitigation measures within the Tucson Active Management Area. The following will be specified in the final MPO, to be approved by the Forest Service before mine construction can begin:

- Use available Central Arizona Project water as a source to conduct recharge within Tucson Active Management Area
- Recharge will occur as close as possible within the Tucson Active Management Area to the Rosemont Copper supply well field in the area of the cone of depression caused by Rosemont Copper water withdrawal.
- To the extent practicable, Central Arizona Project storage credits will be balanced with water to be pumped from mine supply well field, with the intent to maintain a surplus inventory of storage credits prior to pumping groundwater for mineral extraction use.
- Maintain water storage and use inventory records to show that Central Arizona Project recharge credits are balanced against groundwater removed from the Tucson Active Management Area.

For at least 5 years following completion of mining operations, Rosemont Copper will annually fund the U.S. Geological Survey to operate and maintain existing surface water flow measurement gage at Barrel Canyon (09484580).

Rosemont Copper would replace or repair water guzzlers, stock tanks, and other human created water supply structures lost to wildlife or grazing use, whether through direct or indirect project related impacts. The result would be no net loss in the current number of human created water sources for livestock and wildlife. The water source enhancement and mitigation plan would apply to private and public lands contained within Rosemont Copper's Forest Service grazing permits.

With respect to the Upper Santa Cruz Sub-Basin, the mitigation measures are intended to reduce drawdown from pumping as much as possible through recharge and then mitigate remaining effects through the well owner protection program. The extent to which the recharge will be effective at reducing drawdown in the immediate vicinity of the Rosemont Copper pumping is unknown because the exact recharge site is as of yet unknown. Through 2009, 45,000 acre-feet of water have been recharged by Rosemont Copper (15,000 acre-feet per year) at the Pima Mine Road and Avra Valley recharge facilities (Pearce 2010). The Pima Mine Road facility is located within the Upper Santa Cruz Sub-Basin approximately 3 to 4 miles from the mine supply pumping and is within the area expected to be impacted by pumping. However, to date only 600 acre-feet of water has been recharged at the Pima Mine Road facility. The remaining 44,400 acre-feet of water has been recharged at the Avra Valley facility, which, while in the Tucson Active Management Area, is not within the Upper Santa Cruz Sub-Basin or near the mine supply pumping (Pearce 2010). Wherever future recharge occurs, the Tucson Active Management Area as a whole would benefit, but it is unknown whether actual drawdown in the Upper Santa Cruz Sub-Basin would be significantly offset.

The well owner protection program will be effective at mitigating any impacts to well owners near the mine water supply pumping. However, as currently written, this program does not provide a protection measure for well owners who would be impacted outside the agreement area and within the Davidson Canyon/Cienega Basin.

The replacement of improved water sources would be effective at mitigating losses of water for both livestock and wildlife, although some natural unimproved springs would be lost and not replaced.

Irretrievable and Irreversible Commitment of Resources

The proposed action and all action alternatives would result in the same commitment of groundwater quantity resources. In the Upper Santa Cruz Sub-Basin, the resource commitment is limited to the mine water supply withdrawal of approximately 5,400 acre-feet per year for approximately 20 years, for an estimated total withdrawal of 108,000 acre-feet of groundwater. Assuming Central Arizona Project water is available for Rosemont Copper to purchase, there is a commitment from Rosemont Copper to recharge 105 percent of their mine water supply withdrawal, or approximately 113,400 acre-feet. However, the recharge would likely be distributed to recharge facilities located in the Tucson Active Management Area but far from the influence area of the mine water supply wells. Loss of this water from the aquifer in the Upper Santa Cruz Sub-Basin is an irreversible impact. However, impacts from active pumping (i.e., drawdown in aquifer water levels) will recover 100 to 140 years following pumping; these impacts are irretrievable.

The groundwater resource commitment associated with the flow into the mine pit is the approximately 16,000 to 27,000 acre-feet of groundwater withdrawn to maintain minable conditions in the pit during the approximate 20-year active mine life (Montgomery and Associates Inc. 2010; Myers 2010b). This water will be withdrawn either from the pit sump itself, or with the use of dewatering wells or drains. After closure of the mine, a mine pit lake would form. Estimates of the amount of water lost in perpetuity from evaporation by the mine pit lake ranges from 170 acre-feet per year (Montgomery and Associates Inc. 2010) to 370 acre-feet per year (Tetra Tech 2010g). Loss of this water from the aquifer in the Davidson Canyon/Cienega Basin will continue in perpetuity as a result of the formation of the mine pit lake and is an irreversible impact.

Groundwater Quality

Introduction

The proposed action involves water resources and 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. 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 storage facilities, leakage from heap leach processing facilities, and formation of a permanent pit lake following mine closure. Although a pit lake is technically a surface water, it is described in this section because of its direct association with groundwater.

Issues, Cause and Effect Relationships of Concern

Mine operations involve several components that have the potential to affect groundwater. Once disturbed, precipitation falling on waste rock and tailing piles may have the potential to leach metals from the rock, which could infiltrate the aquifer and cause groundwater impacts. 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 disturbed rock formations,

could evolve hazardous hydrologic conditions, which could cause impacts to groundwater, birds, and wildlife.

One significant issue was identified with respect to water 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 may result in exceedances of Arizona Aquifer Water Quality Standards. The mine pit may result in the creation of a permanent pit lake, which may 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 may contribute to degradation of the aquifer.

Issue 3C Factors for Alternative Comparison

- Ability to meet Arizona Aquifer Water Quality Standards
- Ability to demonstrate best available demonstrated control technology

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, the following 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. Specifically, the section addresses the following:

- 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 the following section.

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 completion of mining, 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 are 50 years after pumping, in order to allow the cone of depression resulting from 20 years of groundwater pumping to stabilize. The analysis area shown in figure 46 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 pit; the analysis area encompasses the areas included in the groundwater models conducted for the analysis. Offsite utility corridors were not

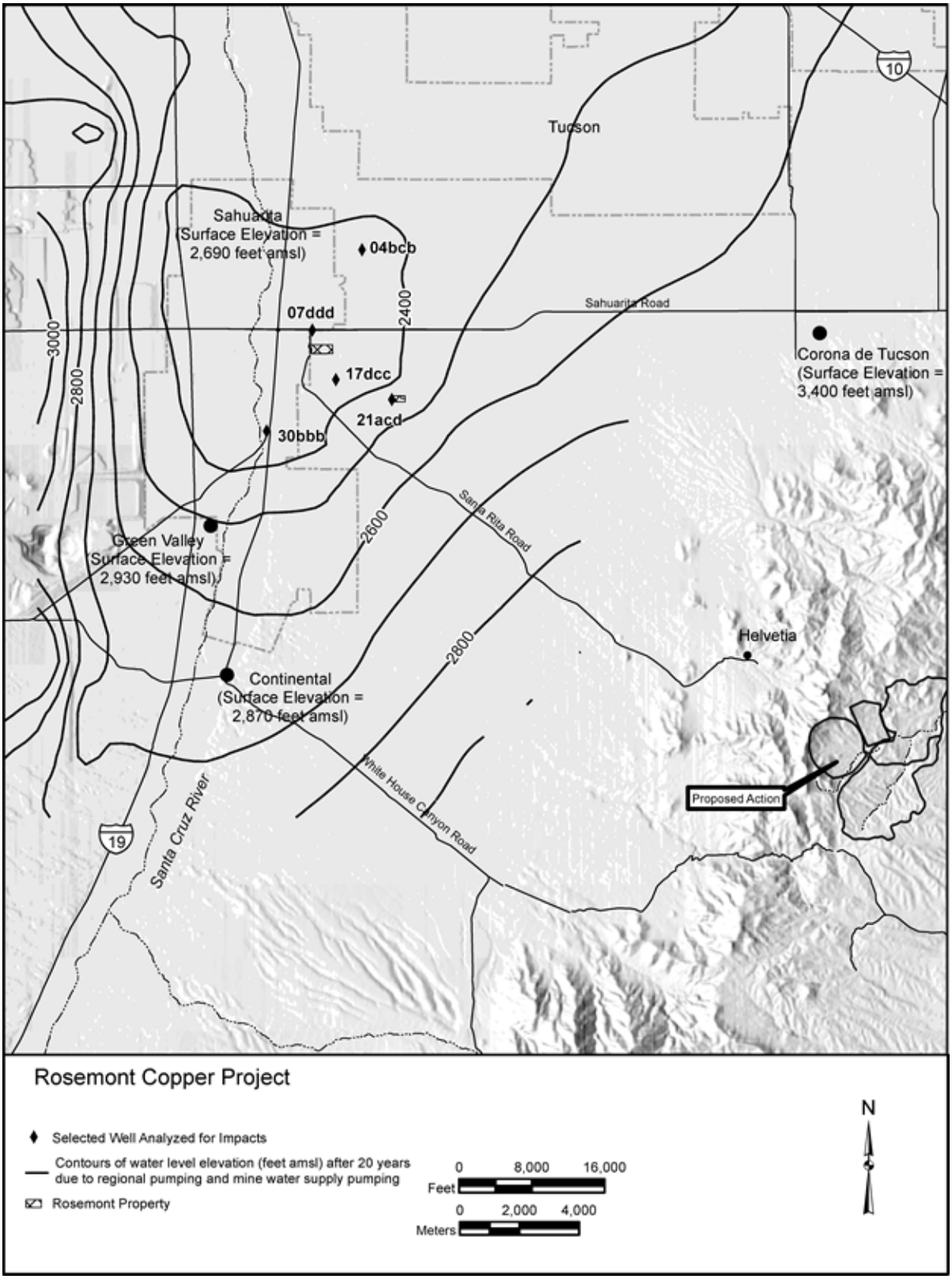


Figure 46. Analysis area for groundwater quality

considered in the analysis area, as impacts on groundwater quality were considered to be negligible and would be unlikely to change the results of impact analysis.

Methodology for Impacts Analysis

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. 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 from water infiltrating from leach facilities
- Expected water quality from water seepage from waste rock
- Expected water quality from water seepage from tailings
- Expected water quality in the mine pit lake
- Potential for the acid conditions in the mine pit lake
- 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 flow models (Errol L. Montgomery and Associates Inc. 2009a, 2010; Montgomery and Associates Inc. 2010; Myers 2010a; Tetra Tech 2010g) are discussed in the "Groundwater Quantity" section. Several additional technical reports consider the resulting 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 1" (Tetra Tech 2010e), with subsequent 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 2010c).

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. Final agreement with the revised reports through the peer review process is currently underway.

Note that the impacts of discharge of seepage to surface waters from waste rock and tailings facilities are analyzed in the "Surface Water Quality" section of this DEIS.

The thresholds of concern for the above indicators are the Arizona Aquifer Water Quality Standards, which govern groundwater quality. Adequate information was found with which to analyze groundwater quality impacts. Unavailable data include the following:

- 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.

- Final peer review of geochemical modeling reports is currently being completed and will be included when available.

Summary of Effects by Issue Measures by Alternative

Table 62 presents the summary comparison of impacts from each alternative.

Table 62. Summary of effects

Issue Measure	No Action	Proposed Action	Phased Tailings	Barrel	Barrel Trail	Scholefield-McCleary
3C: Ability to Meet Arizona Aquifer Water Quality Standards						
Subcomponent 1: Infiltration from Tailings and Waste Rock	None	Modeled water quality for potential seepage from tailings and waste rock meets standards	Same as proposed action	Same as proposed action	Same as proposed action	Same as proposed action
Subcomponent 2: Infiltration from Heap Leach	None	Modeled water quality for untreated seepage from heap leach exceeds standards for cadmium, fluoride, nickel, and selenium; treatment with an engineered biological system meets standards.	Same as proposed action	Same as proposed action	Same as proposed action	Same as proposed action
Subcomponent 3: Mine Pit Lake Water Quality	None	Modeled water quality in mine pit lake meets standards	Same as proposed action	Same as proposed action	Same as proposed action	Same as proposed action
3C: Ability to Demonstrate Best Available Demonstrated Control Technology						
Subcomponent 1: Effectiveness of Tailings and Waste Rock Control Technology	None	Modeled water quality indicates that selected technology is acceptable for preventing groundwater contamination	Same as proposed action	Same as proposed action	Same as proposed action	Same as proposed action
Subcomponent 2: Effectiveness of Heap Leach Control Technology	None	Modeled water quality indicates that selected technology for one type of passive treatment acceptable for treating heap leach seepage	Same as proposed action	Same as proposed action	Same as proposed action	Same as 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, but mitigation pumping by Sierrita would control any migration of plume	Same as proposed action	Same as proposed action	Same as proposed action	Same as proposed action

Affected Environment

Relevant Laws, Regulations, Policies, and Plans

Table 63 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 63. 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	Primacy given to Pima County
Forest Service Manuals 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	18 Arizona Administrative Code Chapter 11
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 U.S. Environmental Protection Agency 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 U.S. Environmental Protection Agency regulates these types of contaminants through the development of national primary and secondary maximum contaminant levels for finished water.

In Arizona, the Arizona Department of Environmental Quality administers the Safe Drinking Water Act (Arizona Administrative Code 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 requires approval from Pima 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 will reach an aquifer, requires issuance of an Aquifer Protection Permit by the Arizona Department of Environmental Quality. Unless the discharge is either specifically exempted by statute (Arizona Revised Statutes 49-250), or if the discharge is authorized under one of the General Aquifer Protection Permits issued by the Arizona Department of Environmental Quality (Arizona Administrative Code 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) will likely be covered under existing general aquifer protection permits. An individual aquifer protection permit will be required for potential discharges at the mine associated with retention ponds, leaching, and potential acid mine drainage.

Mine tailings and heap leach facilities are both considered to be discharging facilities requiring permits (Arizona Revised Statutes 49-241.B.6 and 49-241.B.7).

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.

From a regulatory standpoint, the mine pit lake is neither a navigable water, and thus 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.

Forest Service Guidance

Forest Service Manual 2520 (U.S. Forest Service 1992a) provides guidance for watershed protection and management. Specific areas of responsibility include planning, implementing, and monitoring watershed improvements (including abandoned mine lands); managing riparian areas for long-term conservation, productivity, biological diversity, and ecosystem integrity; and managing wetlands and floodplains.

Forest Service Manual 2530 (U.S. Forest Service 1992b) provides guidance for water resource management. Specific areas of responsibility include integrating water resource management with land management plans, coordinating with other agencies, conducting water resource investigations and collecting hydrologic data, and managing and monitoring water quality. Water quality management and monitoring have the specific objective of protecting and improving water quality to allow beneficial uses on Forest Service land.

Forest Service Manual 2880 (U.S. Forest Service 2008b) provides guidance for analysis of geological resources, hazards, and services. With respect to water resources, Forest Service Manual 2880 provides guidance for the inventory and analysis of groundwater dependent ecosystems. Hydrologic investigation techniques are further elaborated in FS-881, “Technical Guide to Ground Water Resource Management” (Glasser et al. 2007).

Forest Service guidance is nonprescriptive in nature. It assigns responsibilities to Forest Service personnel for data collection and decisions and provides general objectives to be considered when making resource decisions.

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), with pertinent results included in the following description of conditions.

Inorganic and Metal Constituents

Groundwater quality in the project area is considered acceptable for most uses. Total dissolved solids in groundwater samples collected from 38 wells and six springs ranged from 160 to 1,700 milligrams per liter, with an average concentration of 500 milligrams per liter. The field pH ranged from about 6.89 to 8.96, with an average of about 7.6, and the laboratory pH ranged from about 7.9 to 9.5, with an average of about 8.3. Nitrate, a commonly occurring contaminant, ranged from below detection limits to 4.88 milligrams per liter, well below the Arizona Aquifer Water Quality Standard of 10 milligrams per liter. Fluoride, another naturally occurring contaminant, ranged from below detection limits to 2.1 milligrams 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. 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 0.026 milligram per liter, well below the Arizona Aquifer Water Quality Standard of 0.05 milligram per liter. However, it should be noted that the standard for arsenic is proposed to decrease to 0.01 milligram per liter.

Based on these findings, no existing metal contamination of groundwater by past site use, including historic mining, is believed to exist in the project 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; there 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.

Based on these findings, no existing contamination by volatile organic compounds or semivolatile organic compounds is believed to exist in the project area.

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 (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.

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.

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 may vary to some degree by alternative, the location difference is not relevant to evaluating the general impact on groundwater quality; therefore, 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 Facility

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 water seepage from waste rock
- Expected water quality from water infiltrating from heap leach facilities
- Fate and transport of any contaminants reaching the groundwater

Predicted Seepage Rates

Overall, infiltration from precipitation over tailings, waste rock, or the heap leach facility is expected to be negligible. Near-surface storage is expected to be such that any precipitation that does not immediately run off will be stored in the near surface and lost to evaporation or transpiration by vegetation.

No seepage is expected from the waste rock storage areas, although stormwater control basins along the periphery and benches may result in infiltration that may contact waste rock, and very large precipitation events could result in infiltration and seepage.

Seepage from the tailings stack will develop as a result of the loss of the pore water present during stacking.

Seepage from the tailings facility is estimated to rise to 8.4 gallons per minute over the active life of the mine. After closure, the seepage rate from the tailings facility will steadily decrease, reaching zero seepage approximately 500 years after closure.

Seepage from the heap leach facility will be present and collected during the leaching process, which is expected to take approximately 6 years. Seepage will also be present and collected approximately 3 years after cessation of leaching, at which time the heap leach facility will be closed and encapsulated with waste rock. At the time of closure, seepage from the heap leach facility is estimated to be approximately 10 gallons per minute. Modeling indicates that heap leach seepage will decrease to 5 gallons per minute 5 years after closure and to 1 gallon per minute 45 years after closure and that seepage will cease approximately 115 years after closure (Tetra Tech 2010e).

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. Waste rock encapsulation is expected to be beneficial for two reasons: prevention of infiltration through the heap leach, and the presence of large volumes of acid-neutralizing waste rock. However, access to collect and treat the heap leach seepage after encapsulation has not yet been determined; this will be determined as part of the aquifer protection permit.

Expected Water Quality

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 a standard leaching procedure typically conducted under laboratory conditions (known as a synthetic precipitation leaching procedure). The starting solutions were then modeled as moving through the tailings stack. The expected seepage water quality for constituents with a numeric Arizona Aquifer Water Quality Standard is shown in table 64. 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 2010e).

Table 64. 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	–	5.87	7.67
Antimony	0.006	Not present	<0.0004
Arsenic	0.05*	Not present	0.0037
Barium	2	0.017	0.042
Beryllium	0.004	Not present	<0.0001
Cadmium	0.005	Not present	<0.0001
Chromium	0.1	Not present	<0.01
Fluoride	4.0	2.37	0.85
Lead	0.05	Not present	0.00092
Mercury	0.002	Not present	<0.0002
Nickel	0.1	Not present	<0.01
Nitrate and Nitrite (as N)	10	0.001	0.49
Selenium	0.05	0.006	0.00212
Thallium	0.002	Not present	<0.0001

Notes:
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.

* Standard proposed to decrease to 0.01 mg/L.

Waste Rock Facility — Under normal climatic conditions, seepage is not expected to occur from the waste rock storage areas. However, under large precipitation events it is estimated that seepage could occur. Seepage could conceivably occur from infiltration of water from stormwater control structure along the periphery of the waste rock facility. Therefore, geochemical modeling was conducted to estimate seepage water quality (Hudson and Williamson 2011; Tetra Tech 2010e).

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 65 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. Arsenic is predicted to exceed the proposed lower arsenic standard of 0.010 milligram per liter. However, the predicted arsenic concentration of 0.013 milligram per liter is generally in the range naturally observed in groundwater samples within the project area (<0.0005 to 0.0266 milligram per liter).

Table 65. 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	–	7.73	7.67
Antimony	0.006	Not present	<0.0004
Arsenic	0.05*	0.013	0.0037
Barium	2	0.013	0.042
Beryllium	0.004	Not present	<0.0001
Cadmium	0.005	0.0004	<0.0001
Chromium	0.1	Not present	<0.01
Fluoride	4.0	1.18	0.85
Lead	0.05	0.003	0.00092

Constituent	Arizona Aquifer Water Quality Standard (milligrams per liter (mg/L))	Predicted Waste Rock Seepage (mg/L)	Ambient Groundwater Quality (mg/L)
Mercury	0.002	Not present	<0.0002
Nickel	0.1	Not present	<0.01
Nitrate and Nitrite (as N)	10	0.018	0.49
Selenium	0.05	0.036	0.00212
Thallium	0.002	Not present	<0.0001

Notes:

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.

* Standard proposed to decrease to 0.01 mg/L.

Heap Leach Facility — The starting solution for the heap leach facility seepage model was a dilute solution of sulfuric acid, which was then modeled as moving through two rock types expected to be present in the heap (andesite and quartz monzonite porphyry).

Conceptually, following closure of the heap leach facility, the collection system would remain in place and would use a passive or active treatment system in order to neutralize any remaining potential seepage. The details of collection and treatment of the heap leach seepage would be established by the aquifer protection permit; the technology and techniques used are not known at this time.

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 expected seepage water quality, as well as the water quality using each of the passive treatment systems, is summarized in table 66, shown for 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 is able to reduce concentrations of all constituents below numeric Arizona Aquifer Water Quality Standards.

Table 66. 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	–	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

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)
Lead	0.05	0.037	0.037	0.037
Mercury	0.002	Not present	Not present	Not present
Nickel	0.1	**0.592**	8.39E-07	**0.593**
Nitrate and Nitrite (as N)	10	0.107	0.107	0.107
Selenium	0.05	**0.099**	7.6E-13	**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.

* Standard proposed to decrease to 0.01 mg/L.

Seepage from the heap leach facility is regulated under the Aquifer Protection Permit program administered by the Arizona Department of Environmental Quality. While modeling demonstrates the ability to meet groundwater standards with treatment, the actual requirements for treatment, discharge, and monitoring of seepage following closure of the heap leach facility and burial in waste rock will be determined by the Arizona Department of Environmental Quality. A long-term maintenance plan to ensure continuation of treatment, if needed, has not yet been developed and is expected to be included under the Aquifer Protection Permit program administered by the Arizona Department of Environmental Quality.

Fate and Transport of Contaminants

Seepage from the tailings facility is expected to occur because of process water present during deposition, 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 it does because of large precipitation events, it is not expected to exceed any numeric Arizona Aquifer Water Quality Standards. Seepage from the heap leach facility 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 is modeled using the three independent groundwater flow models that were conducted for the project area (Montgomery and Associates Inc. 2010; Myers 2008, 2010a; Tetra Tech 2010g). 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 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 mine operations, groundwater levels beneath the heap leach facility are predicted to decrease by more than 100 feet. Any seepage infiltrating to groundwater beneath the heap leach facility is expected to move toward the mine pit lake.

The cone of depression 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 mine life and after mine closure (Tetra Tech 2010g). 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 toward the mine pit lake.

During the active mine life, groundwater beneath the dry-stack tailings facility will 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 will begin to flow westward to the mine pit lake. However, as seepage from the dry-stack tailings facility are not expected to exceed any numeric Arizona Aquifer Water Quality Standards, there are not expected to be any 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 impact analysis:

- Expected water quality in the mine pit lake
- 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 will not present a threat to groundwater regionally; as described above, 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 as a result of 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 2010c).

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 2010g).

Geochemical modeling (Tetra Tech 2010c) was based on a time frame of 200 years, at which time the pit lake stage will have reached 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 67.

Table 67. 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

The geochemical model considered the starting chemistry of the various sources of water entering the lake, shown in table 68. 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, located 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. It should be noted that humidity cell tests were run for 20 weeks; this has been identified as a minimal amount of time, although sufficient for modeling purposes. Additional testing may be required by the Forest Service for inclusion in the FEIS.

Based on these inputs, four different geochemical modeling scenarios were conducted. 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 68. Numeric Arizona Aquifer Water Quality Standards are included in the table for comparison.

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

Potential to Exceed Water Quality Standards — 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 no constituents exceed numeric Arizona Aquifer Water Quality Standards.

Table 68. Results of geochemical modeling for mine pit lake at 200 years (in milligrams per liter)

Constituent	Numeric Arizona Aquifer Water Quality Standard	Scenario 1: Low Geochemical Loading	Scenario 2: Average Geochemical Loading	Scenario 3: High Geochemical Loading	Scenario 4: Average Loading with Bolsa Quartzite
Aluminum		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		37.3	36.2	37.0	36.0
Cadmium	0.005	0.002	0.002	0.002	0.002
Calcium		89.9	99.8	107.7	100.7
Chloride		9.9	11.1	12.5	11.1
Chromium	0.1	0.004	0.005	0.005	0.005
Copper		0.004	0.004	0.005	0.163
Fluoride		1.1	1.2	1.4	1.2
Iron		Not present	Not present	Not present	Not present
Lead	0.05	0.004	0.015	0.017	0.015
Magnesium		22.7	25.7	30.1	25.6
Manganese		0.229	0.255	0.243	0.254
Mercury	0.002	0.002	0.001	Not present	Not present
Molybdenum		0.137	0.150	0.192	0.154
Nickel	0.1	0.005	0.006	0.007	0.010
pH		8.1	8.0	8.0	8.0
Potassium		5.1	5.7	6.3	5.4
Selenium	0.05	0.013	0.014	0.016	0.014
Silver		0.004	0.004	0.005	0.004
Sodium		31.9	35.9	38.6	35.3
Sulfate		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:
Not present – constituent was not modeled to be present at concentrations above three decimal places.
* Standard proposed to decrease to 0.01 milligram per liter.

Qualitative Comparison of Pit Lake to Surface Water Quality Standards — The mine pit lake is not a navigable water and is not regulated under surface water quality regulations. However, these standards are specific to wildlife use and are therefore useful solely as a tool for assessing the potential impacts to wildlife.

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

- Silver exceeds the surface water standard under all four scenarios.
- Cadmium exceeds the surface water standard under all four scenarios.
- Copper exceeds the surface water standard under all four scenarios.
- Lead exceeds the surface water standard in three of four scenarios.
- Mercury exceeds the surface water standard in two of four scenarios.
- Selenium exceeds the surface water standard (0.002 milligram per liter total selenium) under all four scenarios. This appears to be largely the result of the concentration of selenium naturally observed in groundwater samples collected from area wells (0.00212 milligram per liter), which naturally exceeds the surface water standard.
- Zinc exceeds the surface water standard (0.0493–0.0539 milligram per liter dissolved zinc) under all four scenarios. This also appears to be largely the result of the concentration of zinc naturally observed in groundwater samples collected from area wells (0.694 milligram per liter), which naturally exceeds the surface water standard.

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

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 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 with the Arizona Department of Environmental Quality 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 the Arizona Department of Environmental Quality; 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 water supply pumping and would extend an additional 5 miles southward from there. 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.

Because the exact location and amount of mitigation pumping is not yet known, it was not able to be analyzed in the Montgomery west side model (Errol L. Montgomery and Associates Inc. 2009a, 2010). However, 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 water supply wells. No change in flow direction is expected to occur in the aquifer near the Sierrita plume from the

Rosemont 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" section in figures 39 and 40). More importantly, by its nature, the mitigation pumping is designed to create a cone of depression to capture sulfate-contaminated groundwater and prevent it from migrating further. It is unlikely that the minor amounts of drawdown created by the water supply pumping will significantly affect the results of the Sierrita mitigation pumping or result in any additional migration of the Sierrita sulfate plume.

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 current Arizona Aquifer Water Quality Standards.
- Potential seepage from waste rock piles is expected to meet current Arizona Aquifer Water Quality Standards.
- Untreated seepage from the heap leach facility could exceed Arizona Aquifer Water Quality Standards for cadmium, fluoride, nickel, and selenium. Conceptual modeling shows that seepage after treatment with an engineered biological system is expected to meet current Arizona Aquifer Water Quality Standards. Exact treatment technology and techniques will be determined under the aquifer protection permit.

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. None of the seepage expected from the tailings, or potentially occurring from the waste rock, is expected to impact a navigable water, as these discharges are most likely to be captured by the mine pit lake. Similarly, existing and reasonably future use of groundwater in the area is limited to domestic wells. None of these wells would occur within the area likely to be affected by tailings or waste rock seepage.

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 process and is summarized as follows:

- The dry-stack tailings facility uses filtration technology to dewater tailings prior to placement. By doing so, dry-stack tailings will achieve a greater degree of engineering control than typical slurried tailings with high moisture content. Geochemical modeling of potential seepage from the dry-stack tailings facility demonstrates that the design is capable of preventing discharge of contaminants to groundwater.
- Geochemical modeling of potential seepage from the waste rock facility demonstrates that the design is capable of preventing discharge of contaminants to groundwater.

- Geochemical modeling of the heap leach facility indicates that conceptually at least one type of passive treatment system is capable of preventing discharge of contaminants to groundwater. Continued draindown of the heap leach will require collection and treatment under the aquifer protection permit; details of the technology to be used are not yet determined.
- The process water temporary storage pond, the primary settling basin, pregnant leach solution pond, stormwater pond, and the raffinate pond all consist of single- or double-lined impoundments, some with leak detection systems, that will prevent discharge of contaminants to groundwater.

Proposed Action and Action Alternatives

There are no impacts specific solely to the action alternatives.

Cumulative Effects

There are no reasonably foreseeable activities in the project area that are expected to impact groundwater quality. Therefore, no cumulative effects are considered.

Mitigation Effectiveness and Remaining Effects

Aside from permitting requirements under the aquifer protection permit program, the only mitigation measure specific to groundwater quality is the design of the heap leach facility. The design and location of the heap leach facility is designed to collect all possible drainage and solution, is on top of a stable rock location, and will be encapsulated by waste rock to protect from stormwater infiltration up to the maximum reasoned storm event. The effectiveness of this mitigation measure has already been incorporated into the analysis.

Irretrievable and Irreversible Commitment of Resources

Although water treatment at the point of withdrawal by wells or by active in situ or extractive treatment systems is possible, in general, changes to groundwater quality are for the most part considered to be irretrievable and irreversible. No changes in groundwater quality are expected from tailings seepage, waste rock seepage, treated heap leach seepage, or the mine pit lake.

Surface Water Quantity

Introduction

This section discusses the amount of existing surface water resources in the project area. Surface water resources discussed in this section include washes, creeks, springs, seeps, and stock tanks located within the analysis area. However, because the springs and seeps are altogether dependent on the local groundwater system, the detailed analysis of impacts to the springs and seeps is discussed in the “Groundwater Quantity” section.

The analysis area for surface water quantity resources is based on the following two considerations: (1) the direct modification of the topography and alteration of the surface water regime on the project area as a result of mining and the development of mine infrastructure; and (2) the indirect effects of mining activities on downgradient surface water drainages. Downstream surface water drainages within the analysis area include the immediate sub-watersheds and the portion of Davidson Canyon

that receives discharge from the project area and is tributary to lower Cienega Creek (figure 47). Cienega Creek has not been included within the analysis area for surface water quantity. The drainages affected by the proposed project represent a small proportion of the Cienega Creek watershed (roughly 2 percent), and unlike that for Davidson Canyon, the expected reductions in ephemeral flows are considered negligible. For example, using a regression equation the average-annual runoff for Cienega Creek where it becomes Pantano Wash is estimated to be reduced from 4,412 acre-feet (existing conditions) to 4,369 acre-feet for postmine conditions under the proposed action, less than a 1 percent reduction in runoff (Zeller 2011).

The temporal bounds of analysis includes the construction, operation, closure, and postclosure phases of the project. Analysis of the reclamation and revegetation of the site to prevent erosion from occurring extends 100 years after mine closure, as discussed in the “Soils” section of this DEIS.

Issues, Cause and Effect Relationships of Concern

One significant issue was identified concerning surface water quantity.

Issue 3D: Surface Water Availability

Construction and operation of the mine pit, tailings, waste rock, and leach facilities may result in changes in surface water discharge to Davidson Canyon and Cienega Creek, portions of which are designated an Outstanding Arizona Water by the Arizona Department of Environmental Quality. Additionally, the availability of water for stock water tanks may be reduced.

Issue 3D Factors for Alternative Comparison

- Quantitative assessment of water released and available for beneficial uses
- Determination/estimation of number of stream miles changed from intermittent flow status to ephemeral flow status as a result of the project
- Quantitative assessment of potential lowering of the water table/reduced groundwater flow to Davidson Canyon and Cienega Creek that results in permanent changes in flow patterns and that may affect their Outstanding Arizona Water designations and current designated uses
- Stock watering tanks that will be unavailable (number)
- Change in volume, frequency, and magnitude of runoff from the project area
- Change in recharge of the aquifer by runoff
- Number of seeps and springs lost or impaired

Only changes in surface water quantity are presented in this section; impacts on groundwater flow, recharge of the aquifer, and number of seeps and springs are discussed in the “Groundwater Quantity” section.

Analysis Methodology, Assumptions, Uncertain and Unknown Information

The methodology for assessing changes in surface water quantity consists primarily of hydrologic modeling of storm flows resulting from design precipitation events, which range from the typical to the extreme (specifically the 2-year, 24-hour and 100-year, 24-hour storms) using the U.S. Army Corps of Engineers’ computer program Hydrologic Engineering Center Hydrologic Modeling System, Version 3.4. The same modeling is carried out under baseline conditions and for each action alternative, with both peak flow and total flow volume being modeled. The watershed area considered

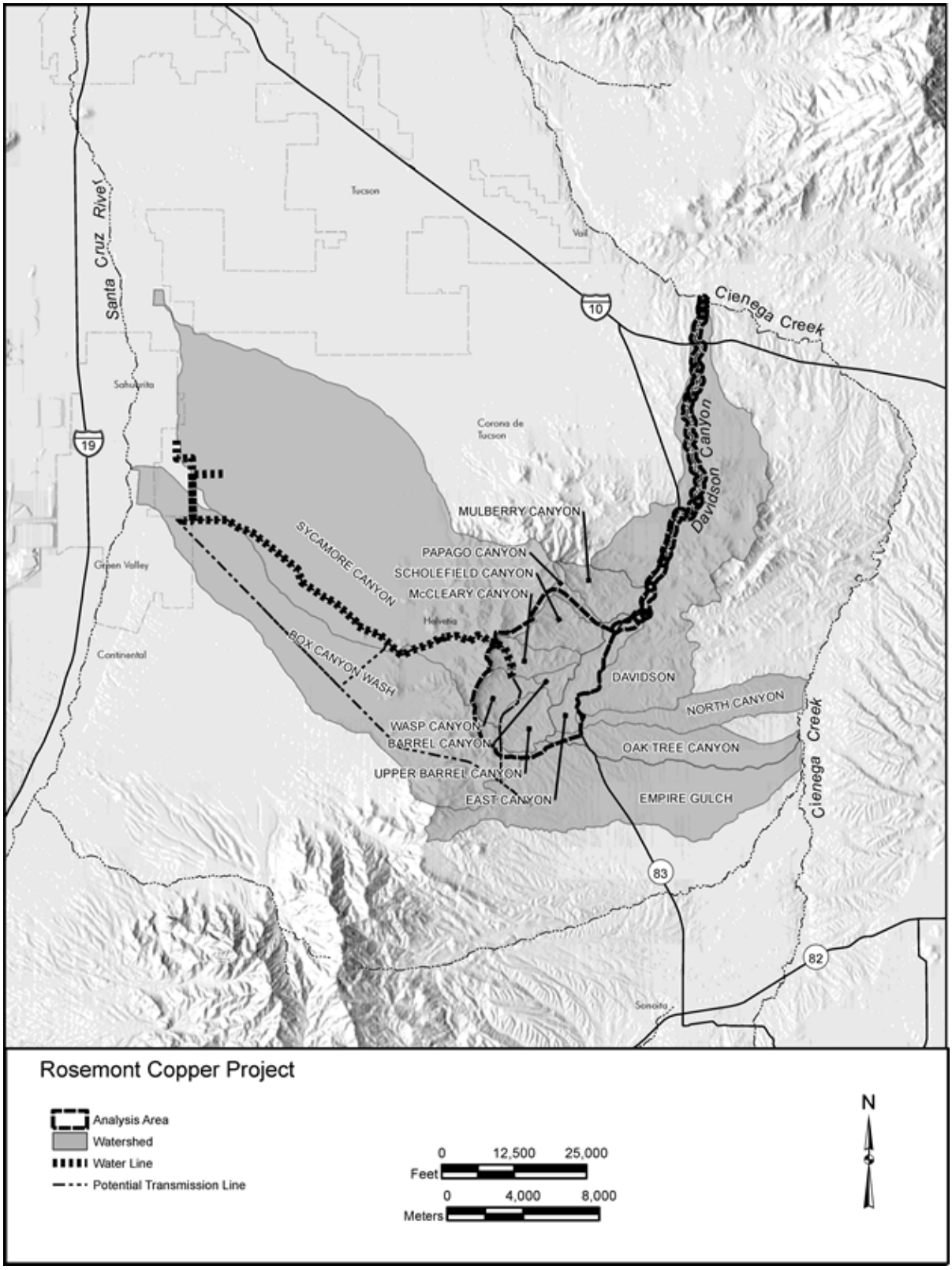


Figure 47. Analysis area for surface water quantity

in this modeling consists of 5,252 acres. That area represents the portion of the watershed above the U.S. Geological Survey stream gage on Barrel Canyon at State Route 83. Below this point, the wash and any contributing watershed will remain undisturbed under all alternatives. Modeling results were then used to evaluate indirect impacts from reduced flows in washes downstream of the stream gage on Barrel Canyon.

Washes, wetlands, and stock ponds in the project area and the water supply pipeline were surveyed using field methods developed by the U.S. Army Corps of Engineers (2008a; 2008b). A preliminary jurisdictional waters determination based on the surveys was submitted to the U.S. Army Corps of Engineers on May 29, 2009, with additional information provided on July 31, 2009, January 5, 2010, and March 1, 2010. The U.S. Army Corps of Engineers has approved the preliminary jurisdictional delineation. The data, as approved, were used to quantitatively assess direct impacts to surface water quantity (i.e., washes, wetlands, and stock ponds) using geographic information system overlays. To date, not all construction areas for power lines and access roads have been field surveyed. But because the power lines will be constructed aboveground and power poles are not expected to be placed in washes and because roads such as those to be constructed for site access typically are constructed in a manner that allows stormwater to pass through culverts or dip crossings, this construction is not considered likely to impact surface water quantity. Because volumes for individual stock ponds are unknown, the analysis uses estimates of stock pond volumes based on available Arizona Department of Water Resources data.

All analyses presented are based on expert resource reports generated using these methodologies and apply to the mine. Linear construction, such as power lines, water supply pipelines, and access roads, is not expected to impact surface water quantity.

Effects on water resources are considered to be significant if one or more of the following is the case:

- the effect is expected or is likely to occur
- the magnitude of the effect is large relative to current or anticipated future water resource conditions
- the magnitude of the effect is large relative to the uncertainty in the method of analysis of impacts
- mitigation of the adverse effect is not provided for or is not anticipated to be effective

Summary of Effects by Issue Measures by Alternative

Table 69 presents the summary comparison of impacts from each alternative.

Table 69. Summary of effects

Issue Measure	No Action	Proposed Action	Phased Tailings	Barrel	Barrel Trail	Scholefield-McCleary
3D: Quantitative assessment of water released and available for beneficial uses	No change	Beneficial uses of ephemeral stream flows primarily related to stock tanks; after mitigation, negligible effect on beneficial uses	Same as proposed action	Same as proposed action	Same as proposed action	Same as proposed action

Issue Measure	No Action	Proposed Action	Phased Tailings	Barrel	Barrel Trail	Scholefield-McCleary
3D: Stock watering tanks that will be unavailable (number)						
Subcomponent 1: Stock tanks directly disturbed (number)	0	15 stock tanks lost 15 mitigated; no net loss	15 stock tanks lost 15 mitigated; no net loss	19 stock tanks lost 19 mitigated; no net loss	19 stock tanks lost 19 mitigated; no net loss	8 stock tanks lost 8 mitigated; no net loss
Subcomponent 2: Downstream stock tanks indirectly impacted (number)	0	6	6	5	5	6
3D: Change in volume, frequency, and magnitude of runoff from the mine						
Subcomponent 1: Reduction in volume of stormwater flow from the project area (percent)	0	45.8%	44.3%	33.8%	42.0%	22.8%
Subcomponent 2: Reduction in 100-year, 24-hour peak flow from the project area (percent)	0	53.1%	49.9%	34.9%	40.0%	29.5%
Subcomponent 3: Reduction in flow along Davidson Canyon (percent)	0	9.7%	7.1%	5.4%	6.7%	3.6%
Subcomponent 4: Change in recharge to the aquifer by runoff	0	Reduction in recharge expected but not quantified	Reduction in recharge expected but not quantified	Reduction in recharge expected but not quantified	Reduction in recharge expected but not quantified	Reduction in recharge expected but not quantified

Affected Environment

Relevant Laws, Regulations, Policies, and Plans

Table 70 lists the applicable laws, regulations, and policies related to the use, protection, and management of surface water quantity resource 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.

Federal

Forest Service Guidance

Forest Service Manuals 2520, 2530, and 2880 provide guidance for watershed protection and management for both surface and groundwater resources. These manuals and technical guides are described in the “Groundwater Quantity” section.

Table 70. Summary of the Federal, State, and local regulatory requirements applicable to the project with respect to surface water resources

Law/Regulation	Regulates
Federal	
Forest Service Manuals 2520, 2530, and 2880 and FS-881, "Technical Guide"	Watershed protection and management, water resource management, geological resources, and groundwater management
State	
Dam Safety Permit	
Surface Water Rights	Diversion of springs, surface flow, and certain wells
Local	
Pima County Floodplain and Erosion Hazard Management Ordinance	Regulatory floodplains and riparian habitat designated by Pima County

State

Dam Safety Permit (Arizona Administrative Code R12-15, Article 12)

Arizona Department of Water Resources regulates the safety of dams within the State of Arizona. Dam safety rules are applicable only to certain dams, with exemptions based on purpose, height, and capacity. The compliance dam located in the Barrel Canyon drainage may require Arizona Department of Water Resources approval prior to construction. Retention structures within the boundaries of the mine may also require approval, unless exempted under the dam safety rules.

Surface Water Rights

Water rights within the State of Arizona operate within a bifurcated legal framework in which surface water rights are considered completely separately from groundwater rights. Surface water rights are assigned under the legal doctrine of prior appropriation, or "first in time, first in right." However, historically, the administrative process of claiming or registering a surface water right has not considered other water rights already claimed on the same water source. Thus, most water sources within the state are over-appropriated, with multiple claims on the same water. The process of sorting through the priority of these conflicting rights is being handled by the Superior Court under the Arizona General Stream Adjudication. In addition to surface water sources, withdrawals from certain groundwater wells will eventually also be prioritized as surface water rights, depending on their effect on surface water sources.

Surface water rights that are located within the project area fall under the General Stream Adjudication of the Gila River. Currently, the Gila River Adjudication is focusing only on the first sub-watershed, that of the San Pedro River. No prioritization has yet occurred for surface water rights within the project area.

Local

Title 16 Pima County Floodplain and Erosion Hazard Management Ordinance (2010-FC5)

Pima County Flood Control District regulates flooding and erosion hazards on private property within unincorporated areas of Pima County through the Floodplain and Erosion Hazard Management Ordinance. The goal of the ordinance is twofold. The first goal of the ordinance is to ensure that new development within floodplains is safe from flooding and erosion hazards and does not adversely impact adjacent property. This is accomplished through implementation of the floodplain use permit

process and conformance with the National Flood Insurance Program, as administered by the Federal Emergency Management Agency.

The second goal of the ordinance is to protect natural resources within flood-prone areas. These riparian areas are recognized by the county for their importance in mitigating flood hazards, providing natural erosion control, and promoting recharge into underground aquifers. As such, Pima County Board of Supervisors has adopted maps of regulated riparian habitat throughout the county. As part of the floodplain use permit process, proposed developments are subject to review for impacts to mapped regulated riparian habitat if more than ⅓ acre of the habitat is disturbed.

Existing Conditions

Regional Hydrologic Setting

The project lies within the Basin and Range physiographic province, which is characterized by northwest-trending mountain ranges separated by broad, thick alluvial basins. The project area lies at the border of the Sonoran Desert and Mexican Highland sub-provinces of southeastern Arizona and southwestern New Mexico (Tetra Tech 2010d). The Sonoran Desert sub-province consists of low mountain ranges and broad valleys, while the Mexican Highland sub-province is characterized by greater altitudes and local relief, along with dissected basins.

Hydrometeorology

Precipitation

The proposed project is located in southern Arizona on the eastern front of the Santa Rita Mountain range, which is surrounded by arid desert basins. Because of the physiography of this region, which consists of wide basins surrounded by mountain ranges, significant variation in the precipitation pattern occurs over short distances. Precipitation data are available for the project area from a variety of sources and periods, as shown in table 71, including a monitoring station that was recently installed at the project area near the center of the proposed open pit.

In general, average annual precipitation ranges from 16 to 23 inches, with roughly half occurring as a result of convective storms during the summer monsoon season (July through September) and the remaining half occurring as a result of frontal storms during the winter season (November through March). May and June are typically the driest months. Winter precipitation falls partly as snow between November and April, averaging less than 8 inches of snowfall with little lasting accumulated depth.

Temperature

Monthly average temperature data are available from the onsite weather station and from several of the same stations for which precipitation data are available, as summarized in table 72.

Onsite, the average maximum monthly temperature ranges from 64°F in January to 93°F in June. Elsewhere, the average maximum monthly temperature ranges from a low of approximately 59°F in January to a high of approximately 92°F in June.

Table 71. Summary of average monthly precipitation (in inches) from various sources

Month	Sellers* (1931 to 1970)	Helvetia† (1916 to 1950)	Canelo 1 NW† (1971 to 2000)	Santa Rita Experimental Range† (1971 to 2000)	Rosemont Mine Site‡ (2006 to 2008)
January	–	1.58	1.22	1.73	0.59
February	–	1.72	1.18	1.66	0.79
March	–	1.14	0.93	1.78	0.45
April	–	0.52	0.45	0.66	0.45
May	–	0.28	0.2	0.30	0.51
June	–	0.67	0.72	0.55	0.98
July	–	4.05	4.41	4.83	5.51
August	–	4.15	4.03	4.26	3.74
September	–	2.19	1.68	2.40	1.62
October	–	0.68	1.04	2.06	0.24
November	–	1.22	0.84	1.30	1.11
December	–	1.52	1.38	1.88	1.16
Annual Total Precipitation	**16**	**19.7**	**18.1**	**23.41**	**17.12**
Average Annual Snowfall	**–**	**7.7**	**5.3**	**4.0**	**–**

* University of Arizona (Hargis and Harshbarger n.d. (1978)).

† Western Regional Climate Center (2009).

‡ Tetra Tech (2009a)

Table 72. Summary of average monthly temperatures (°F) from various sources

Month	Station*							
	Helvetia (1916 to 1950) Average Maximum	Helvetia (1916 to 1950) Average Minimum	Canelo 1 NW (1971 to 2000) Average Maximum	Canelo 1 NW (1971 to 2000) Average Minimum	Santa Rita Experimental Range (1971 to 2000) Average Maximum	Santa Rita Experimental Range (1971 to 2000) Average Minimum	Rosemont Mine Site† (2006 to 2010) Average Maximum	Rosemont Mine Site† (2006 to 2010) Average Minimum
January	57.93	35.85	57.90	26.10	60.40	37.50	63.8	26.6
February	61.14	38.25	61.50	28.20	64.30	39.70	68.9	25.3
March	66.42	42.43	66.10	31.70	68.60	43.20	76.5	29.0
April	74.83	49.40	73.70	36.70	76.00	48.30	77.0	35.2
May	82.88	55.97	81.80	43.40	83.80	55.80	85.9	43.8
June	92.12	64.41	90.40	52.40	93.30	64.60	92.5	56.8
July	91.27	67.63	88.30	59.80	92.00	66.80	91.9	60.7
August	87.93	65.82	85.50	58.40	89.10	65.20	88.5	61.1
September	86.49	63.45	83.80	52.70	86.50	62.30	85.2	54.4
October	78.27	54.45	76.50	41.90	78.60	54.50	83.0	37.4
November	67.80	43.60	65.90	31.80	67.70	42.80	77.4	31.3
December	60.55	38.26	58.20	26.70	60.70	37.50	69.4	22.8

* Western Regional Climate Center (2009).

† Data provided by Rosemont Copper.

Evaporation

Evaporation pan data do not exist for the same stations that were used for the precipitation and temperature data; however, evaporation pan measurements were added to the onsite weather station in June 2008, and evaporation pan data are available from other weather stations in southern Arizona. Nearby stations with pan evaporation data include Tucson University of Arizona, with more than 100 years of data, and Nogales 6 N, with more than 50 years of data. The closest station is in Nogales. In addition to the limited onsite evaporation pan measurements, estimates of pan evaporation rates have been determined for the project area based on the 50 years of continuous data for both precipitation and evaporation measurements recorded at the nearby Nogales weather station (Carrasco 2009). The projected project area pan evaporation rates range from a low of 2.89 inches per month in August to a high of 10.75 inches in June, with an estimated annual evaporation rate of 71.52 inches (table 73).

Table 73. Average monthly pan evaporation for nearby stations and the project area (inches)

Month	Tucson, University of Arizona (1894 to 2007)*	Nogales 6 N (1952 to 2007)*	Rosemont Copper Project (2008)*	Estimated Pan Evaporation Rosemont Copper Project Area†
January	3.25	3.59	–	4.13
February	4.57	4.46	–	4.28
March	6.95	7.01	–	7.11
April	9.88	9.35	–	8.50
May	12.87	11.91	–	10.38
June	14.91	13.31	–	10.75
July	13.17	10.00	4.77	4.93
August	11.65	8.28	2.92	2.89
September	10.35	8.06	4.11	4.40
October	7.81	7.17	2.32	6.15
November	4.73	4.49	2.20	4.11
December	3.37	3.57	2.22	3.89
Annual Total Pan Evaporation	**103.51**	**91.20**	–	**71.52**

* Tetra Tech (2009a).

† Tetra Tech (Carrasco 2009).

Surface Water

Past activities that have affected surface water quantity resources on the Coronado National Forest include historic grazing activities and mining. Use of natural resources on public lands for grazing livestock and mining dates back to settlement times (Baker Jr. et al. 2004). Historic excessive or improper livestock grazing practices in the Southwest have resulted in the loss of herbaceous cover and litter and an increase in erosion, surface runoff, flooding, and downcutting. The effects of grazing in the project area are fully discussed in the “Livestock Grazing” section. Monitoring by the Coronado has found that conditions on the grazing allotments in the project area are satisfactory. Numerous small-scale and several large-scale mining projects have occurred in the past either on or in the vicinity of the project area. Between 1994 and 2005, there were six projects in the area that impacted waters of the United States, most of which had less than 0.5 acre of impact. Two exceptions were a restoration project that impacted 2.5 miles of waters of the United States and a road project that impacted 3 miles.

Washes and Creeks (Natural Drainages) in Project Area

The project area is located in the foothills on the east side of the Santa Rita Mountains. This area is drained by ephemeral watercourses that flow primarily in a northeasterly direction from high-elevation ridges on the eastern flank of the Santa Rita Mountains through foothills toward larger drainages located at lower elevations on the basin floor. Four major drainages occur in the primary area of disturbance: Wasp, McCleary, Scholefield, and Barrel Canyons. Scholefield, Wasp, and McCleary Canyons drain to Barrel Canyon, which then joins Davidson Canyon approximately 4 miles to the east of the project area. Davidson Canyon wash flows northwesterly between the Empire and Santa Rita Mountains into Cienega Creek, which eventually enters Pantano Wash. The distance from the confluence of Barrel and Davidson Canyons to the outlet of Davidson Canyon at Cienega Creek is approximately 14 miles. Drainage from these systems eventually reaches the Santa Cruz River north of Tucson.

Barrel Canyon watershed is the largest of the four major drainages that occur in the primary area of disturbance. Two sub-watersheds, Upper and Lower Barrel, total more than 2,300 acres and combine to make Barrel Canyon proper. Barrel Canyon is the largest of the affected watersheds, extending almost 4 miles from its headwaters to its confluence with East Canyon; the average sandy-bottom channel width for washes in Barrel Canyon is estimated to be 51 feet. For comparison purposes, average wash widths in Wasp, McCleary, and Scholefield Canyons are approximately 38, 29, and 27 feet, respectively. Table 74 presents details on the four primary watersheds that occur within the project area.

Table 74. Summary of primary watersheds within the project area

Watershed	Drainage Size (acres)	Drainage Size (square miles)	Average Drainage Length (feet)	Average Wash Width (feet)	Average Slope (%)
Barrel Canyon*	2,304	3.6	20,581	51	4.1
Wasp Canyon	1,408	2.2	9,250	38	14.1
McCleary Canyon	1,536	2.4	16,635	29	6.9
Scholefield Canyon	2,048	3.2	11,643	27	12.0

* Includes both Upper Barrel and Lower Barrel Canyons.

Somewhat smaller portions of additional watersheds occur within the perimeter fenceline (see figure 47). These watersheds include Oak Tree Canyon, North Canyon, Empire Gulch, Papago Canyon, Sycamore Canyon, and Box Canyon Wash. Papago Canyon is located to the north and drains to Davidson Canyon. East, Oak Tree, and North Canyons are located east of the mine and drain east to join Cienega Creek. Empire Gulch is located southeast of the mine and also drains east to join Cienega Creek. Sycamore Canyon and Box Canyon Wash are located west of the crest of the Santa Rita Mountains, and both drain to the Upper Santa Cruz River.

Field reconnaissance was conducted by WestLand Resources Inc. (2010a; 2010f; 2010g) for the purpose of collecting data on drainage features within the project area. Results of their efforts indicate that perennial or nearly perennial surface water within the project area is limited to very small pools at spring sites or to stock ponds. Of the drainage features identified and recorded for the project area, more than 90 percent (265 out of 288) were identified as being ephemeral washes.

Groundcover varies from desert brush in the steep rocky terrain of the east half of the project area to herbaceous and mountain brush on the west side. Trees and shrubs are dense along the margins of washes and within floodplain areas, where moisture is stored in the alluvium.

Stream bed material found within the major drainages consists of unconsolidated sand, gravel, silt, and clay. This recent alluvium is 2 to 4 feet thick on the bottom of the major drainages (Tetra Tech 2007e). Floodplains at the lower elevations of the major washes are not more than 100 feet wide and are considerably more restricted in upstream reaches at higher elevations. Figure 47 depicts the major drainage basins on the project area, and table 75 summarizes the size and characteristics of the watersheds. Perennial or intermittent surface water in the project area occurs only as very small pools or stock ponds; all of the washes and drainages are ephemeral.

Table 75. Summary of affected watersheds within the project area

Watershed	Drainage Size (acres)	Elevation Range (feet above mean sea level)
Upper Barrel Canyon	1,728	5,400 to 4,800
Lower Barrel Canyon	576	4,950 to 4,550
East Canyon	2,295	5,200 to 4,250
Wasp Canyon	1,408	6,100 to 4,800
McCleary Canyon	1,536	5,700 to 4,550
Scholefield Canyon	2,048	5,800 to 4,400
Papago Canyon	606	5,800 to 4,400
North Canyon	4,069	5,000 to 4,300
Oak Tree Canyon	4,884	5,350 to 4,350
Empire Gulch	14,269	6,400 to 4,300
Box Canyon Wash	22,958	6,600 to 2,700
Sycamore Creek	47,392	6,300 to 2,600

Water Resources Downgradient of the Mine

Most of the surface drainage from the project area leaves via the Barrel Canyon drainage, including Scholefield and Papago Canyons, which drain a small portion of the northeastern part of the project area. Barrel Canyon connects with the Davidson Canyon drainage east of State Route 83, approximately 4 miles downstream of the project area. Farther downstream in the watershed (approximately 14 miles), Davidson Canyon is tributary to Cienega Creek. Cienega Creek is the main surface water drainage in a basin that flows northwest into the Tucson Active Management Area and covers an area measuring approximately 605 square miles in southern Arizona (figure 48). Cienega Creek is an ephemeral stream with significant reaches (approximately 8 miles) of perennial water as it flows through Las Cienegas National Conservation Area. Farther downstream, Cienega Creek discharges into Pantano Wash, which eventually flows into the Santa Cruz River on the northwest side of Tucson. Oak Tree Canyon, North Canyon, and Empire Gulch, which drain a small portion of the southeast of the project area, all flow directly into Cienega Creek upstream of the confluence of Cienega Creek and Davidson Canyon. Both Davidson Canyon and Cienega Creek are outside any area of direct impact from the proposed project but could be indirectly impacted by reductions in ephemeral and perennial stream flow.

Davidson Canyon and Cienega Creek support riparian habitat and are classified by Pima County as important riparian areas. South and east of the project area, Cienega Creek passes through the Las Cienegas National Conservation Area. North of the project area, Cienega Creek passes through the Cienega Creek Natural Preserve, which stretches from just south of Interstate 10 northwest to Colossal Cave Road. The western boundary of the Las Cienegas National Conservation Area is approximately 3 miles from the eastern boundary of the project area.

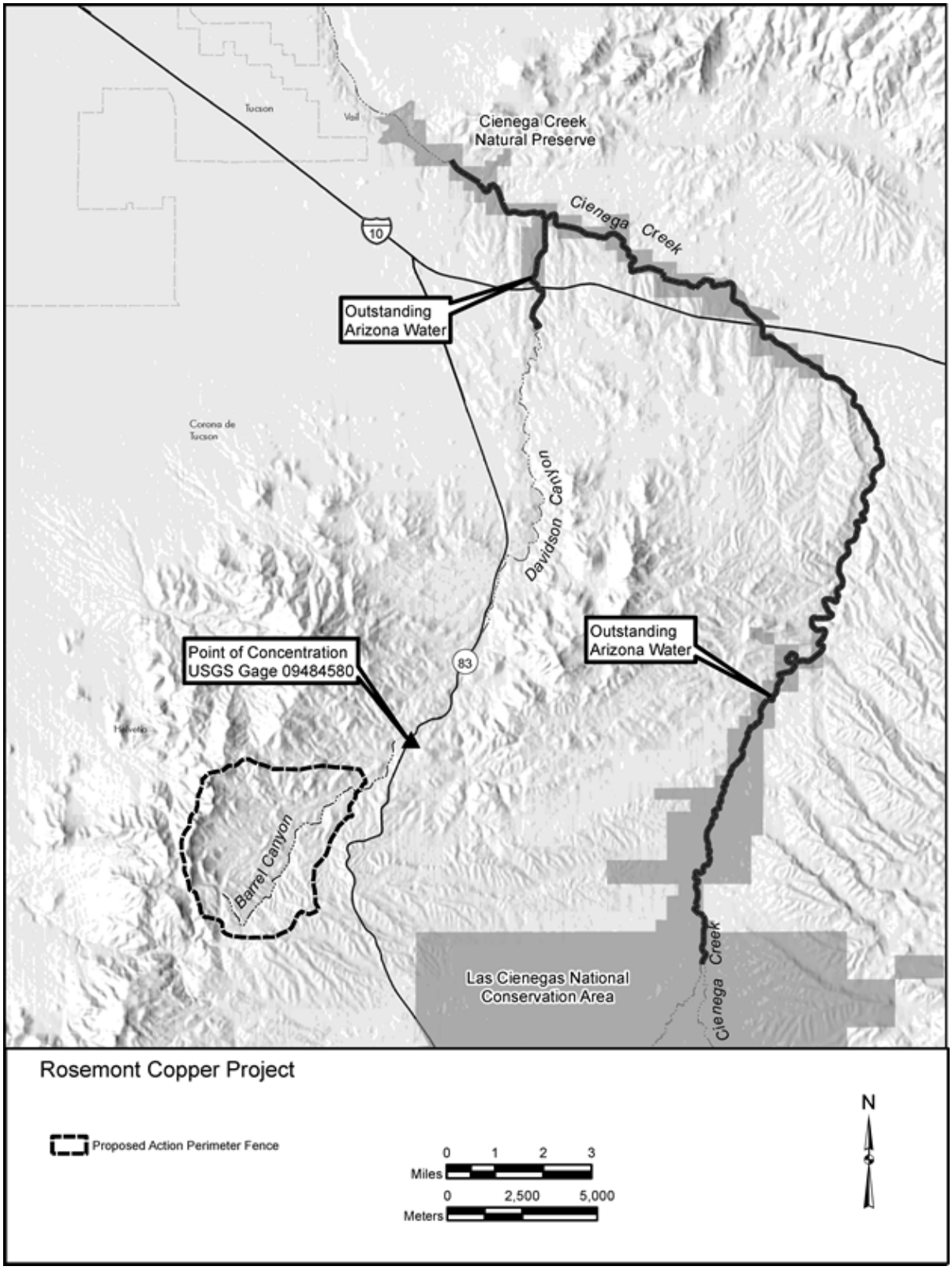


Figure 48. Downgradient surface waters

Cienega Creek is divided into two sections: the upper section, which drains the central valley east of the project area; and the lower section, which flows through a narrow valley and empties into Pantano Wash north of the project area. Between the confluence with Davidson Canyon and the "Narrows" section, impermeable bedrock forces water to the surface, creating stretches of perennial flow. Limited flow data exist for both Davidson Canyon and Cienega Creek; data from U.S. Geological Survey Gage No. 09484550 on Cienega Creek (approximately 8 miles east of the project area) indicate perennial flow at this location from 2000 to 2009 (U.S. Geological Survey 2011).

A reach of Davidson Canyon approximately 11 miles downstream of the project area has been designated an Outstanding Arizona Water by the Arizona Department of Environmental Quality. This reach is identified as a perennial, free-flowing reach; however, field visits conducted in January 2010 to investigate spring flow within Davidson Canyon found that most of the southern portion of the reach was dry (Tetra Tech 2010a). With the exception of small perennial sections, based on data from 1968 through 1975 (Arizona Department of Water Resources 2011a), both Davidson Canyon and Cienega Creek are intermittent streams that flow for limited portions of the year.

Watershed Yield

Various calculations have been made in previous literature concerning the amount of water leaving the area watersheds as runoff. These analyses were made solely on the Barrel and Scholefield Canyon watersheds, which form a total watershed area of approximately 9,000 acres. Estimates of flow leaving these watersheds as runoff range from 900 to 1,500 acre-feet per year (Hargis and Harshbarger n.d. (1978)). At existing conditions, the average annual runoff from contributing watersheds associated with the project area to the point of concentration (U.S. Geological Survey Gage No. 09484580) is estimated to be 1,407 acre-feet (Krizek 2010c).

Streamflow

Flow monitoring at seeps and springs and in washes is an ongoing activity in and around the project area. Runoff from the drainage areas to the point of concentration at U.S. Geological Survey Gage No. 09484580 is typically intermittent and of short duration. Historic peak flow data exist for Barrel Canyon from 1962 through 1976, and there are daily streamflow data after January 23, 2009 (U.S. Geological Survey 2010). The maximum peak flows in major drainages on the project area are related to episodic heavy thunderstorm precipitation during the wet months; all peak flows in Barrel Canyon occurred during the months of July through September. Peak flows recorded annually from 1962 through 1976 at Barrel Canyon range from approximately 150 cubic feet per second to nearly 2,000 cubic feet per second (table 76). The available 2009 flow data indicate that Barrel Canyon is an ephemeral drainage, with only occasional flow. At existing conditions, the 100-year regulatory flood peak at the point of concentration (U.S. Geological Survey Gage No. 09484580) is estimated to be 8,072 cubic feet per second (Krizek 2010c).

Springs and Seeps Inventory

Springs occur when groundwater discharges to the ground surface. The springs and seeps that occur within the project area and surrounding vicinity are attributed to one of several sources: (1) shallow, local, perched aquifers; (2) stormwater flow stored in stream channel sediments and forced to the surface by geological constrictions or fractures; or (3) the deep regional aquifer (Tetra Tech 2010a). The occurrence of springs and seeps is discussed here, but because they are altogether dependent on the local groundwater system, detailed analysis of the impacts to the springs and seeps is discussed in the "Groundwater Quantity" section.

Table 76. Annual peak flows in Barrel Canyon at State Route 83 bridge, 1962 to 1976

Year	Date Peak Flow Occurred	Peak Stage Height (feet)	Peak Flow (cubic feet per second)
1962	Unknown	2.54	140
1963	Unknown	2.57	145
1964	September 10, 1964	4.78	879
1965	September 8, 1965	3.64	480
1966	Unknown	2.97	260
1967	September 1967	3.04	323
1968	July 26, 1968	6.15	1,600
1969	July 23, 1969	1.7	<15.0
1970	July 20, 1970	5.6	1,350
1971	August 1971	6.87	1,900
1972	July 1972	2.92	240
1973	Unknown	1.23	<10.0
1974	September 21, 1974	5.64	1,350
1975	September 13, 1975	4.6	980
1976	August 1976	5.24	1,100

Source: U.S. Geological Survey (2010).

Note: Data are from U.S. Geological Survey gage no. 09484580.

A summary of the seeps and springs in the project area is shown in table 40 in the "Groundwater Quantity" section. Little information has been consistently collected from these springs with respect to flow quantity, frequency, or water quality; data are limited primarily to observations and sampling in 1975 and again in 2006 and 2007. Little can be said about the long-term seasonal variation in these springs; however, based on the discharge measurements collected, all springs exhibit very low rates of discharge. None of the springs in the vicinity of the project area are particularly large; most have flow of less than 1 gallon per minute. Based on the limited monitoring period, only Helvetia and Rosemont Springs seem to have perennial flow (Tetra Tech 2010a). Several of the springs and seeps in the analysis area have been developed in the past, and all of the springs are believed to be being used for stock and wildlife watering as well as recreational purposes.

Surface Water Rights

Surface water rights associated with the project include those located on deeded land, as well as those located on Coronado National Forest land, as summarized in table 77. Identified surface water rights filed with the Arizona Department of Water Resources include diversions from 10 springs (including Questa, Horse Pasture, McCleary, and Rosemont Springs) and multiple diversions from six washes (including Wasp, Barrel, and McCleary Canyons). Priority of these surface water rights has not yet been determined through the General Stream Adjudication.

Table 77. Summary of surface water rights associated with project area

General Location	Water Right Number	Name of Water Source	Cadastral Location
Deeded/Fee Lands	33-93235.2	Questa Spring	D-18-16 27dd
Deeded/Fee Lands	33-93236.2	Horse Pasture Spring	D-18-16 15aa
Deeded/Fee Lands	33-93277.1	Barrel Canyon	D-18-16 29ba
Deeded/Fee Lands	33-93278.1	McCleary Canyon	D-18-16 19cc
Deeded/Fee Lands	33-93279.1	Wasp Canyon	D-18-16 29cd
Deeded/Fee Lands	33-96516.0	Wasp Canyon	D-18-15 36ab

General Location	Water Right Number	Name of Water Source	Cadastral Location
Deeded/Fee Lands	36-25948.1	Rosemont Spring	D-18-16 32bc
Deeded/Fee Lands	36-25954	Unnamed Spring	D-18-15 23ba
Coronado National Forest	38-93308.1	Unnamed Wash	D-18-16 33cc
Coronado National Forest	38-93309.1	Unnamed Wash	D-18-16 34bc
Coronado National Forest	38-93310.1	Unnamed Wash	D-18-15 25dd
Coronado National Forest	36-25911	Wasp Canyon	D-18-15 D-18-16
Coronado National Forest	36-25912	McCleary Canyon	D-18-16
Coronado National Forest	36-25945	McCleary Spring	D-18-16 30ab
Coronado National Forest	36-25946	Unnamed Spring	D-18-16 30cd
Coronado National Forest	36-25947	Unnamed Spring	D-18-16 30cd
Coronado National Forest	36-25950	Unnamed Spring	D-18-16 21bc
Coronado National Forest	36-25951	Unnamed Spring	D-18-16 29ab
Coronado National Forest	36-25956	Unnamed Spring	D-18-16 19cd

Source: Pearce (2007).

Stock Tanks

Ongoing grazing activities and associated stock tank development and maintenance occur on and around the project area. Stock tanks associated with the project include those located on deeded land and on Coronado National Forest land, as summarized in table 78. Data were obtained from Arizona Department of Water Resources Surface Water Rights and Statement of Claimant databases as well as from U.S. Geological Survey topographic maps. The water source that feeds these stock ponds varies. Most commonly, the stock ponds are constructed earthen berms within drainages that impound surface runoff. There are several stock ponds in the project area that are known to be fed by springs and that have been developed with concrete structures to capture spring flow (WestLand Resources Inc. 2010a).

Table 78. Summary of stock tanks associated with project area

Watershed	Water Right Number	Name of Water Source	Cadastral Location
Barrel Canyon	38-57582	Stock Tank*	D-19-16-06ab
Wasp Canyon	38-26056	Upper Barrel Tank†	D-18-15-25dc
East Barrel Canyon	38-49861	Section 33 Tank*	D-18-16-33cc
Barrel Canyon	38-70799	Unnamed Stock Tank*	D-19-16-05bc
Barrel Canyon	38-24457	Barrel Tank‡	D-19-16 06dd
Barrel Canyon	38-62339	North Basin Tank 2‡	D-19-16 05bc
East Barrel Canyon	38-70879	Section 33 Tank	D-18-16-33cc
Barrel Canyon	Coronado National Forest	Unnamed Tank‡	D-18-16 32c
East Barrel Canyon	38-26061	Dirt Tank†‡	D-18-16 33cc
Davidson Wash		Unnamed Tank‡	D-17-17-07b
Davidson Wash		Unnamed Tank‡	D-17-16-36a
McCleary Canyon	Asarco	Unnamed Stock Pond†	D-18-16-19cc
McCleary Canyon	38-26053	McCleary Tank†	D-18-16-30bb
Barrel Canyon	38-62329	South Basin 4 Tank*	D-19-16-06dd
Upper Barrel Canyon	38-70161	East Dam Header Tank*	D-18-16-29ac
Barrel Canyon		East Dam Tank‡	D-18-16 28ac
Barrel Canyon	38-40329	North Basin Tank*	D-19-16 05bc
Upper Barrel Canyon	38-70775	North Dam Header Tank*	D-18-16-29ac

Watershed	Water Right Number	Name of Water Source	Cadastral Location
Box Canyon		Unnamed Tank[§] (2 tanks)	D-19-15 01da
Davidson Canyon		Unnamed Tank[§]	D-18-16 01ab
Wasp Canyon	38-70881	Section 25*	D-18-15-25dd
Davidson Wash	38-63384	4th of July Tank*	D17-17-30ab
Davidson Wash	38-66914	Unnamed Stock Tank*	D17-17-30cd

* Data are from Arizona Department of Water Resources (Arizona Department of Water Resources 2011b) Surface Water Filings database.

[†] Data are from Arizona Department of Water Resources (2005) Statement of Claimant database.

[‡] Data are from U.S. Geological Survey Map/Geographic Names Information System.

[§] Data are from U.S. Forest Service (2011c).

Environmental Consequences

This section presents only impacts associated with surface water quantity. Impacts to riparian habitat are discussed in the “Biological Resources” section, and impacts to springs and seeps are discussed in the “Groundwater Quantity” section.

Direct and Indirect Effects of Each Alternative

Specific impacts analyzed for each alternative include surface water peak flows, average annual surface water flow volume, and number of stock tanks both directly and indirectly impacted. Surface water flows from the project area were calculated in both cubic feet per second and acre-feet per year to the U.S. Geological Survey gage located by the State Route 83 bridge.

No Action Alternative

Under baseline conditions (no action), surface water within the project area consists solely of stock tanks or ephemeral flows that occur as the result of precipitation events. Although springs and seeps occur within the project area, spring flow has not been found to provide any significant base flow to local washes (Montgomery and Associates Inc. 2009). The no action alternative would result in no further impacts to the quantity of surface water resources. Grazing will continue. Stock tanks, springs, and seeps will continue to be monitored and maintained for use by stock and wildlife. Ephemeral washes on the project area will continue to flow in response to precipitation.

Impacts Common to All Action Alternatives

The following elements are common to all action alternatives:

- Pit location and operations size
- Production rates and processing facility output
- Mineral processing operations and techniques and use of similar major mining equipment
- Overall footprint of the general plant site—arrangement of the facilities may differ
- Location of heap leach
- Stormwater that has come in contact with the mine pit, ore processing facilities, or mine maintenance plant areas (contact water) would be prohibited from surface discharge by the stormwater permit. Stormwater diversion channels would be constructed to route non-contact

surface water runoff around the project area and from undisturbed areas within the project to natural drainages downgradient from the mine site.

- Surface runoff that has not come into contact with tailings would be directed from the outer waste rock shell slopes into sediment ponds using minor diversion channels.
- Stormwater from above the mine pit would be diverted around disturbed areas to the extent practical. Stormwater that falls within the mine pit and associated disturbed areas, especially stormwater that comes into contact with ore, would be contained onsite and used for mining and processing purposes.
- Concurrent reclamation and appropriate best management practices would progress up the outer slopes of the waste rock facility as buttresses are constructed. This would limit erosion potential, while minor diversion channels would be used to direct noncontact runoff to downgradient sediment ponds.
- Stormwater from the waste rock and tailings facilities, including the waste rock buttresses that are not reclaimed or stabilized, would be routed to sediment control structures, where any overflow discharging offsite would be monitored for chemical and sediment content in accordance with the mining stormwater general permit.
- Primary access to the operations will be State Route 83.
- Infrastructure requirements—water and power will be delivered to the mine from the west, and small areas of disturbance to Sycamore Canyon and Box Canyon Wash located west of the crest of the Santa Rita Mountains will occur because of perimeter fencing, access roads, and utility lines.
- Approximate width associated with the power line is assumed to be 100 feet.
- Width associated with the water pipeline is assumed to be 50 feet, including berms and maintenance access.
- Access roadway width for the primary road is 70 feet and for the secondary road is 20 feet, including safety berms and shoulders.
- Potential formation of a pit lake following mine closure.

For each action alternative, as mining operations progress over time, ephemeral stormwater flows from the project area will change, primarily as the result of retention of water from certain portions of the mine and from changes in surface topography and characteristics from disturbed areas such as the pit, operating facilities, and tailings and waste rock disposal areas.

All of the action alternatives will result in alteration of the natural surface hydrology. Impacts related to surface water quantity that are common to all action alternatives include the modification of stormwater peak flows, modification to overall runoff volume from the watersheds, and direct loss of stock tanks. The direct loss of springs through dewatering or surface disturbance is discussed in the “Groundwater Quantity” section, and the direct loss of riparian areas is addressed in the “Biological Resources” section. Changes in erosion potential resulting from changes in ephemeral flows are assessed in the “Surface Water Quality” section.

Direct impacts to stock tanks will occur under all action alternatives and are discussed below.

Direct—Loss of Stock Tanks

Stock tanks will be directly lost as a result of surface disturbance under all alternatives except for the no action alternative. Based on a review of U.S Geological Survey topographic maps and Arizona

Department Water Resources database (Arizona Department of Water Resources 2011b), expected stock tank losses per action alternative range from 8 to 19 and are summarized in table 79.

Table 79. Direct impacts to stock tanks by alternative

Alternative	Stock Tanks Lost	Names of Stock Tanks	Estimated Total Capacity Lost per Alternative (acre-feet per year)
No Action	0		
Proposed Action	15	Upper Barrel Tank Barrel Tank North Basin Tank 2 McCleary Tank South Basin 4 Tank East Dam Header Tank North Basin Tank North Dam Header Tank Section 25 6 Unnamed Tanks	90
Phased Tailings	15	Upper Barrel Tank Barrel Tank North Basin Tank 2 McCleary Tank South Basin 4 Tank East Dam Header Tank North Basin Tank North Dam Header Tank Section 25 6 Unnamed Tanks	90
Barrel	19	Upper Barrel Tank 2 Section 33 Tanks Barrel Tank North Basin Tank 2 Dirt Tank McCleary Tank South basin 4 Tank East Dam Header Tank East Dam Tank North Basin Tank North Dam Header Tank Section 25 6 Unnamed Tanks	114
Barrel Trail	19	Upper Barrel Tank 2 Section 33 Tanks Barrel Tank North Basin Tank 2 Dirt Tank McCleary Tank South basin 4 Tank East Dam Header Tank East Dam Tank North Basin Tank North Dam Header Tank Section 25 6 Unnamed Tanks	114

Alternative	Stock Tanks Lost	Names of Stock Tanks	Estimated Total Capacity Lost per Alternative (acre-feet per year)
Scholefield-McCleary	8	Upper Barrel Tank McCleary Tank East Dam Header Tank East Dam Tank North Dam Header Tank Section 25 Tank 2 Unnamed Tank	48

The capacity of each individual stock tank is not known, but Arizona Department Water Resources (Arizona Department of Water Resources 2011b) records indicate that stock tanks in the project area each use from approximately 0.1 to 6.0 acre-feet of water per year. Assuming all the stock tanks directly impacted by the project area have the capacity to hold 6.0 acre-feet of water per year, the estimated total capacity lost per alternative would range from 48 to 114 acre-feet per year. These direct losses of stock tanks are considered to be significant.

Direct—Loss of Stormwater Flows

Stormwater peak flows and volume for all action alternatives were modeled using the U.S. Army Corps of Engineers' computer program Hydrologic Engineering Center Hydrologic Modeling System, Version 3.4 (Chee 2010; Krizek 2010a, 2010b, 2010c, 2010d). Modeling results were validated using the U.S. Geological Survey Bulletin 17B statistical analysis and Region 13 Regional Regression Equation. The direct effects on stormwater peak flows and volume are proportionate to the contributing area for each alternative, which varies by action alternative. Table 80 provides a summary of the alternatives and their impacts on various watersheds; details are presented for each action alternative.

Table 80. Impacts to surface runoff by alternative

Alternative	Contributing Drainage Area (square miles)	Watersheds with Major Impacts	Change in Runoff Volume
No Action	14	None	NA
Proposed Action	6.82	Barrel, McCleary, Wasp	Reduced by 45.8% from baseline
Phased Tailings	7.06	Barrel, McCleary (delayed 10 years), Wasp	Reduced by 44.3% from baseline
Barrel	8.65	Barrel, McCleary, Wasp	Reduced by 33.8% from baseline
Barrel Trail	7.56	Barrel, McCleary, Wasp	Reduced by 42% from baseline
Scholefield-McCleary	10.35	Barrel, Wasp, Scholefield	Reduced by 22.8% from baseline

Note: NA = Not applicable.

With respect to modification of stormwater peak flows and volume, reductions in runoff are primarily important because they indirectly impact the water availability for downstream use. Ephemeral flows, such as those found throughout the project area, are of importance as follows: (1) to downstream user surface water rights, (2) for sustaining riparian vegetation, (3) for wildlife, (4) in some cases to supply spring flow, and (5) for groundwater recharge in the channel. This section addresses the downstream users; indirect impacts from reduced stormwater flow to riparian vegetation and wildlife are discussed in the "Biological Resources" section. The reduction of in-channel groundwater recharge and indirect impacts to springs, including several springs in Davidson Canyon (Reach

2 Spring, Escondido Spring) believed to rely on ephemeral flows stored in shallow alluvial sediments, are discussed in the "Groundwater Quantity" section.

With respect to downstream users, because of the flashy nature of ephemeral flows, in-channel storage such as a reservoir or stock tank would be required in order to use any significant amount of ephemeral flow. No reservoirs are located within the analysis area; however, there are stock tanks located on the downstream channels that would be impacted under all action alternatives. Modification of stormwater peak flows and volume is also important for erosion potential and threat to property and human health and safety.

Indirect impacts to beneficial uses

It is expected that all action alternatives would have an indirect effect on Davidson Canyon as a result of the changes in surface flow patterns in the project area. The average annual runoff for Davidson Canyon Wash at its confluence with Cienega Creek was modeled for the proposed action alternative using regression equations. Model results show that runoff for the proposed action is predicted to be reduced from 514 acre-feet for existing conditions to 464 acre-feet for postmine conditions, slightly less than a 10 percent reduction once postmine conditions are considered (Zeller 2011). Runoff estimates at the confluence of Davidson Canyon Wash and Cienega Creek were not modeled for the remaining action alternatives; however; they can be approximated base on the estimate that the project area constitutes about 16 percent of the total Davidson Canyon watershed (Tetra Tech 2010a). Given that stormwater flows from the project area for the remaining action alternative would be reduced by 22.8 to 44.3 percent; stormwater flow in the Davidson Canyon watershed is estimated to be reduced by 3.6 to 7.1 percent.

Specific surface water quantity impacts remaining after implementation of stormwater mitigation measures that are common to all action alternatives would include indirect impacts to downstream water users such as impoundment features and riparian vegetation. The significant use of ephemeral flows can typically only be accomplished through in-channel impoundments like reservoirs or stock tanks; water use by riparian vegetation and wildlife would also be considered a beneficial use. Based on the Arizona Department of Water Resources surface water filing database (Arizona Department of Water Resources 2011b), all surface water filings in Davidson Canyon downstream of the project area are stock tanks.

Indirect impacts to downstream riparian and wildlife

Indirect impacts to downstream water use by riparian vegetation and wildlife as a result of reduction in ephemeral stream flow are detailed in the "Biological Resources" section.

Indirect impacts to downstream recreation

Ephemeral flows typically do not support any specific recreation opportunities. Indirect impacts to surface water used for recreation would be minor and are considered insignificant.

Indirect impacts to downstream stock tanks

Downstream stock tanks would be indirectly impacted under all action alternatives as a result of a reduction in ephemeral storm flows. The stock tanks impacted are shown in table 81.

Table 81. Indirect impacts to downstream stock tanks

Alternative	Watershed	Name of Water Source	Cadastral Location
Scholefield-McCleary	Barrel Canyon	Unnamed Tank	D-18-16 32c
Proposed Action and Phased Tailings	Barrel Canyon	East Dam Tank	D-18-16 28ac
All Action Alternatives	Davidson Canyon	Unnamed Tank	D-17-17 07b
All Action Alternatives	Davidson Canyon	Unnamed Tank	D-17-16 36a
All Action Alternatives	Davidson Canyon	4th of July Tank	D-17-17 03ab
All Action alternatives	Davidson Canyon	Unnamed Tank	D-18-16 01ab
All Action Alternatives	Davidson Canyon	Unnamed Stock Tank	D-17-17 03cd

All action alternatives will indirectly impact five downstream stock tanks in Davidson Canyon. Three of the action alternatives (proposed action, Phased Tailings, and Scholefield-McCleary) will indirectly impact one additional downstream stock tank in Barrel Canyon. The capacity of each individual stock tank that will be indirectly impacted is not known; however, Arizona Department of Water Resources (Arizona Department of Water Resources 2011b) records indicate that stock tanks downstream of the project area each use approximately 0.1 to 14.6 acre-feet of water per year. Assuming that all the stock tanks indirectly impacted by the project have the capacity to hold 14.6 acre-feet per year, an estimate of total capacity lost is 73 to 87.6 acre-feet per year, depending on the action alternative.

The proposed action will indirectly impact a total of six downstream stock tanks; considering that the average annual runoff of storm flow from the proposed action is 762 acre-feet (table 82), it would take a small portion of the total flow (approximately 11.5 percent) to fill all of the impacted stock tanks. As for the remaining action alternatives, the requirement of total flow to fill the impacted stock tanks would be less (7.8 to 11.2 percent).

Because flow volumes from each action alternative would be more than sufficient to fill downstream stock tanks that would be indirectly impacted by any action alternative, this impact to downstream users is considered insignificant.

Proposed Action

A total area of 6,226 acres is within the perimeter fenceline for the proposed action. The majority of disturbance would occur in Barrel, Wasp, McCleary, and Scholefield Canyons. There are very small areas where the perimeter fence extends into canyons to the east—44.6 acres in Oak Tree Canyon and 73.9 acres in Empire Gulch Canyon. No project facilities or features, however, are proposed to be located in these eastern watersheds. Surface water management facilities include stormwater basins and diversions around the facility to convey storm events that occur upgradient of the pit, operating facilities, waste rock, and tailings storage areas. These diversion structures would place the water into a central drain intended to provide hydraulic connection between the upgradient side of the project area and the downgradient side; therefore, runoff from any watershed area located upgradient of the proposed action is expected to arrive at the U.S. Geological Survey gaging station (Krizek 2010c). Permanent diversion structures are designed to carry at least the 100-year, 24-hour storm event; drainage features to transfer stormwater from the top of the dry-stack tailings are designed to carry the 500-year, 24-hour storm; and stormwater control basins on top of the wide benches in the waste rock storage area are designed to contain storm flows up to the 500-year, 24-hour storm event (Krizek 2010c; Tetra Tech 2010h).

Table 82 summarizes the modeled watershed yield from baseline and proposed conditions.

Table 82. Summary of expected changes to stormwater flow under the proposed action

Condition	Discharge Area (square miles)	100-year, 24-hour Peak Flows (cubic feet per second)	Average Annual Volumes (acre-feet)	Change in 100-year, 24-hour Peak Flows (%)	Percent Change in Average Annual Volumes (%)
Baseline*	14	8,072	1,407	–	–
Proposed Action*	6.82	3,785	762	−53.1	−45.8

Source: Krizek (2010c).

* At point of concentration: U.S. Geological Survey gage no. 09484580.

Phased Tailings Alternative

A total area of 6,122 acres is within the perimeter fence line for the Phased Tailings Alternative, which allows for the tailings to be stored in two separate phases, effectively isolating the tailings footprint to an area of Barrel Canyon and leaving McCleary Canyon open for a period of approximately 10 years. There are very small areas where the perimeter fence extends into canyons to the east—44.6 acres in Oak Tree Canyon and 73.9 acres in Empire Gulch Canyon. No project facilities or features, however, are proposed to be located in these eastern watersheds.

Stormwater controls include basins and diversions around the facility to convey storm events that occur upgradient of the pit, operating facilities, waste rock, and tailings storage areas. Surface water drainage channels would be placed every 100 feet of vertical rise on the outer slopes of the dry-stack tailings and waste rock facility. Stormwater would flow to stilling pools/drop-structures, natural ground, or stormwater basins. Drop structures located on the east side of the dry-stack tailings facility would drain to the U.S. Geological Survey gaging station facility. Other diversion structures would place the water into a central drain or pond; therefore, runoff from any watershed located upgradient of the Phased Tailings Alternative is not expected to arrive at the U.S. Geological Survey gaging station (Krizek 2010a). Permanent diversion structures would be designed to carry at least the 100-year, 24-hour storm event; the top of the dry-stack tailings and stormwater control basins in the waste rock storage area are expected to contain storm flows up to the 500-year, 24-hour storm event.

Table 83 summarizes the modeled watershed yield from baseline and Phased Tailings Alternative conditions.

Table 83. Summary of expected changes to stormwater flow under Phased Tailings Alternative

Condition	Discharge Area (square miles)	100-year, 24-hour Peak Flows (cubic feet per second)	Average Annual Volumes (acre-feet)	Change in 100-year, 24-hour Peak Flows (%)	% Change in Average Annual Volumes (%)
Baseline*	14	8,072	1,407	–	–
Phased Tailings*	7.06	4,044	784	−49.9	−44.3

Source: Krizek (2010a).

* At point of concentration: U.S. Geological Survey gage no. 09484580.

Barrel Alternative

A total area of 6,859 acres is within the perimeter fenceline for the Barrel Alternative, for which the dry-stack tailings and waste rock would be confined to Barrel Canyon. Primary access to the site

would be in the McCleary Canyon and Barrel Drainage areas and would cross into Scholefield Canyon near the intersection with State Route 83. There are very small areas where the perimeter fence extends into canyons to the east—55.6 acres in Oak Tree Canyon and 73.9 acres in Empire Gulch Canyon. No project facilities or features, however, are proposed to be located in these eastern watersheds.

Stormwater controls for this alternative include basins and diversions around the facility to convey storm events upgradient of the pit, operating facilities, waste rock, and tailings storage areas. A total of 16,460 feet of permanent diversion structures would be designed to carry at least the 100-year, 24-hour storm event. Surface water drainage channels would be placed every 100 feet of vertical rise on the outer slopes of the dry-stack tailings. Stormwater would flow to stilling pools/drop-structures, natural ground, or rock slopes adjacent to the waste rock storage area. A portion of the diversion channel would route stormwater runoff around the plant site area to McCleary Canyon Wash, which would eventually drain to the U.S. Geological Survey gaging station facility; drop structures located on the west side of the dry-stack tailings facility would drain to the U.S. Geological Survey gaging station as well. Stormwater runoff from the pit diversion and other runoff from any watershed located upgradient of the Barrel Alternative are expected to arrive at the U.S. Geological Survey gaging station (Krizek 2010b). Permanent diversion structures would be designed to carry at least the 100-year, 24-hour storm event; the top of the dry-stack tailings and stormwater control basins in the waste rock storage area are expected to contain storm flows up to the 500-year, 24-hour storm event.

The heap leach facility would be located in the Barrel Drainage within the tailings facility footprint. Drainage around the facility is sufficient to contain the 100-year, 24-hour storm event with pumping capacity to manage additional flows. During operation, perimeter berms and buttresses would be located in the Barrel Drainage and would serve as ultimate containment if there were a breach of the heap leach facility. After closure, the heap leach would be covered by waste rock and is not expected to come into contact with precipitation or runoff.

Table 84 summarizes the modeled watershed yield from baseline and Barrel Alternative conditions.

Table 84. Summary of expected changes to stormwater flow under Barrel Alternative

Condition	Discharge Area (square miles)	100-year, 24-hour Peak Flows (cubic feet per second)	Average Annual Volumes (acre-feet)	Change in 100-year, 24-hour Peak Flows (%)	% Change in Average Annual Volumes (%)
Baseline*	14	8,072	1,407	–	–
Barrel Alternative*	8.65	5,254	932	−34.9	−33.8

Source: Krizek (2010b).

* At point of concentration: U.S. Geological Survey gage no. 09484580.

Barrel Trail Alternative

A total area of 6,859 acres is within the perimeter fence line for the Barrel Trail Alternative, for which the dry-stack tailings and waste rock would be confined to Barrel Canyon and an unnamed tributary of Barrel Canyon. The majority of disturbance for this alternative would occur in Barrel, Wasp, McCleary, and Scholefield Canyons. There are very small areas where the perimeter fence extends into canyons to the east—55.6 acres in Oak Tree Canyon and 73.9 acres in Empire Gulch Canyon. No project facilities or features, however, are proposed to be located in these eastern watersheds.

Stormwater controls for this alternative include basins and diversions around the facility to convey storm events upgradient of the pit, operating facilities, waste rock, and tailings storage areas. The largest stormwater control feature associated with this alternative is the new Barrel Canyon drainage. Its alignment runs between the dry-stack tailings and the waste rock storage. This drainage feature would be stepped, with sloping channel segments and stilling pools, and the channel would be designed to convey stormwater runoff from the reclaimed surface. The south side of the waste rock storage area would retain runoff detention basins for the 500-year, 24-hour event. Volumes exceeding that would be routed down the waste rock slopes to sediment basin. The east side of the waste rock storage area has a ridge running adjacent to State Route 83 that would serve as a drainage divide for the benches. Stormwater on the east side of the ridge would eventually flow to the U.S. Geological Survey gaging station. Stormwater controls associated with the dry-stack tailings facility would consist of drainage benches and drop structures; pooling on top surfaces of the facility would be limited. Stormwater runoff from the pit diversion channel south of the open pit is expected to be retained between the toe of the waste rock storage area and an adjacent natural ridge and would not drain to the U.S. Geological Survey gaging station (Chee 2010).

Table 85 summarizes the modeled watershed yield from baseline and Barrel Trail Alternative conditions.

Table 85. Summary of expected changes to stormwater flow under Barrel Trail Alternative

Condition	Discharge Area (square miles)	100-year, 24-hour Peak Flows (cubic feet per second)	Average Annual Volumes (acre-feet)	Change in 100-year, 24-hour Peak Flows (%)	Percent Change in Average Annual Volumes (%)
Baseline*	14	8,072	1,407	–	–
Barrel Trail Alternative*	7.56	4,845	816	−40.0	−42.0

Source: TetraTech (Chee 2010).

* At point of concentration: U.S. Geological Survey Gage No. 09484580.

Scholefield-McCleary Alternative

A total area of 7,208 acres is within the perimeter fenceline for the Scholefield-McCleary Alternative, for which the dry-stack tailings would be located entirely within Scholefield Canyon and waste rock would be located outside canyon bottoms within McCleary Canyon and between Wasp and Barrel Canyons. The majority of disturbance for this alternative would occur in the four major drainages (Barrel, Wasp, McCleary, and Scholefield Canyons). Stormwater controls for this alternative include basins and diversions around the facility to convey storm events upgradient of the pit, operating facilities, waste rock, and tailings storage areas. Surface water drainage benches would be placed every 100 feet of vertical rise on the outer slopes of the dry-stack tailings and waste rock storage areas. Stormwater would flow to stilling pools/drop structures or to natural ground. A portion of the diversion channel would route stormwater runoff around the plant site area to Barrel Canyon Wash, which would eventually drain to the U.S. Geological Survey gaging station. Stormwater from drainage benches and pit diversion would drain to the U.S. Geological Survey gaging station as well. Stormwater from other runoff from any watershed located upgradient of the Scholefield-McCleary Alternative is not expected to arrive at the U.S. Geological Survey gaging station (Krizek 2010d). Permanent diversion structures would be designed to carry at least the 100-year, 24-hour storm event; the top of the dry-stack tailings and stormwater control basins in the waste rock storage area are expected to contain storm flows up to the 500-year, 24-hour storm event.

Table 86 summarizes the modeled watershed yield from baseline and Scholefield-McCleary Alternative conditions.

Table 86. Summary of expected changes to stormwater flow under Scholefield-McCleary Alternative

Condition	Discharge Area (square miles)	100-year, 24-hour Peak Flows (cubic feet per second)	Average Annual Volumes (acre-feet)	Change in 100-year, 24-hour Peak Flows (%)	Percent Change in Average Annual Volumes (%)
Baseline*	14	8,072	1,407	–	–
Scholefield-McCleary Alternative*	10.35	5,689	1,086	−29.5	−22.8

Source: Krizek (2010d).

* At point of concentration: U.S. Geological Survey gage no. 09484580.

Because the proposed action presents challenges with regard to long-term management of stormwater flows and because the Phased Tailings and Barrel Alternatives have fewer overall impacts than the proposed action, WestLand Resources Inc. (2010a) concluded that either the Phased Tailings or Barrel Alternatives would be the least environmentally damaging practicable alternative for the project. With respect to impacts to stormwater quantity and data presented here, the Scholefield-McCleary Alternative is the least damaging because it directly impacts only eight stock tanks, and the reduction in peak flows and runoff is the lowest of all action alternatives.

Cumulative Effects

The Council on Environmental Quality defines a cumulative impact as “the impact on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable actions regardless of what agency (federal or nonfederal) or person undertakes such other actions” (40 Code of Federal Regulations 1508.7). As outlined in the chapter 3 introduction, cumulative impacts of past and present actions are identified and analyzed in the “Affected Environment” part of each resource section, including for “Surface Water Quantity.” 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 chapter 3 introduction. The following reasonably foreseeable action from that list was determined to contribute to a cumulative impact to surface water quantity:

- Potential expansion of limestone quarry in the Davidson Canyon drainage system northeast of the Santa Rita Mountains.

The expansion of the limestone quarry in the Davidson Canyon drainage system would be expected to have an impact to surface water quantity from possible direct impacts to washes and instream flow. This project would most likely disturb stock tank in the watershed and contribute to changes in flow in Davidson Canyon.

Mitigation Effectiveness

Several mitigation measures will be implemented to minimize impacts to surface water quantity, including the following:

- Development of a Rosemont Water Source Enhancement and Mitigation Plan

- Diversion of surface water from undisturbed areas of the watershed around mining activities
- Construction of a surface water control dam
- Reclamation of mine facilities following mine closure
- Replacement of stock tanks that are lost in the project area
- Revegetation with native seed mix and tree plantings to reduce the potential for erosion

The Rosemont Water Source Enhancement and Mitigation Plan will be developed to include the expanse of the Rosemont Ranch lands that surround the Helvetia and Rosemont Mining districts and shall demonstrate no net loss in numbers of surface water sources for livestock and wildlife. This includes both seasonal and permanent stock tanks, seeps, and springs. For each individual source of surface water lost to wildlife or grazing use, whether through direct or indirect project related impacts, the Rosemont Water Source Enhancement and Mitigation Plan will identify mitigation sources that will be created to provide a replacement water source in the area impacted. Therefore, the remaining effect would be no net loss of stock tanks in the Rosemont Copper's Forest Service grazing permits. This mitigation effort will reduce any significant direct loss of stock tanks to negligible levels. This action will not mitigate for any indirect impacts to stock tanks located downstream of and outside the grazing permit area.

As for stormwater diversion, where stormwater rules and management plans allow, diversions consistent with topography shall be designed and operated to route stormwater efficiently through or around project facilities and to transport runoff water to downstream watersheds.

Reclamation of the mine facility will occur after mine closure in accordance with the final Rosemont Reclamation Plan, which will identify specific areas to be developed for the post-mining land use for surface water drainages. To help mitigate erosion, the reclamation plan will specify the density and sizes of native riparian species to plant along artificial diversions commensurate with the types of vegetation that would naturally occur with that type of flow regime and will specify reclamation goals and methods for the postmining conditions. These mitigation efforts will be developed in cooperation with the Coronado, Bureau of Land Management, U.S. Army Corps of Engineers, U.S. Fish and Wildlife Service, and other agencies as appropriate and will be detailed in a mitigation land plan as required.

Additional proposed measures are designed for monitoring surface water resources and include sharing surface water data. For the purpose of obtaining surface water flow data, Rosemont Copper will annually fund the U.S. Geological Survey to operate and maintain the existing surface water flow measurement gage at Barrel Canyon (gage no. 09484580). Rosemont Copper will also perform periodic monitoring and maintenance of spillways, diversions, and other permanent surface water facilities in accordance with specific permit conditions. To share these data, a Rosemont Copper Mine water website will be constructed, updated annually, and maintained by Rosemont Copper, with concurrence by the Coronado. All water related data and reports will be accessible to the general public at this location, including all surface water quantity data and monitoring reports.

Construction of a surface water control dam located in Lower Barrel Canyon is for the most part primarily designed to allow collection of surface water samples and would have little impact to surface water quantity. As such, impacts to surface water quantity would still occur under each alternative.

Irretrievable and Irreversible Commitment of Resources

As for surface water quantity, the loss of stock tanks that would be directly impacted by the footprint of mining operations associated with any action alternative would be irretrievable. There is a commitment from Rosemont Copper to replace the stock tanks in the area impacted; therefore, the surface water resource associated with stock tanks would not be irreversible. With respect to surface water flows from the project area, all action alternatives would result in some variation of irreversible and irretrievable commitment of surface water resources, with each action alternative resulting in varying amounts of indirect loss to ephemeral flow in downstream drainages.

Surface Water Quality

Introduction

This section discusses the quality of existing surface water resources in the project area and analysis area. Surface water resources are the same as those listed for "Surface Water Quantity."

The analysis area for surface water quality is based on the same considerations as those listed for "Surface Water Quantity." Downstream surface water drainages within the analysis area include the immediate sub-watersheds and the Davidson Canyon watershed, which receives discharge from the project area and is tributary to lower Cienega Creek. The analysis area is depicted in figure 49.

Issues, Cause and Effect Relationships of Concern

Two significant issues were identified concerning surface water quality.

Issue 3E: Surface Water Quality

Construction and operation of tailings, waste rock, and leach facilities may result in sediment or other pollutants reaching surface water and degrading water quality, leading to a loss of beneficial uses. Sediment may enter streams, increase turbidity, and exceed water quality standards. Downstream segments of Davidson Canyon and Cienega Creek have been designated Outstanding Arizona Waters by the Arizona Department of Environmental Quality. Outstanding Arizona Waters are Tier 3 waters for antidegradation purposes and are given the highest level of antidegradation protection.
As outstanding resource waters, Tier 3 waters must be maintained and protected, with no degradation in water quality allowed.

Issue 3E Factors for Alternative Comparison

- Ability to meet Arizona Surface Water Quality Standards
- Area (in acres) and locations that may be affected by surface water quality impacts and the duration (in years) of those impacts

Issue 4: Impacts on Springs, Seeps, and Riparian Habitats

This issue relates to the potential impacts on riparian and wetland habitat that would result from the alteration of surface and subsurface hydrology from the pit and other operations. Potential impacts may include loss of riparian habitat and fragmentation of riparian habitat and corridors, including Cienega Creek.

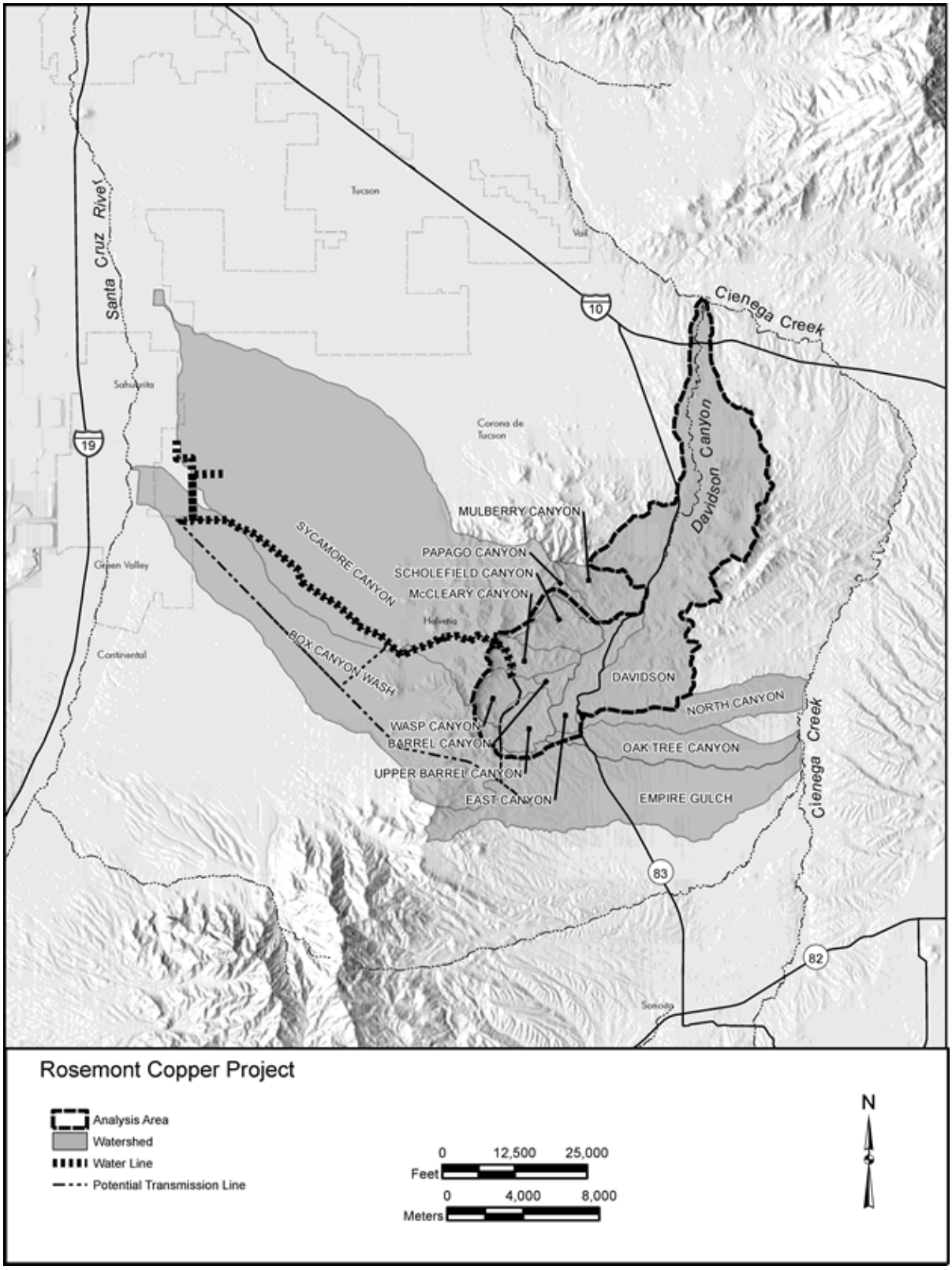


Figure 49. Analysis area for surface water quality

Issue 4 Factors for Alternative Comparison

- Riparian habitat disturbed, unique or uncommon riparian habitat disturbed, and wildlife corridors disturbed (acres)
- Riparian habitat lost and unique or uncommon riparian habitat lost (acres)
- Seeps and springs degraded or lost (number)
- Qualitative assessment of ability to meet legal and regulatory requirements for riparian areas

Riparian issue factors that address springs and seeps as well as qualitative impacts to riparian areas are analyzed in the "Groundwater Quantity" section.

The following factors have also been analyzed in order to provide a complete analysis of surface water quality impacts:

- Area of potentially jurisdictional waters of the United States impacted (acres)
- Area of total riparian habitat impacted as identified by site-specific survey (acres)
- Area of important riparian areas designated by Pima County impacted (acres)

Only changes in surface water quality are presented in this section. Impacts on riparian habitat and wildlife corridors are detailed in the "Biological Resources" section, and impacts on seeps and springs are discussed in the "Groundwater Quantity" section of this DEIS.

Analysis Methodology, Assumptions, Uncertain and Unknown Information

The methodology for assessing changes in surface water quality consists of four components. First, the potential for acid rock drainage impacts on surface water is qualitatively assessed. Second, the expected changes in sediment yield (specifically, total suspended solids concentrations) from the project area to the U.S. Geological Survey stream gage in Lower Barrel Canyon are modeled using the 1968 Pacific Southwest Inter-Agency Committee method (Pacific Southwest Inter-Agency Committee 1968). The potential for downstream scour or aggradation caused by changes to upstream sediment yield is assessed based on the watershed area disturbed by the mine relative to the overall watershed area of Barrel and Davidson Canyons. The same modeling is carried out under baseline conditions for all action alternatives, except for the Barrel Alternative, for which modeling is still pending. Because the watershed area for the Barrel Alternative is very similar in size to the Barrel Trail Alternative, estimates for sediment analysis for the Barrel Alternative were interpolated, which will serve the analysis purposes until the Barrel Alternative analysis can be completed. Third, the potential for contaminants other than sediment to enter natural drainage ways is qualitatively assessed. Fourth, the requirements for discharge control under Clean Water Act permits are qualitatively assessed.

Impacts to riparian habitat are assessed in detail in the "Biological Resources" section. Impacts to riparian vegetation resulting from the potential reduction in spring flow or streamflow are addressed in the "Groundwater Quality" section.

All analyses presented are based on expert resource reports generated to date. Sediment yield modeling has been performed for only the portion of the Barrel Canyon watershed upstream of the U.S. Geological Survey stream gage. Based on the proportion of the modeled area to the Davidson Canyon watershed as a whole, qualitative estimates of sediment yield for the remainder of the downstream watershed were made.

Approval of the preliminary jurisdictional waters delineation was completed on November 1, 2010, by the U.S. Army Corps of Engineers. Using geographic information system overlays, the direct impacts to potentially jurisdictional waters of the United States resulting from the proposed project and alternatives will be quantitatively assessed. Changes in surface water quality or quantity resulting from the power lines, water supply pipelines, and access roads were not specifically modeled in the expert resource reports. Consideration was given to analyzing these potential impacts to surface water quality. However, for several reasons, analysis of these activities would not change the impacts disclosed in this section. In general, impacts from these linear features would have a small footprint in washes and are temporary in nature, occurring only during construction and then reclaimed following construction. Unlike the mine operations, linear construction does not tend to concentrate disturbance on a single stream channel like Davidson Canyon, and disturbance would be short lived (days rather than years). Disturbances are expected to be relatively small and to be mitigated by best management practices for construction (i.e., typical trench construction or jack-and-bore methods for pipelines or wash avoidance for power lines). Power lines would be constructed aboveground with unpaved associated maintenance roads and would be expected to have negligible impacts because no transmission poles would be constructed in washes and the only permanent impact to a wash would occur at culverted road crossings. Culverted road crossings would be designed with proper erosion control and energy dissipation measures. Effective detention upstream of culverts would be designed so that they have the positive effect of reducing erosive peak flow and extending flow durations to promote better flow regimes, increase recharge, and generally improve habitat. Additionally, implementation of stormwater best management practices as required under the stormwater pollution prevention plan would further prevent the potential for erosion during and after construction. All disturbed areas would be hydroseeded with native grasses and completely stabilized following construction.

Limited surface water quality data are available for the project area. In 2009, stormwater samples were collected from the project area in order to document baseline surface water quality conditions. Some parameters were not tested for or not reported during this sampling, either because the parameter was not detected in the laboratory or below laboratory detection limits. These baseline stormwater quality data have not been used as a basis for future predictions of runoff water quality, and these missing parameters have not affected the analysis of impacts.

Summary of Effects by Issue Measures by Alternative

Table 87 presents the summary comparison of impacts from each alternative.

Table 87. Summary of effects

Issue Measure	No Action	Proposed Action	Phased Tailings	Barrel	Barrel Trail	Scholefield-McCleary
3E: Area (in acres) and locations that may be affected by surface water quality impacts	None	Impacts to 2.5 miles of Barrel Canyon (23 acres), and 14 miles of Davidson Canyon (234 acres)	Same as proposed action	Same as proposed action	Same as proposed action	Same as proposed action
3E: Duration of impacts	None	Full impacts during active mine life (25 years), gradually reducing but never to premine conditions	Same as proposed action	Same as proposed action	Same as proposed action	Same as proposed action
3E: Ability to meet Arizona Surface Water Quality Standards						

Issue Measure	No Action	Proposed Action	Phased Tailings	Barrel	Barrel Trail	Scholefield-McCleary
Subcomponent 1: Sediment delivery to the U.S. Geological Survey Gaging Station (% change)	0	−51.3	−49.6	−38.2 (interpolated)	−38.2	−26.1
Subcomponent 2: Sediment delivery to the Barrel Canyon outlet (% change)	0	−18.0	−17.4	−13.4 (interpolated)	−13.4	−9.1
Subcomponent 3: Sediment delivery to Davidson Canyon outlet (% change)	0	−5.1	−5.0	−3.8 (interpolated)	−3.8	−2.6
Subcomponent 4: Potential for acid rock drainage	None	Acid-base accounting and kinetic testing indicate that all but one of the rock types to be excavated are nonacid generating. The waste rock management plan will ensure that waste rock and tailings with acid-generating potential are encapsulated and buffered by acid-neutralizing rock types. There is a low probability for generation of acid rock drainage.	Same as proposed action	Same as proposed action	Same as proposed action	Same as proposed action
Subcomponent 5: Potential for other contaminants	None	Leachate from tailings and waste rock facilities is expected to meet all water quality standards and will not impact surface waters. Untreated heap leachate is expected to exceed water quality standards; treatment with engineered biological system meets standards. There is no potential, however, for heap leachate to reach surface waters.	Same as proposed action	Same as proposed action	Same as proposed action	Same as proposed action
Other Effects Considered						
Loss of waters of the United States to mine footprint (acres)	0	47.8	44.9	39.9	53.3	31.5
Loss of total riparian habitat to mine footprint (acres)	0	213.8	220.8	207.5	210.8	83.4

Affected Environment

Relevant Laws, Regulations, Policies, and Plans

Table 88 lists the applicable laws, regulations, and policies related to the use, protection, and management of surface water quality 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 88. Summary of the Federal, State, and local regulatory requirements applicable to the project with respect to surface water resources

Law or Regulation	Regulates
Federal	
Clean Water Act – Section 404	Discharge of dredged or fill material into waters of the United States
Clean Water Act – Section 303	Primacy given to State of Arizona
Executive Order 11988 – Floodplain Management	Occupancy and modification of floodplains
Executive Order 11990 – Wetlands	Destruction, loss, or degradation of wetlands
Forest Service Manuals 2520, 2530, and 2880 and FS-881 Technical Guide	Watershed protection and management, water resource management, geological resources, and groundwater management
State	
Clean Water Act – Section 401 State Water Quality Certification	Surface water quality
Clean Water Act – Section 402	Primacy given to State of Arizona
Arizona Pollutant Discharge Elimination System	Surface water quality from point and nonpoint sources, including stormwater
Local	
Pima County Floodplain and Erosion Hazard Management Ordinance	Regulatory floodplains and riparian habitat as designated by Pima County

Federal

Clean Water Act (33 United States Code 1251–1376)

The Clean Water Act, as amended by the Water Quality Act of 1987, is the major Federal legislation governing water quality. The objective of the Clean Water Act is "to restore and maintain the chemical, physical, and biological integrity of the nation's waters."

Important sections of the Clean Water Act are as follows.

Clean Water Act Section 401

Section 401 (Water Quality Certification) requires an applicant for any Federal permit that proposes an activity that may result in a discharge to waters of the United States to obtain certification from the appropriate state that the discharge will comply with other provisions of the Clean Water Act. Arizona Revised Statutes (49-202(B)-(H)) outline the State's water quality certification procedures for any Federal permit or license that involves a discharge to waters of the United States. Arizona Department of Environmental Quality may certify, deny, or waive water quality certification. No Federal permit or action may be approved if the State denies certification.

Clean Water Act Section 402 / Arizona Pollutant Discharge Elimination System (Arizona Revised Statutes 49-255.01)

Section 402 of the Clean Water Act establishes the National Pollutant Discharge Elimination System, a permitting system for the discharge of any pollutant (except for dredged or fill material) into waters of the United States. Since 2002, the Arizona Department of Environmental Quality has had primacy over Section 402 through implementation of the Arizona Pollutant Discharge Elimination System. The Arizona Pollutant Discharge Elimination System program regulates discharge of pollutants into

navigable waters of the United States. Historically, the Arizona Department of Environmental Quality has considered virtually all waterways in Arizona, including dry washes, to fall under the jurisdiction of the Arizona Pollutant Discharge Elimination System program and gives special consideration to those that have been designated Outstanding Arizona Waters.

The Arizona Pollutant Discharge Elimination System program regulates both point and nonpoint sources of discharge. The most common nonpoint source regulated is stormwater runoff from construction activities and industrial sites. Coverage under the Arizona Pollutant Discharge Elimination System may be obtained either through issuance of an Individual Permit or a General Permit by the Arizona Department of Environmental Quality (Arizona Administrative Code R18-9-C901). There are five general permits that historically have been issued: de minimis discharges, stormwater runoff from construction activities (the construction general permit), stormwater runoff from concentrated animal feeding operations, stormwater runoff from industrial sites (the multi-sector general permit), and discharge of stormwater from municipal stormwater systems.

A new De Minimis Permit was approved by the Arizona Department of Environmental Quality on April 27, 2010, and authorization may be requested from the Arizona Department of Environmental Quality at this time. The Construction General Permit is currently active, and authorization may be requested from the Arizona Department of Environmental Quality at this time. A new Multi-sector General Permit for Stormwater Discharges Associated with Industrial Activity/Mineral Industry was approved by the Arizona Department of Environmental Quality on December 20, 2010, and authorization may be requested at this time. This mining multi-sector general permit specifically applies to stormwater runoff from industrial activities related to metal mining, including tailings, waste rock, haul roads, milling, and ancillary facilities. A key condition for using the general permit is that stormwater runoff is not mixed with mine drainage or process water. If the general permit is found to be applicable to the mine, the stormwater discharge is deemed acceptable, provided that the permit conditions are followed, including best management practices, stabilization measures, good housekeeping measures, sediment controls, inspection requirements, and record-keeping requirements. Additionally, the mining general permit requires monitoring for several parameters, many of which are hardness dependent, that are specific to copper mining operations. Sector-specific analytical monitoring values for hardness-dependent parameters in the mining general permit are provided in a separate stormwater guidance document.

Multiple surface water permits will be required for this project. Minor temporary discharges, such as pipeline hydrostatic testing or well testing, may be covered as de minimis discharge. Construction and operation of the mine facility itself may likely be covered under the 2010 mining multisector general permit. Linear construction activities, including road building, utility line construction, and other ground disturbance performed off the mining facility site and greater than 1 acre in size, will require separate coverage under the construction general permit.

Clean Water Act Section 404

Section 404 establishes a permit program for the discharge of dredged or fill material into waters of the United States, including wetlands. This permit program is jointly administered by the U.S. Army Corps of Engineers and U.S. Environmental Protection Agency. Consultation with the U.S. Fish and Wildlife Service and State Historic Preservation Officer may also be required before issuance of a permit to ensure compliance with the Endangered Species Act and National Historic Preservation Act. The immediate regulatory decision regarding which activities fall under Section 404 of the Clean

Water Act lies with the U.S. Army Corps of Engineers Los Angeles District. In general, there are three methods for obtaining a permit under Section 404: authorization under a nationwide permit, authorization under a regional general permit, or issuance of an individual permit. For all aspects of the proposed project, including road and utility line crossings of waters of the United States, an individual permit will be required. The decision regarding which activities are jurisdictional will be made by the U.S. Army Corps of Engineers.

Clean Water Act Section 303

The Arizona Department of Environmental Quality has developed surface water quality standards, including narrative limitations, to define water quality goals for Arizona's streams and lakes and provide the basis for controlling discharge of pollutants to surface waters. Beneficial uses for water bodies are identified in state water quality standards (18 Arizona Administrative Code Chapter 11, Article 1) and must be achieved and maintained as required under the Clean Water Act. Beneficial uses can include support of aquatic life, fish consumption, public water supply, and irrigation.
The 303(d) list, as required by Section 303(d) of the Clean Water Act, is a list of water bodies that have a designated beneficial use that is impaired by one or more pollutants. Water bodies included on this list are referred to as "impaired waters." The state must take appropriate action to improve impaired water bodies by establishing total maximum daily loads and reducing or eliminating pollutant discharges.

Executive Orders

Executive Order 11988 (May 24, 1977) directs each Federal agency to take action to avoid the long- and short-term adverse impacts associated with the occupancy and modification of floodplains. Agencies are required to avoid direct or indirect support of floodplain development whenever there is a practicable alternative.

Executive Order 11990 (May 24, 1977) directs Federal agencies to minimize the destruction, loss, or degradation of wetlands and to preserve and enhance the natural and beneficial value of wetlands in carrying out programs that affect land use.

Forest Service Guidance

Forest Service manuals that provide guidance for watershed protection and management are discussed in the "Groundwater Quantity" section of this chapter.

Local

Title 16, Pima County Floodplain and Erosion Hazard Management Ordinance (2010-FC5)

The Pima County Floodplain and Erosion Hazard Management Ordinance is discussed in the "Surface Water Quantity" section of this chapter.

Existing Conditions

Waters of the United States

As mentioned in the "Surface Water Quantity" section, past activities on the Coronado National Forest include historic grazing activities, mining, and six projects in the vicinity of the project area that have impacted waters of the United States. Current conditions on the grazing allotments within the project area are satisfactory.

Many of the named and unnamed ephemeral drainages on the project area have been determined to be potentially jurisdictional waters of the United States by the U.S. Army Corps of Engineers. WestLand Resources Inc. (2010f; 2010g) has completed a jurisdictional delineation to map and estimate the total acreage of potentially jurisdictional drainages in the project area and associated waterline (figure 50). The preliminary jurisdictional waters delineation was approved by the U.S. Army Corps of Engineers on November 1, 2010. The WestLand Resources delineation estimates that there are approximately 123.18 acres of waters of the United States on the project area. The potentially jurisdictional areas include the ephemeral drainages associated with Barrel, Scholefield, Wasp, McCleary, Mulberry, and Papago Canyons, as well as numerous small, unnamed, ephemeral tributary drainages that flow into these canyons. Table 89 provides a list of drainages and the total acreage of potentially jurisdictional waters of the United States within the project area, including the proposed waterline alignment.

Table 89. Summary of preliminary jurisdictional waters delineation

	Area of Analysis (acres)	Potential Waters of the United States (acres)	Identified Features
Mine site (WestLand Resources Inc. 2010f)	9,136	101.6	154 ephemeral drainages 10 stock tanks 2 concrete dams 7 springs 1 leaking wellhead 1 wetland (Scholefield Spring)
Water line (WestLand Resources Inc. 2010g)	1,158	21.58	95 ephemeral drainages

Riparian Areas

Important riparian areas, as defined by Pima County, are regulated riparian habitat. Disturbance to Important Riparian Areas as a result of development is reviewed during the floodplain permitting process. Important riparian areas can include any of the various classifications of regulated habitat type that provides critical watershed and water resource management function and landscape linkages. Important riparian areas are valued for their higher water availability, vegetation density, and biological productivity, compared with adjacent uplands (Pima County Regional Flood Control District 2010). A total of 494.4 acres of important riparian areas is located within the project area.

An onsite riparian habitat assessment was performed based on normalized difference vegetation index display values developed from satellite imagery for the project area (WestLand Resources Inc. 2010a). Five different classes of riparian habitat, ranging from xeroriparian to hydroriparan, were delineated. The densest, highest quality riparian habitat was found in a short wet reach in upper McCleary Canyon and in association with Scholefield Spring.

Surface Water Quality

Given the ephemeral nature of streamflow within the project area, there are no publicly available data characterizing the quality of surface waters within Wasp, McCleary, Barrel, or Davidson Canyons. Some surface water monitoring in and around the project area has occurred at seeps and springs and in washes as an ongoing activity, but those data typically are not publicly available. Some surface water quality data exist for the area far downstream on Cienega Creek, but data from this area are generally too far removed from the analysis area to be of use. In general, however, none of the

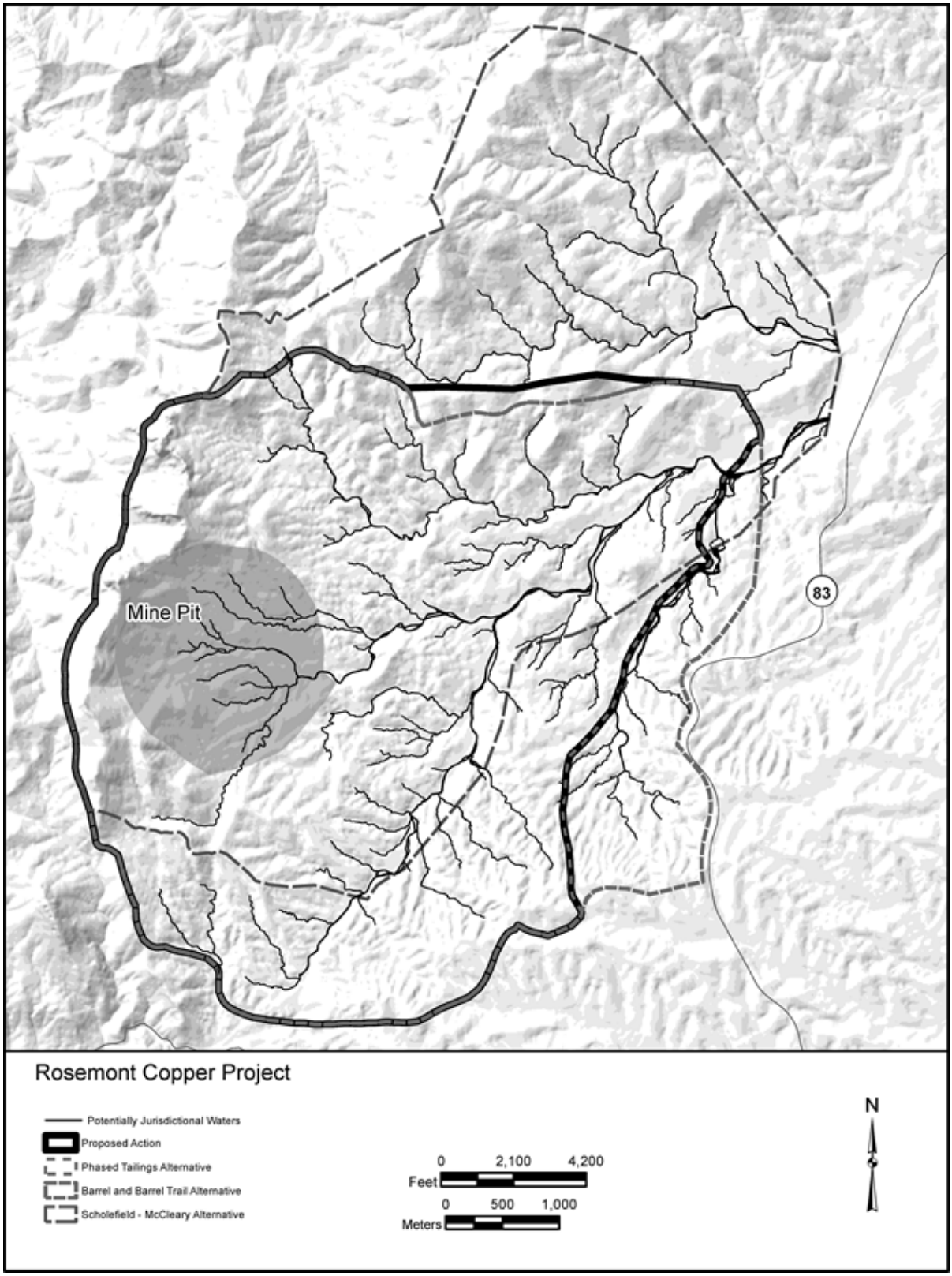


Figure 50. Potentially jurisdictional waters of the United States (WestLand Resources Inc. 2010f, 2010g)

drainages within the project area have been designated by the Arizona Department of Environmental Quality as being impaired or as having other water quality concerns. A portion of Davidson Canyon has been designated an Outstanding Arizona Water by the Arizona Department of Environmental Quality. The relevant portion is from approximately 10 miles downstream of its confluence with Barrel Canyon to its confluence with Cienega Creek. This reach begins approximately where perennial and intermittent stream flow begins, which is associated with discharge from the Reach 2 Spring. The Outstanding Arizona Water designation ensures that existing surface water quality standards will be maintained and protected for the surface water designated use. Designated uses for washes in Barrel Canyon and upper Davidson Canyon include Aquatic and Wildlife (ephemeral), Partial Body Contact, and Agricultural Livestock Watering. Designated uses in the Outstanding Arizona Water section of Davidson Canyon include Aquatic and Wildlife (ephemeral), Agricultural Livestock Watering, Fish Consumption, Full Body Contact, Partial Body Contact, and Aquatic Wildlife (warm water) (Arizona Department of Environmental Quality 2009).

Transportation of sediment is a naturally occurring process on watersheds and is affected by factors such as vegetation, climate, topography, and land use. Sediment yield is the amount of sediment or eroded material from a watershed that is delivered to the stream channel. Based on Tetra Tech (Zeller 2010b) baseline sediment delivery modeling, the average amount of sediment yield expected from the project area is 1.15 acre-feet of sediment per year per square mile of watershed.

Baseline stormwater quality samples were collected from the project area in July and September 2009 (Tetra Tech 2010h) and are presented in table 90. Sampling occurred near the compliance point dam (RP2 in table 90) and upstream of the compliance point dam near the proposed dry-stack tailings facility (Junction, Junction 1, and Factory 125 in table 90). These samples indicate that current stormwater runoff from the project area exceeds Arizona Surface Water Quality Standards associated with Agricultural Livestock Watering and Aquatic Wildlife (warm water) acute exposure for the following constituents: dissolved copper, total copper, total arsenic, total cadmium, and total lead.

Table 90. Results of baseline water quality samples

Parameter					Aquatic and Wildlife (ephemeral) Acute (milligrams per liter (mg/L))	Agricultural Livestock Watering (mg/L)
	7/1/2009	**7/21/2009**	**9/4/2009**	**9/6/2009**		
	RP2	**RP2**	**RP2**	**RP2**		
Average hardness*[†]					88	
Arsenic (dissolved)	0.01	0.029	<0.1	<0.01	0.44[¶]	
Arsenic (total)	<0.300[‡]	**0.45**[§]	NT	**0.34**[§]		0.2
Cadmium (dissolved)	<0.0020	<0.003	<0.03[‡]	<0.003	0.02014[¶]	0.05
Cadmium (total)	<0.200[‡]	**0.053**[§]	NT	0.0.9		0.05[¶]
Total chromium (dissolved)	<0.0050	<0.010	<0.10	<0.010		
Total chromium (total)	<0.500	<0.500	NT	0.26		1[¶]
Copper (dissolved)	**0.0497**[§]	**0.032**[§]	<0.10[‡]	**0.022**[§]	0.02062[¶]	
Copper (total)	8.53	29	9.1	0.17		0.5[¶]
Lead (dissolved	<0.0020	<0.010	<0.1	<0.01	0.11855[¶]	
Lead (total)	4.64	6.5	3.8	0.25		0.1[¶]
Mercury (dissolved)	<0.0002	NT	NT	NT	0.005[¶]	

Parameter					Aquatic and Wildlife (ephemeral) Acute (milligrams per liter (mg/L))	Agricultural Livestock Watering (mg/L)
Mercury (total)	<0.0020	NT	NT	NT	0.01[¶]	
Nickel (dissolved)	<0.0050	<0.010	<0.10	<0.010	3.723[¶]	
Nickel (total)	<0.500	0.56	0.29	<0.08		
Selenium (total)	<0.200[‡]	<0.250[‡]	NT	<0.25	0.033[¶]	0.05
Silver (dissolved)	<0.0010	<0.0050[‡]	<0.05[‡]	<0.002	0.00258[¶]	
Silver (total)	<0.100	<0.05	NT	<0.02		
Zinc (dissolved)	<0.05	<0.05	<0.5	<0.05	0.998[¶]	
Zinc (total)	3.6	NT	NT	9.9		25[¶]
	Junction (mg/L)	**Junction (mg/L)**	**Junction (mg/L)**	**Junction (mg/L)**		
Average hardness*[†]					114	
Arsenic (dissolved)	NT	0.029	<0.10	<0.010	0.44	
Arsenic (total)	<0.150	0.22	NT	<0.10		0.2[¶]
Cadmium (dissolved)	NT	<0.0030	<0.030	<0.0030	0.0259	0.05[¶]
Cadmium (total)	<0.100	<0.030	NT	<0.030		0.05[¶]
Total chromium (dissolved)	NT	<0.010	<0.10	<0.010		
Total chromium (total)	<0.250	0.16	NT	<0.10		1[¶]
Copper (dissolved)	NT	0.043	<0.10	<0.010	0.02632	
Copper (total)	1.12	8.3	NT	<0.10		0.5[¶]
Lead (dissolved)	NT	<0.010	<0.10	<0.010	0.15715	
Lead (total)	0.421	1.8	NT	0.14		0.1[¶]
Mercury (dissolved)	NT	NT	NT	NT	0.005	
Mercury (total)	<0.0002	NT	NT	NT		0.01[¶]
Nickel (dissolved)	NT	<0.010	<0.10	<0.010	4.646	
Nickel (total)	<0.250	0.19	NT	<0.10		
Selenium (total)	<0.100	<0.25	NT	<0.25	0.033	0.05[¶]
Silver (dissolved)	NT	<0.0050	<0.050	<0.0010	0.00403	
Silver (total)	<0.050	<0.050	NT	<0.0050		
Zinc (dissolved)	NT	<0.050	<0.50	<0.050	1.243	
Zinc (total)	0.93	5.4	NT	<0.50		25[¶]
	7/23/2009					
	Junction 1 (mg/L)					
Average hardness*[†]					43	
Arsenic (dissolved)	<0.010				0.44[¶]	
Arsenic (total)	0.043					0.2[¶]
Cadmium (dissolved)	<0.0030				0.01117[¶]	0.05
Cadmium (total)	0.0033					0.05
Total chromium (dissolved)	<0.010					
Total chromium (total)	0.04					1[¶]
Copper (dissolved)	**0.043**[§]				0.01165[¶]	
Copper (total)	**2.6**[§]					0.5[¶]
Lead (dissolved)	<0.010				0.06078[¶]	
Lead (total)	**0.49**[§]					0.1[¶]

Parameter					Aquatic and Wildlife (ephemeral) Acute (milligrams per liter (mg/L))	Agricultural Livestock Watering (mg/L)
Mercury (dissolved)	NT				0.005¶	
Mercury (total)	NT					0.01
Nickel (dissolved)	<0.010				2.235¶	
Nickel (total)	0.044					
Selenium (total)	<0.025				0.033¶	0.05
Silver (dissolved)	<0.0050‡				0.00091¶	
Silver (total)	<0.0050					
Zinc (dissolved)	<0.050				0.597¶	
Zinc (total)	1.4					25¶
	7/9/2009	**7/11/2009**				
	Factory 125 (mg/L)	**Factory 125 (mg/L)**				
Average hardness*†					88	
Arsenic (dissolved)	< 0.10	< 0.1			0.44¶	
Arsenic (total)	< 0.10	< 0.10				0.2§
Cadmium (dissolved)	< 0.05	< 0.05			0.02014¶	0.05
Cadmium (total)	< 0.050‡	< 0.050‡				0.05¶
Total chromium (dissolved)	< 0.1	< 0.1				
Total chromium (total)	< 0.10	< 0.10				1¶
Copper (dissolved)	< 0.1‡	< 0.1‡			0.02062¶	
Copper (total)	0.17	**4.3§**				0.5¶
Lead (dissolved)	< 0.15‡	< 0.15‡			0.11855¶	
Lead (total)	**0.25§**	**1.2§**				0.1¶
Mercury (dissolved)	NT	NT			0.005¶	
Mercury (total)	NT	NT				0.01¶
Nickel (dissolved)	< 0.08	< 0.08			3.732¶	
Nickel (total)	< 0.08	0.08				
Selenium (total)	< 0.1‡	< 0.10‡			0.033¶	0.05
Silver (dissolved)	< 0.02‡	< 0.02‡			0.00258¶	
Silver (total)	< 0.02	< 0.020				
Zinc (dissolved)	< 0.5	< 0.5			0.998¶	
Zinc (total)	0.6	2.9				25¶

Source: Tetra Tech (2010h).

Note: NT = Not tested for listed parameter.

* Aquatic and Wildlife (ephemeral–Acute), Agricultural Livestock Watering, Fish Consumption, Full Body Contact, and Aquatic Wildlife (warm water–Acute) standards were calculated based on the hardness value. The hardness value was lower than what had been expected based on local geology. This resulted in some detection limits being higher that the standards calculated using hardness. These detection limits have since been reduced.

† Water samples were not analyzed for hardness; value represents average hardness.

‡ Indicates that the detection limit was above the surface water quality standard.

§ **Indicates an exceedance of a surface water quality standard.**

¶ Lowest applicable surface water quality standard.

Environmental Consequences

Direct and Indirect Effects of Each Alternative

No Action Alternative

Under baseline conditions (no action), surface water within the project area consists of stock tanks, ephemeral flows that occur as the result of precipitation events, and a few springs or seeps. Under the no action alternative, the Coronado has an ongoing responsibility for managing water resources on Forest Service lands (see Forest Service Manuals 2670.12, 2670.32, 2620.5, and 2670.31; the 1986 forest plan, as amended; and the Endangered Species Act). The no action alternative would not change the Forest Service's responsibility for managing water resources and would result in no further impacts to the quality of surface water resources. Grazing would continue. Stormwater flows, springs, and seeps would continue to be monitored. Ephemeral washes on the project area would continue to flow in response to precipitation, and the natural occurrence of sediment yield would continue.

Impacts Common to All Action Alternatives

As mentioned previously, some elements are common to the proposed action and all action alternatives and include the following:

- Pit location and operations size will be the same;
- Production rates and processing facility output will be the same;
- Overall footprint of the general plant site will be the same; arrangement of the facilities may differ;
- Location of heap leach will be the same;
- Primary access route to the operations will be State Route 83;
- Mineral processing operations and techniques and use of similar major mining equipment will be the same;
- Infrastructure requirements: water and power will be delivered to the mine;
- Approximate width associated with the power line is assumed to be 100 feet;
- Width associated with the water pipeline is assumed to be 50 feet, including berms and maintenance access; and
- Access roadway width for primary roads is 70 feet and for secondary roads is 20 feet, including safety berms and shoulders.

All of the alternatives, with the exception of the no action alternative, will result in surface water quality impacts to some degree. Direct impacts related to surface water quantity that are common to all action alternatives include potential impacts from acid rock drainage, impacts from erosion and sedimentation, and impacts from other contaminants associated with industrial operations. Indirect impacts to water quality under each action alternative include changes in sediment yield caused by the loss of waters of the United States and riparian areas and changes in downstream geomorphology caused by changes in sediment yield. Although disturbed acreage varies slightly for each action alternative, there are no substantial differences in impacts. The following impacts apply to all action alternatives.

Surface Disturbance of Potential Waters of the United States

Waters of the United States support riparian areas and provide natural erosion and sediment control across the watershed. They have the capacity to carry or reduce pollutants and nutrients, thus their loss can indirectly affect water quality. Table 91 summarizes the direct impacts on potential waters of the United States, riparian areas, and presence/absence of special aquatic sites for each alternative. Special aquatic sites, as defined in 40 Code of Federal Regulations 230.3(q-1), include sanctuaries, refuges, wetlands, mud flats, vegetated shallows, coral reefs, and riffle and pool complexes.
One special aquatic site was identified within the project area and consists of wetlands associated with Scholefield Spring.

Table 91. Summary of impacts under each action alternative on potential waters of the United States and riparian habitat, expressed in acres lost and the presence/absence of special aquatic sites

Impact (acres lost)	Proposed Action	Phased Tailings	Barrel	Barrel Trail	Scholefield-McCleary
Potential Waters of the United States Direct Indirect Total	42.0 5.8 47.8	40.1 4.8 44.9	37.7 2.2 39.9	50.5 2.8 53.3	26.5 5.0 31.5
Direct impacts to total riparian habitat	213,8	220.8	207.5	210.8	83.4
Special aquatic sites	No	No	No	No	Yes

Source: WestLand Resources Inc. (2010a).

Sediment Yield

Indirect effects on surface water quality include changes in downstream sediment yield from the baseline caused by the loss of waters of the United States and riparian areas and changes in downstream geomorphology caused by changes in sediment yield.

Waters of the United States and vegetation associated with riparian habitat offer natural erosion control across the landscape. Dredging and filling these streams, along with clearing vegetation in the project area, would directly affect sediment yield generated off the project area. Changes in sediment yield are of concern for several reasons: (1) a loss of soil from the project area would occur, (2) movement of that soil into stream channels can affect water quality by increasing total suspended sediment in surface water flows, and (3) changes in sediment yield can result in geomorphological changes to downstream washes, causing problems with soil scour or aggradation. The impacts to soil loss from the project area are discussed in detail in the “Soils” section. The impact of the movement of soil from the project area is analyzed in this section and is based on modeling performed by Tetra Tech (Zeller 2010a). Impacts to the geomorphology of downstream washes are also discussed in this section.

One of the major functions of a stream is to transport sediment. Ephemeral channels such as those found in the project area have a cyclical pattern of infill and erosion. In this pattern, sediment movement usually occurs as pulses associated with flash thunderstorm flows that push large amounts of coarse sediment through the system (Levick et al. 2008). Long-term stream sedimentation behavior is based on the equilibrium between erosion and deposition of sediment delivered to the system. When that delivery system is disrupted or altered, changes to stream aggradation (the rising of the grade of a stream bed) and scour (the erosive removal of sediment) will occur until the system reaches equilibrium once again.

Sediments in ephemeral channels are usually deep, consisting mostly of sand and gravels. While sediment-laden runoff is not desirable, a decrease in sediment production in headwaters will cause narrowing of channels as sediment-starved waters cut into channel deposits left by larger flows. This downcutting can ultimately increase the gradient of the channel and is likely to result in the formation of discontinuous gullies as gradient adjustments shift farther and farther downstream. Additionally, as channels become narrower and alluvial bed material is removed, out-of-bank flows will be reduced, and formerly rich floodplain areas can become hydrologically disconnected; this disrupts water, sediment, and nutrient enrichment of these areas (Levick et al. 2008). Modeling of aggradation or scour effects resulting from the project may be conducted prior to the FEIS.

Sediment from the project area would enter stormwater flows through erosion of native soils, tailings, and waste rock. The stormwater management facilities onsite have been designed to maintain total suspended sediment concentrations in stormwater runoff similar to baseline conditions. No actual sampling or measurement of total suspended sediment under baseline conditions has occurred in the project area; these types of samples are difficult to collect properly and are not commonly included in water quality analyses. The prediction of future sediment loads under each alternative uses standard erosion modeling techniques that consider soil, vegetation, and rainfall characteristics but does not require baseline sediment loads to be known. The lack of samples of sediment load in stormwater in the project area does not affect the analysis. Sediment delivery was modeled to the U.S. Geological Survey gaging station in Lower Barrel Canyon Wash, the downstream stormwater control point for postmining conditions for each alternative (Zeller 2010a). The sediment yield for the baseline condition (no action alternative) and all the action alternatives is summarized in table 92.

Table 92. Summary of postmine average annual sediment delivery to the U.S. Geological Survey gaging station for each alternative

Condition	Contributing Watershed Area (square miles)	Average Annual Sediment Delivery* (acre-feet)	Sediment Concentration* (parts per million)	% Change from Baseline
No Action	14	16.0	16,407	–
Proposed Action	6.82	7.84	16,194	−51.3
Phased Tailings	7.06	8.12	16,210	−49.6
Barrel	8.65	9.95 (interpolated)	16,273 (interpolated)	−38.2 (interpolated)
Barrel Trail	8.65	9.95	16,273	−38.2
Scholefield-McCleary	10.35	11.90	16,317	−26.1

Source: Zeller (2010a; 2010b).

* Based on sediment delivery to the U.S. Geological Survey gaging station in Lower Barrel Canyon.

A comparison of the results of each action alternative with baseline conditions indicates that sediment delivery to the U.S. Geological Survey gaging station would be reduced to varying degrees for each alternative. This reduction would primarily be a direct result of the reduction in the contributing watershed area.

Based on Tetra Tech (Zeller 2010a) baseline sediment delivery modeling, the average amount of sediment expected from the types of watersheds found within the project area is 1.15 acre-feet of sediment per year per square mile of watershed. The estimated decrease in sediment yield from disturbed areas upstream of the U.S. Geological Survey gaging station ranges from approximately 26 to 51 percent, depending on the action alternative. This decrease in sediment yield would primarily be the result of the changes in the contributing watershed area, which would be caused by capture

from mine facilities. Changes in sediment delivery to portions of Barrel and Davidson Canyons downstream of the U.S. Geological Survey gaging station have the potential to cause aggradation or scour, including riparian areas in the reaches designated Outstanding Arizona Waters.

Based on the level of existing information on stream channel characteristics and stream morphology, current sediment loads and sediment movement predictions of future aggradation or scour are not feasible. For the purposes of effects analysis for Barrel Canyon downstream of the gaging station, quantitative estimates can be reasonably determined based on the Tetra Tech sediment delivery modeling and the change in predicted average-annual runoff at key locations downstream of the proposed mine. Using a regression equation, the average annual runoff downstream of the gaging station to Davidson Canyon is estimated to be 1,489 acre-feet for existing conditions and 971 acre-feet for the proposed action postmine conditions (Zeller 2011). This constitutes a 35 percent reduction in average annual flow. A rough estimate of changes in sediment yield to downstream reaches of Barrel Canyon was calculated based on these reductions in flow and the assumption that sediment yield across Barrel Canyon is relatively homogeneous. Reductions in sediment yield from 35 percent less flow are predicted to range from 26 to 51 percent; therefore, estimates of reductions in sediment yield for the entire Barrel Canyon watershed area can be calculated to range from 9 to 18 percent. This indicates that sediment transport that could eventually be delivered downstream of the gaging station could be reduced from approximately 9 to 18 percent as a result of mining activities. The reach of Barrel Canyon that could potentially be affected is approximately 2.5 miles long, from the U.S. Geological Survey gaging station to the confluence with Davidson Canyon. The bridge at State Route 83, just downstream of the gaging station, could be impacted by this reduction in sediment delivery.

Similarly, quantitative estimates of sediment yield for the Davidson Canyon watershed were based on the Tetra Tech sediment delivery modeling and the predicted reduction in average-annual flow at the confluence of Davidson Canyon and Cienega Creek. The average-annual runoff on Davidson Canyon at Cienega Creek is estimated to be 514 acre-feet for existing conditions and 464 acre-feet for post-mine conditions (Zeller 2011). This constitutes a 10 percent reduction in average-annual flow. Based on these reductions in flow and the assumption that average annual sediment yield for the overall Davidson Canyon is approximately equal to that modeled for the upper watersheds, estimates of changes in sediment yield to Davidson Canyon can be made. Reductions in sediment yield from 10 percent less flow are predicted to range from 26 to 51 percent; therefore, estimates of reductions in sediment yield for the total watershed can be calculated to range from 3 to 5 percent. This indicates that sediment transport that could eventually be delivered to the lower reaches of Davidson Canyon could decrease by approximately 3 to 5 percent as a result of mine activities. The reach of Davidson Canyon that could potentially be affected is approximately 14 miles long, from the confluence with Barrel Canyon to the confluence with Cienega Creek.

All action alternatives would result in a significant reduction in sediment yield from the Barrel Canyon watershed. With respect to total suspended sediment concentrations, this reduction in sediment yield would be beneficial in maintaining the water quality of ephemeral storm flows. With respect to changes in downstream geomorphology, the reduction in sediment delivery to downstream portions of Barrel Canyon is estimated to be as much as 18 percent; this represents a significant part of the sediment yield to Barrel Canyon as a whole and could cause changes in the geomorphology of the channel between the mine and the confluence with Davidson Canyon.

Field investigations into the channel morphology of Davidson Canyon conducted by Tetra Tech (2010a) indicated that the system currently is either in equilibrium with respect to sediment load or

that the sediment supply to the head reaches of the canyon is slightly greater than the transport capacity of the wash. This excess transport capacity would tend to modify, at least to some degree, the tendency for scour that would occur as a result of reductions in sediment yield. The change in sediment yield to Davidson Canyon is estimated to be approximately 5 percent and is unlikely to represent a significant change in geomorphology.

Location and Duration of Surface Water Quality Impacts

The reach of Barrel Canyon that could be affected is approximately 2.5 miles long, from the U.S. Geological Survey gaging station to the confluence with Davidson Canyon. The bridge at State Route 83, just downstream of the gaging station, could be impacted by this reduction in sediment delivery. This reach of Barrel Canyon represents approximately 23 acres that could be impacted by the 9 to 18 percent reduction in sediment load. The reach of Davidson Canyon that could potentially be affected is approximately 14 miles long, from the confluence with Barrel Canyon to the confluence with Cienega Creek. This reach of Davidson Canyon represents approximately 234 acres that could be impacted by the 3 to 5 percent reduction in sediment load. The duration of these impacts would be throughout the active mine life. A lesser level of impact would be expected to occur in perpetuity. While some ephemeral stream flow and sediment yield would be expected to return to Barrel and Davidson Canyons after mine closure because of the gradual reduction in active stormwater control, the mine pit will always act to capture precipitation, and hydrologic conditions would not be expected to return to premine levels.

Potential for Acid Rock Drainage

Acid rock drainage is a natural process that takes place as mineralized rock surface areas are oxidized when they are exposed to weathering and when the resulting stormwater runoff, or drainage, from the rock becomes acidic. As the drainage becomes more acidic, it has an increased capacity to leach out other elements, particularly metals, from the rock. This can result in polluted runoff, which can impact the quality of surrounding surface water bodies. Acid rock drainage occurs naturally in the environment at a very slow pace, but mining activities accelerate the process by exposing a large amount of rock to weathering in a short amount of time. Additionally, mine-processed rock and fractured waste rock have an increased amount of exposed surface area that can come into contact with water and oxygen.

Alkalinity in mine runoff water primarily comes from dissolved carbonate. When mine water has a pH greater than 4.5, it is said to contain alkalinity and can neutralize acid. However, it is the net alkalinity (alkalinity greater than acidity) or net acidity (acidity greater than alkalinity) of the water that will determine whether the mine rock contains enough alkalinity to neutralize the mineral acidity before it is eventually used up and comes to equilibrium (Metesh et al. 1998).

At the Rosemont Copper Mine, the ore is contained primarily within limestone and skarn (metamorphosed limestone) rocks, with minor amounts in quartz monzonite porphyry (igneous), andesite (volcanic), and arkose (sandstone) rocks. Waste rock will also be composed of these same rock types. Geological materials at the project area were characterized using the acid-base accounting technique. Acid-base accounting measures the acid-producing and acid-neutralizing potential of a sample and is used to classify a material as either potentially acid generating or inert with respect to acid generation. Composite acid-base accounting testing was used to evaluate the degree to which results from geochemical testing represent the overall geochemical tendencies of various rock types found in the project area. A total of 226 samples, representing 17 different rock types, was analyzed from the project area. In general, the total sulfide content of host rock at the project area is low, less

than 3 percent. Although sulfide mineralization is present at the project area, acid-neutralizing limestone (calcium carbonate) is abundant (Tetra Tech 2010b, 2010c). Additionally, topsoil samples were collected and analyzed for their acid-generating potential (Tetra Tech 2010e). In these static tests, 11 percent of the topsoil samples (2 out of 19) and 5 percent of the rock samples (11 out of 226) indicated the potential for acid generation. Static testing is generally considered a preliminary screening analysis, with more reliable kinetic testing conducted if there are indications that there may be acid-generating potential. Sixteen 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.

At the conclusion of the proposed project, final reclamation of the project area would include reclamation and closure of the facilities and final regrading and revegetation of the Rosemont Ridge landform. The Rosemont Ridge landform would consist of waste rock from the open pit, a closed heap leach facility, and a closed dry-stack tailings facility; these facilities will be buttressed and capped with inert waste rock. Direct precipitation and runoff from the Rosemont Ridge landform have the potential to generate acid rock drainage because sulfide minerals, such as those proposed to be mined, have the potential to generate sulfuric acid when exposed to water and air. Based on the observed overall abundance of potential acid-neutralizing rock types, however, it is believed that the naturally occurring lime content of the ore-bearing and waste rock material would neutralize any sulfuric acid produced in the processed ore (tailings) or waste rock and that the generation of acid rock drainage is unlikely (Tetra Tech 2010b). Because the tailings and heap leach facilities, as well as any waste rock with potentially acid-generating material, will be buttressed and capped with inert, acid-neutralizing rock, the potential for acid rock drainage is considered low. Seepage modeling has been conducted to estimate the volume and water quality of any seepage from the tailings, waste rock, and heap leach facilities (Hudson and Williamson 2011; Tetra Tech 2010d). While the tailings facility has a greater potential than the heap leach facility for acid rock generation, chemical analysis indicates that neither facility will exceed Arizona Aquifer Water Quality Standards, even without buffering effects of the inert waste rock. Where seepage might occur below these facilities, the impacts are assessed in the “Groundwater Quality” section. Seepage water quality, as it pertains to surface water, is discussed in more detail later in this section.

Proposed mitigation would consist of encapsulation of rock believed to have acid rock drainage potential and continual testing of waste rock for acid rock drainage potential. The waste rock would be managed during mining by monitoring potentially acid-generating and nonacid-generating materials and placing materials in designated areas. Modeling results show that the Bolsa Quartzite was the only non-ore rock type that indicated a net capacity to generate acidic drainage (Tetra Tech 2010b, 2010c). Potentially acid-generating waste rock would not be used for construction of the perimeter buttresses, tailings starter buttresses, drains, or channel grading fills but instead would be placed in the interior of waste rock storage areas and would be encapsulated by the acid-neutralizing and nonacid-generating waste materials (Tetra Tech 2009a). Inert waste rock shall be used to build haul roads and buttresses around waste rock storage and tailings areas to provide a buffer zone that would isolate potentially acid-generating materials from water infiltration and discharge.

The above design is intended to eliminate or reduce the potential for any acid rock drainage; proper implementation of this design and placement of waste rock and tailings is critical. The methodology for stacking and placing waste rock and tailings is part of the Aquifer Protection Permit, to be issued by the Arizona Department of Environmental Quality. The aquifer protection permit submittal shall

include details on the waste rock storage area and best available demonstrated control technology, intended to provide the quality control necessary to properly implement the waste rock design.

Routine inspections of the waste rock storage area shall be performed from the time construction begins and will continue quarterly and after every major storm or surface flow event for the term of the Arizona Department of Environmental Quality Aquifer Protection Permit. Inspections will include a visual assessment of the integrity of the waste rock storage area and the physical appraisal of design capacity. Additionally, testing of the sediment ponds located downgradient of the waste rock storage area shall serve as a final control point where water will be temporarily impounded. The compliance point dam, as detailed in the following section, will be the final sediment pond located at the outlet of Barrel Canyon. The location for the compliance point dam was chosen because it is the downgradient edge of the collective drainages associated with project activities and is based on the pollutant management area as developed in the aquifer protection permit. It is here that final water quality testing for contaminants of concern (as required by the mining multisector general permit) would be performed prior to release into the natural channel (Tetra Tech 2009a).

Because inert waste rock would be used to build buttresses around waste rock storage and tailings areas to provide acid buffering, there is little potential for acid rock drainage. Proper implementation of the waste rock stack design and routine inspections of the waste rock storage area are components of the Arizona Department of Environmental Quality Aquifer Protection Permit. Modeling and geochemical analysis indicate that acid rock drainage is unlikely to occur. However, if acid rock drainage were to occur, it would be identified early during the planned testing of sediment ponds located downgradient of the waste rock storage area. This would serve as a final control point where water quality testing would be performed prior to release. Any discharge into the sediment ponds from the tailings, waste rock, or heap leach facilities is regulated under the aquifer protection permit program; plans for monitoring discharges for the presence of acid rock drainage conditions and contingency plans to address if alert levels are exceeded will be developed under that regulatory program.

The acid-base accounting tests on compost samples (Tetra Tech 2010b), subsequent kinetic testing (Tetra Tech 2010c), and assessment of the ability of the waste rock to control acid rock drainage, as well as implementation of the mitigation measures proposed, indicate that there is a low probability for impacts to surface water quality to occur from acid rock drainage (Tetra Tech 2010c).

Potential for Other Contaminants

In order to estimate the potential for other contaminants to come into contact with stormwater at the mine pit itself, processing facilities, and tailings and waste rock disposal areas, geochemical fate and transport modeling was performed for the dry-stack tailings facility, heap leach facility, and waste rock storage area (Hudson and Williamson 2011; Tetra Tech 2010e). The model was constructed using 21 constituents for the waste rock area, 25 constituents for the heap leach facility, and 28 parameters for the dry-stack tailings. The modeling results indicate that untreated seepage from the heap leach facility would exceed numeric Arizona Aquifer Water Quality Standards; seepage treated with an engineered biological system would meet numeric Arizona Aquifer Water Quality Standards. The waste rock storage area resulted in an arsenic concentration of 0.013 milligram per liter, below the current Arizona Aquifer Water Quality Standard of 0.05 milligram per liter but slightly above the proposed 0.01 milligram per liter standard for arsenic. A list of each of the constituents for each area tested is presented in table 93; the expected water quality seepage from the waste rock storage area, heap leach facility, and dry-stack tailings facility is provided in tables 94 through 96, respectively.

Table 93. Fate and transport model constituents

Waste Rock Storage Area	Heap Leach Facility	Dry-Stack Tailings Facility
pH	pH	pH
pe (oxidation potential)	pe (oxidation potential)	Aluminum
Total Alkalinity (as calcium carbonate ($CaCO_3$))	Total Alkalinity (as $CaCo_3$)	Antimony
Aluminum	Silver	Arsenic
Arsenic	Aluminum	Barium
Barium	Arsenic	Beryllium
Carbon	Barium	Cadmium
Calcium	Carbon	Calcium
Cadmium	Calcium	Chlorine
Chlorine	Cadmium	Chromium
Copper	Chlorine	Copper
Fluorine	Chromium	Fluorine
Iron	Copper	Iron
Potassium	Fluorine	Lead
Magnesium	Iron	Magnesium
Manganese	Potassium	Manganese
Molybdenum	Magnesium	Mercury
Nitrite + Nitrate (as Nitrogen)	Manganese	Molybdenum
Sodium	Molybdenum	Nickel
Oxygen	Sodium	Potassium
Lead	Nickel	Selenium
Sulfur	Nitrite + Nitrate (as Nitrogen)	Silver
Selenium	Oxygen	Sodium
Zinc	Lead	Sulfate
	Sulfur (Sulfate + Sulfide)	Thallium
	Selenium	Uranium
	Zinc	Zinc
		Nitrite + Nitrate (as Nitrogen)

Source: Tetra Tech (2010d).

Table 94. Expected water quality from waste rock storage area seepage

Constituent	Arizona Aquifer Water Quality Standard (milligrams per liter (mg/L))	Predicted Waste Rock Seepage (mg/L)
pH	Not established	7.73
pe (oxidation potential)	Not established	12.9
Total Alkalinity (as calcium carbonate ($CaCO_3$))	Not established	35.9
Total Dissolved Solids	Not established	2216
Aluminum	Not established	0.114
Antimony	0.006	Not present
Arsenic	0.05*	0.013
Barium	2	0.013
Beryllium	0.004	Not present
Carbon	Not established	21.1
Calcium	Not established	626
Cadmium	0.005	0.0004

Constituent	Arizona Aquifer Water Quality Standard (milligrams per liter (mg/L))	Predicted Waste Rock Seepage (mg/L)
Chloride	Not established	7.01
Chromium	0.1	Not present
Copper	Not established	0.007
Fluoride	4.0	1.18
Iron	Not established	0.001
Lead	0.05	0.003
Magnesium	Not established	3.36
Manganese	Not established	0.0
Molybdenum	Not established	0.055
Mercury	0.002	Not present
Nickel	0.1	Not present
Nitrite + Nitrate (as Nitrogen)	10	0.018
Oxygen	Not established	7.43
Potassium	Not established	7.42
Selenium	0.05	0.036
Sodium	Not established	18.9
Sulfur	Not established	1531
Thallium	0.002	Not present
Zinc	Not established	0.004

Sources: Hudson (2011); Tetra Tech (2010e).

Notes:

Not established – a numeric Arizona Aquifer Water Quality Standard has not been established for the constituent.

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

* Standard proposed to decrease to 0.01 mg/L.

Table 95. Expected water quality from heap leach facility 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	not established	3.04	6.31	6.59
pe	Not established	17.6	−3.27	14.0
Total Alkalinity (as calcium carbonate ($CaCO_3$))	Not established	−173	1,905	497
Total Dissolved Solids	Not established	2,848	1,717	2,828
Aluminum	Not established	57.7	0.127	0.0115
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
Calcium	Not established	**442**	**237**	**649**
Cadmium	0.005	**0.307**	0.002	**0.305**
Chloride	Not established	5.980	5.975	5.981
Chromium	0.1	0.034	0.009	0.034
Copper	Not established	62.2	0.002	0.49

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)
Fluoride	4.0	**5.23**	2.64	1.96
Iron	Not established	4.844E-04	4.84E-04	5.30E-09
Lead	0.05	0.037	0.037	0.037
Magnesium	Not established	150	105	150
Manganese	Not established	0.214	0.214	7.147E-04
Mercury	0.002	Not present	Not present	Not present
Molybdenum	Not established	0.004	1.476E-29	0.002
Nickel	0.1	**0.592**	8.39E-07	**0.593**
Nitrite + Nitrate (as Nitrogen)	10	0.107	0.107	0.107
Selenium	0.05	**0.099**	7.60E-13	**0.099**
Silver	Not established	0.005	0.005	0.005
Sodium	Not established	9.34	9.33	9,34
Sulfate	Not established	2089	0.88	1871
Sulfide	Not established	0.00E+00	656	0.00E+00
Thallium	0.002	Not present	Not present	Not present
Zinc	not established	17.6	0.3	17.6

Sources: Hudson (2011); Tetra Tech (2010e).

Notes:

Exceedances are bolded.

Not established – a numeric Arizona Aquifer Water Quality Standard has not been established for the constituent.

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

* Standard proposed to decrease to 0.01 mg/L.

Table 96. Expected water quality from dry-stack tailings facility seepage

Constituent	Arizona Aquifer Water Quality Standard (milligrams per liter (mg/L))	Predicted Tailings Seepage (mg/L)
pH	Not established	5.87
pe	Not established	14.7
Total Alkalinity (as calcium carbonate ($CaCO_3$))	Not established	0.206
Total Dissolved Solids	Not established	810
Antimony	0.006	Not present
Arsenic	0.05*	Not present
Barium	2	0.017
Beryllium	0.004	Not present
Cadmium	0.005	Not present
Calcium	Not established	188
Carbon	Not established	0.909
Chloride	Not established	3.98
Chromium	0.1	Not present
Fluoride	4.0	2.37
Lead	0.05	Not present
Magnesium	Not established	19.61

Constituent	Arizona Aquifer Water Quality Standard (milligrams per liter (mg/L))	Predicted Tailings Seepage (mg/L)
Mercury	0.002	Not present
Molybdenum	Not established	0.076
Nickel	0.1	Not present
Nitrite + Nitrate (as Nitrogen)	10	0.001
Potassium	Not established	9.35
Selenium	0.05	0.006
Sodium	Not established	26.5
Sulfate	Not established	559
Thallium	0.002	Not present

Sources: Hudson (2011); Tetra Tech (2010e).

Notes:

Not established – a numeric Arizona Aquifer Water Quality Standard has not been established for the constituent.

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

* Standard proposed to decrease to 0.01 mg/L.

As required under the mining multisector general permit, all stormwater from the mine pit and processing facilities would be contained onsite and recycled as process water; changes in stormwater quality from these areas of the mine would be considered insignificant. In order to mitigate potential changes in water quality resulting from stormwater encountering tailings and waste rock, which would form more and more of the disturbed area over time, a series of stormwater controls such as diversion channels and detention pools designed to handle large 100-year, 24-hour storm events (Tetra Tech 2009a) would be constructed to intercept stormwater runoff and route it around the mine facilities. Application to Arizona Department of Environmental Quality for coverage under the General Permit for Stormwater Discharges requires the following: (1) analytical monitoring of stormwater discharges for parameters specific to the copper mining sector, and (2) development of a stormwater pollution prevention plan to outline best management practices that will be used to minimize the discharge of pollutants in stormwater from the site. The stormwater pollution prevention plan for the project will identify the stormwater outfalls, chemical and sediment content, monitoring schedule, and analytical parameters that will be monitored as part of the project.

A point of compliance, or small dam, has been designed for temporary impoundment at the lower end of the Barrel Canyon drainage before stormwater is slowly released into the natural drainage. This rock dam would be approximately 6 feet tall and has been designed as a porous, flow-through sediment pond with a relatively small capacity of 2 acre-feet. It would be constructed in year 0 using inert waste rack and would provide the last point of detention in the series of stormwater controls and a point for surface water flows to be monitored and tested; testing and discharge requirements are administered under the Aquifer Protection Permit and Arizona Pollutant Discharge Elimination System permitting programs. The point of compliance dam would be constructed as an unlined embankment, and normally, the area behind the embankment would be empty. Water would temporarily impound behind the dam during storm events and then would be slowly released downstream through the porous rock-fill embankment. Design of the compliance point dam is such that large flows are expected to overtop and occasionally destroy the dam. If the dam were damaged or destroyed by a storm event, it would be repaired and rebuilt as necessary. Because the compliance point dam would be constructed of inert rock and would be rebuilt, any possible effects of the dam's

being destroyed are considered insignificant. After closure of the project facilities, the compliance point dam would be evaluated and removed under the prevailing Clean Water Act permitting program.

Results of baseline surface water sampling indicate stormwater runoff from the tailings and waste rock facilities from all action alternatives are not expected to further degrade the existing surface water quality in the project area (Tetra Tech 2010d; Thornbrue 2010). Because mitigation measures are designed to contain wastewater onsite and because monitoring protocols will be put in place at the point of compliance, the potential for other contaminants to enter surface water is considered low; therefore, changes in water quality below the compliance point dam would be considered insignificant. Further, under the mining multisector general permit that is expected to be issued for the mine, the requirements for maintaining stormwater quality in compliance with appropriate surface water quality limits are enforceable by the Arizona Department of Environmental Quality. Further, permit requirements would prohibit any discharges that occur to surface waters in Barrel Canyon from causing or contributing to a decrease in the water quality or assimilative capacity of Davidson Canyon. Assimilative capacity is the ability of a water body to accept pollutant loadings without a decrease in its original water quality. Assimilative capacity is defined in the surface water quality standards as the difference between the baseline water quality concentration for a pollutant and the most stringent applicable surface water quality criterion for that pollutant (Arizona Administrative Code R-18-11-101).

All Action Alternatives

With the exception of the varying amount of impacts associated with each alternative as listed in tables 91 and 92, there are no further impacts solely specific to a particular action alternative.

Cumulative Effects

The Council on Environmental Quality defines a cumulative impact as “the impact on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable actions regardless of what agency (federal or nonfederal) or person undertakes such other actions” (40 Code of Federal Regulations 1508.7). As outlined in the chapter 3 introduction, cumulative impacts of past and present actions are identified and analyzed in the “Affected Environment” part of each resource section, including for “Surface Water Quality.” 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 chapter 3 introduction. The following reasonably foreseeable actions from that list were determined to contribute to a cumulative impact to surface water quality:

- Maintenance of roads, both forest and private, for support of permitted grazing operations.
- Potential expansion of limestone quarry in the Davidson Canyon drainage system northeast of the Santa Rita Mountains.

These activities would be expected to cause disturbance and possibly contribute to erosion potential within the same watershed as the disturbance caused by the proposed mine. Maintenance of roads is expected to cause minimal additional disturbance, as the areas associated with these roads have already been disturbed and in most cases erosion control is in place.

The expansion of the limestone quarry in the Davidson Canyon drainage system would be expected to have an impact on surface water quality from possible direct impacts to washes and waters of the United States and possible erosion and sedimentation. This project would increase the amount of disturbance in the watershed, which would affect watershed function, contributing to changes in flow in Davidson Canyon and sediment load.

Mitigation Effectiveness

Numerous mitigation measures are included in all action alternatives to reduce impacts to surface water quality. These include the following:

- Diversion of surface water from undisturbed areas of the watershed around mining activities
- Segregation of waste rock and encapsulation of rock believed to have the potential to result in acid rock drainage impacts to surface water by waste rock that has acid-buffering characteristics
- Continual testing of waste rock for acid rock drainage potential
- Use of lined ponds and retention of all stormwater flows in contact with ore bodies and other active mining facilities for reuse as process water
- Collection of stormwater from tailings and waste rock disposal areas in sediment ponds for further water quality testing prior to discharge to natural drainages
- Reuse or recycling of most process water
- Revegetation of tailings buttress walls to prevent erosion of sediment during mine operation
- Reclamation of mine facilities following mine closure, including seeding and tree planting to control erosion
- Use of best management practices, stabilization measures, and sediment control measures to meet water quality requirements under the General Permit for Stormwater Discharges Associated with Industrial Activities/Mineral Industry

To control surface water contamination from the proposed facilities, a stormwater management and drainage system designed to prevent contamination outside containment areas would be developed. Prudent design criteria and methods developed for each alternative would provide for the appropriate capacity of process water and tailings storage to protect against flooding or overtopping. Where long-term mine facilities would remain, permanent water control structures that may exist beyond the life of the mine would be installed, and periodic monitoring and maintenance of spillways, diversions, and other permanent facilities would be undertaken. A plan would be developed to identify and ensure isolation of potentially acid-generating waste rock, prevention of acid generation from mine waste, and additional mitigation measures that would be necessary should prevention measures fail. Water quality in the runoff generated from waste rock and tailings piles would be monitored, and pollutants would be collected and disposed of. Materials would be managed using geochemical analysis and acid-base accounting methods; areas of potential acid generation on the interim and ultimate pit wall would be identified and appropriate management strategies developed.

As required by law, monitoring of runoff would occur, and should monitoring indicate a failure to comply with Arizona surface water quality standards, Rosemont Copper would comply with all surface permit monitoring, reporting, and contingency conditions. Additionally, these data and reports would be made publicly available through a Rosemont Copper Mine water website. The website would be constructed, updated annually, and maintained by Rosemont Copper, with concurrence by

the Coronado. All water related data and reports would be accessible to the general public at this location, including all surface water quality data and monitoring reports.

Rosemont Copper would develop a revegetation plan that includes planting native grasses, shrubs, and trees in order to achieve long-term stabilization of disturbed areas and reduce the potential for erosion and sedimentation. The plan would include specifications and goals for the salvage, storage, and use of growth media from disturbed areas to provide sufficient cover on all disturbed areas to be reclaimed. The areas to be revegetated would be contoured, graded, prepared, and seeded in accordance with the specifications in the approved reclamation plan.

A stormwater pollution prevention plan that outlines site-specific control measures to regulate stormwater discharges associated with mining activities would be developed in accordance with the mining multisector general permit. A stormwater pollution prevention plan that outlines site-specific control measure to regulate stormwater discharges associated with offsite road and utility construction would be developed in accordance with the construction general permit. Best management practices would be used to control erosion and prevent pollutants, including sediment, from entering surface water. General best management practices to be used would include the following:

- Prepare and implement erosion control actions before starting surface-disturbing activities;
- Disturb the smallest area practical and implement concurrent reclamation when feasible;
- Maintain erosion and sediment control measures until the reclamation effort has met established standards and bonds have been released;
- Manage runoff from disturbed areas to reduce sediment from leaving the project area;
- Employ good housekeeping methods;
- Conduct routine inspections and maintenance;
- Use berms and ditches to control runoff from road surfaces;
- Install settling basins, hay bales, and/or silt fences to control sediment in ditches;
- Use stormwater dispersion terraces, silt fences, gabion sediment traps, and/or straw bale barriers as needed to minimize road runoff onto undisturbed areas between and downhill from roads;
- Seed road cuts with an approved seed mix; use hydroseeding on steep or more erodible cuts and fills as appropriate;
- Maintain sediment control measures after storm events; and
- Monitor effectiveness of ongoing erosion and sediment control measures and modify where appropriate.

As indicated, these best management practices, as well as those associated with the waste rock, are expected to reduce impacts from all pollutants, including acid rock drainage and other nonsediment pollutants, to insignificant levels.

The mitigation measures discussed above will, to an extent, help reduce sediment yield from disturbed areas under each action alternative. Each alternative would result in the loss of the natural erosion control offered by riparian areas; however, considering the mitigation measures that will be implemented, the overall development itself would have a beneficial effect with respect to total suspended sediment and water quality, compared with baseline sediment yield conditions.
No mitigation measures are proposed for any changes in downstream geomorphology caused by the reduction of sediment yield from the project area.

Mitigation measures for impact to waters of the United States include those specifications identified in the Clean Water Act Section 404 individual permit. Mitigation potentially includes the purchase and set aside of offsite mitigation areas, payment in lieu of mitigation to an established restoration program, and/or permittee responsible onsite mitigation.

Irretrievable and Irreversible Commitment of Resources

With respect to surface water quality, the resources that will be irretrievable and irreversible include the following: (1) the indirect effect on water quality as a result of the loss of waters of the United States and riparian areas that would be impacted by the footprint of mining operations associated with any action alternative, and (2) the reduction of sediment movement downstream, in channels.