Integrated Watershed Summary

The Rosemont Project

June 2012

ROSEMONT COPPER
A Bridge to a Sustainable Future
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Acronyms Used In This Document

ABA  acid-base accounting
AD   Anno Domini (1 AD is approximately 2000 years ago)
ADEQ Arizona Department of Environmental Quality
ADWR Arizona Department of Water Resources
AEC  Applied Environmental Consultants
AF   acre-feet
AGP  acid generating potential
AMA  Arizona Mining Association
amsl above mean sea level
ANP  acid neutralization potential
AP   acid potential
APP  Aquifer Protection Permit
ARD  acid rock drainage
ASTM American Society for Testing and Materials
AWQS Aquifer Water Quality Standards
AZGS Arizona Geological Survey
AZPDES Arizona Pollutant Discharge Elimination System
AZWQS Arizona Water Quality Standards
BADCT Best Available Demonstrated Control Technology
BLM Bureau of Land Management
BMP  Best Management Practice
cfs  cubic feet per second
CNF  Coronado National Forest
CO₂  carbon dioxide
DEIS Draft Environmental Impact Statement
DTW  depth-to-water
EA   Engineering Analytics
EPM  equivalent porous medium
ET   evapotranspiration
FEMA Federal Emergency Management Agency
ft   feet
GCL  Geosynthetic Clay Liner
GNIS USGS Geographical Name Information System
gpm gallons per minute
HCT  humidity cell testing
HDPE  high-density, polyethylene
HEC-HMS Hydrologic Engineering Center Hydrologic Modeling System
IPCC Intergovernmental Panel on Climate Change
LDPE  low-density, polyethylene
Acronyms Used In This Document (continued)

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<tr>
<th>Acronym</th>
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<tr>
<td>M&amp;A</td>
<td>Montgomery &amp; Associates</td>
</tr>
<tr>
<td>mg/L</td>
<td>milligram per liter</td>
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<td>MPO</td>
<td>Mine Plan of Operations</td>
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<td>million tons</td>
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<td>MWMP</td>
<td>Meteoric Water Mobility Procedure</td>
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<td>Outstanding Arizona Waters</td>
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<td>PAG</td>
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<td>Pregnant Leach Solution</td>
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<tr>
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<td>tons per day</td>
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<td>WRSA</td>
<td>Waste Rock Storage Area</td>
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The Rosemont Project

EXECUTIVE SUMMARY

This Integrated Watershed Summary has been developed by Rosemont Copper Company (Rosemont) to address comments received in response to the draft environmental impact statement (DEIS) for the Rosemont Mine Plan of Operations (MPO). The DEIS was prepared by representatives of the Coronado National Forest (CNF) to fulfill the U.S. Department of Agriculture, Forest Service’s (USFS) role as lead agency responsible for assessing the direct, indirect, and cumulative impacts associated with the proposed development of the Rosemont Copper Project (Project) under the National Environmental Policy Act (NEPA). Many of the comments received on the DEIS reflected concern about impacts to water resources and specifically about the relationship between the proposed development at the Project site and existing features of the regional watershed. This document integrates the results of analyses on geochemistry, seepage, surface water quantity and quality, geomorphology, groundwater quantity and quality, and aquatic resources into an accessible document that fully characterizes the Project’s impacts to water resources both at the Project site and at a watershed scale. Most of these analyses were also included in the DEIS. However, this document concisely describes the information related to water resources and demonstrates how the studies and analyses relevant to water resources have been used to improve the Project designs in order avoid and manage impacts on the environment and water resources within the Cienega Creek/Davidson Canyon watersheds.

The proposed Project site is located on the northeastern slopes of the Santa Rita Mountains in southern Arizona, in a region known as the Basin and Range Province. This area encompasses a large number of mountain ranges separated by broad alluvial valleys, and the region has great diversity of topography, climate, water, and biological resources.

The Project site itself lies within a recognized mining district and includes remnants of abandoned mines and dumps from the late nineteenth and early twentieth centuries. A comprehensive body of long-established patented and unpatented mining claims covers the area of the proposed Project. It is a ‘hard rock’ mining site with substantial mineral resources, but limited surface water, groundwater and biological resources, especially in comparison with surrounding areas some miles distant.
Rosemont recognized from the beginning of its mine planning phase the importance of designing the Project to comprise the best possible ‘fit’ with its neighbors—human and environmental. To that end, Rosemont commissioned a wide range of established, capable, and professionally respected consulting firms to conduct studies of the existing environment and to analyze the potential effects of the proposed Project on the area. To date, almost 400 reports have been completed, describing studies conducted over five (5) years. The design of the Project has been guided by the results of these studies in order to avoid or minimize environmental impacts. The studies have been thoroughly reviewed by consulting firms retained by, and responsible to, the USFS, and many of the studies have been modified and revised according to the recommendations of the USFS consultants. ‘State of the art’ environmental monitoring, modeling, and analytical techniques were used to predict impacts and are the basis for the conclusions in this report. These conclusions include:

- The natural geochemistry of the vast majority of the rock to be excavated at the Project site is alkaline (over 90%). This natural characteristic of the Rosemont site provides a primary level of protection for the environment. The small percentage of potentially acid-generating material that is present at the site can be managed within the facilities by blending with abundant acid-neutralizing materials.

- As a second level of protection for water quality, Rosemont’s facilities have been designed to limit seepage to extremely low rates—in the case of tailings facilities and heap leach facilities, these rates are orders of magnitude lower than in older copper mines in Arizona. These design elements were specifically used to avoid impacts to water resources.

- The Open Pit will create a permanent hydraulic sink. All groundwater flow within its capture zone will be towards the pit; no outflow from the Pit Lake will occur due to terminal Pit Lake conditions. Any seepage from the waste rock and tailings storage area that occurs within the extent of this capture zone will report to the Pit Lake.

- Groundwater levels surrounding the pit will decline within two (2) to three (3) miles of the pit, with the area affected by groundwater decline gradually expanding for many years after the mine closes but the magnitude of the decline attenuating with increasing distance from the pit. The expected groundwater level declines are very small in the critical environmental areas along Cienega Creek and in the Outstanding Arizona Water (OAW) section of Davidson Canyon. Declines in these areas are estimated at less than one (1) foot once groundwater equilibrium is reached. There is uncertainty inherent in characterizing impacts so distant in both time and space, especially when the impact is small. However, models using different assumptions produced comparable
results, and the models were run to 1,000 years after the cessation of mine dewatering to estimate possible impacts at these areas.

- Reductions in storm-induced surface water flows will be substantial in the small ephemeral drainages immediately downstream of the Project. However, for the larger Davidson Canyon watershed and the much larger Cienega Creek watershed, the flow reductions will represent a small incremental change, particularly given the wide natural variability in precipitation and surface water flow. The range of post-mining flows will remain within the pre-mining range of flows based on these natural variations.

- Reductions in sediment load will be substantial for the small drainages in which the Project facilities are located. However, for the larger Davidson Canyon and Cienega Creek watersheds, these reductions in sediment load will be negligible.

- Within the area covered by Project facilities, effects on aquatic resources will be substantial, resulting in almost complete relocation, reconstruction, or displacement of existing stream channels and springs. Outside the Project site, however, effects on aquatic resources and waters of the U.S. will be minimal compared to natural variations caused by drought cycles and resulting vegetative changes.

- The Project-induced changes in surface water, water quality, sedimentation, and groundwater will be negligible outside the immediate Project Area. Impacts will be further reduced with implementation of the mitigation elements which were described by the USFS in the DEIS and of a mitigation plan that will be required by the U.S. Army Corps of Engineers (USACE).

In summary, the studies of geochemistry, seepage, groundwater, surface water, sedimentation, and aquatic resources undertaken to characterize Project impacts have been extensive, and were conducted by qualified engineers, hydrologists, geologists, and other environmental scientists. These studies have been thoroughly reviewed by independent qualified consultants working for the USFS. Results of the studies, and refinements resulting from USFS input, have been incorporated into the design of the Project facilities to avoid and manage impacts to aquatic and water resources. The final determinations of this complex and extensive process are that, outside of a few miles from the mine, the Project’s effects on important regional water and biological resources are minor. Even though impacts will increase closer to the Project disturbance, they are still predicted to be in compliance with state and federal regulations that are protective of aquatic, surface water, and groundwater resources.
1 PURPOSE AND SCOPE

Rosemont is planning the development of an open pit mining and mineral processing operation known as the Rosemont Copper Project (Project) on the east side of the Santa Rita Mountains, southeast of Tucson, Arizona in Pima County. A MPO was submitted to the CNF. The CNF is the administrative unit of the USFS responsible for assessing environmental impacts associated with the Project as the lead agency in the NEPA process.

The USFS retained independent consultants as needed to provide expertise in evaluating the MPO, and a DEIS was prepared by the CNF to evaluate and describe the direct, indirect and cumulative impacts on environmental resources associated with the Project. The USFS has accepted comments on the proposed Project, both during scoping, which occurred prior to the development of the DEIS, and in the formal comment period under the NEPA process after a notice of availability of the DEIS was published in the Federal Register on October 19, 2011 (76 Fed. Reg. 64893). The Project’s potential to impact water resources is one of the issues that has received significant study and generated appreciable concern in comments from agencies, organizations and the public, both before and after the publication of the DEIS. This Integrated Watershed Summary report is intended to respond to these concerns in a format that is clear and comprehensive.

Rosemont is also seeking a permit pursuant to Section 404 of the Clean Water Act (CWA) to discharge dredged or fill material in conjunction with the Project. The USACE is the agency responsible for issuing permits under Section 404 and has issued a public notice for Rosemont’s Section 404 permit application. USACE is a cooperating agency on the DEIS and is relying on the DEIS to fulfill its NEPA obligations. The U.S. Environmental Protection Agency (EPA) has oversight authority under Section 404 for permits issued by the USACE.

Consistent with NEPA, the best available data were used in the DEIS to describe the affected environment and environmental consequences of the Project. The DEIS incorporated the results of water resource investigations that were complete and those that were ongoing. However, the DEIS did not always describe, in detail, the data or sensitivity analyses results that drove the design of those investigations. Rather, this information was contained in the documents referenced in the DEIS. Because this information was not in the body of the DEIS, some comments questioned the validity of the methods used to quantify Project impacts. Rosemont recognizes that the sheer bulk of available study data, as well as the data’s presentation in numerous discrete reports relevant to specific areas of expertise prepared by various consultants, can be overwhelming. The volume of technical work completed now increases the challenge inherent in piecing together an up-to-date picture of the Project’s relationship to water resources and water quality issues.

The purpose of this Integrated Watershed Summary is to describe the strategic investigation, planning, and management efforts that have resulted in the
development of the Project MPO and informed the preferred alternative, and to concisely present the results of interdisciplinary investigations that quantify and qualify the impacts of the Project to regional water resources. Adjustments to some Project facilities have been incorporated into the most current Project design concepts as a direct result of the NEPA process. The water resources investigations were reviewed in light of the concerns raised in some of the DEIS comments, which resulted in some analysis adjustments and model refinements, and the addition of sensitivity analyses to establish the stability of model results in spite of changed assumptions. In addition, data from ongoing investigations has been incorporated. Effort and resources have been devoted to providing additional clarity for issues identified in the DEIS comments.

This report begins by describing the regional setting of the Project Area, including an analysis of baseline conditions for geology, climate, precipitation, surface water, groundwater, and biological resources. The project setting description provides a concise and current overview of Project features relevant to water resource discussions. This narrative describes how water resources issues were investigated to characterize Project impacts, and how the comprehensive MPO and the design of specific Project features were developed to avoid and manage impacts. Finally, information on geochemistry as it relates to water quality at the Project site, watershed-wide surface water resources, groundwater resources and their potential interaction with surface water, and aquatic resources is provided. Although these topics are addressed in separate sections, these issues are interrelated and the discussion uses an interdisciplinary approach when appropriate.

The objective of this report is to provide a single, comprehensive source of information that integrates, summarizes, and clarifies the extensive scientific work relevant to water resources issues that has been completed on this Project. The intent is to further the discussion and to support responsible development of a strategically and economically important mineral resource. References to more detailed technical support documents are included to facilitate the reader in locating supporting data or additional information.
2 REGIONAL SETTING

The Project site is located approximately 30 miles southeast of Tucson in southern Arizona (Appendix Figure 2-1). It lies within the basin and range physiographic province characterized by narrow mountain ranges separated by valleys or basins that form the lowland areas. Mountain ranges in southern Arizona are often referred to as “Sky Islands.” High altitude ecosystems are isolated from other ranges by lower elevation desert and grasslands. The climate and ecosystem differences limit the migration of some species from one range to another. Cooler, forested habitats exist in the higher elevations, while hotter and drier habitats occur in the lowland desert and grassland areas. In this report, the “Project Area” is defined as approximately 4,000 acres of proposed development for Project facilities (e.g., Dry Stack Tailings Facility, Waste Rock Storage Area, Open Pit, etc.). The broader area that has been studied to characterize the Project’s impacts to water resources is termed the “Study Area.” This section also discusses the larger regional area, which includes southern Arizona.

The Sonoran Desert, which is the hottest of the major North American deserts (Chihuahuan, Great Basin, Mojave, and Sonoran), is located immediately west of the Project (Appendix Figure 2-1; Weiss and Overpeck 2005). Peaks in the Santa Rita Mountains, where the Project is located, are over 6,000 feet above mean sea level (amsl). Mount Wrightson, which is located a dozen miles to the south and outside of the immediate Project Area, has an elevation of 9,453 feet amsl. The topography descends into the Cienega Creek and Davidson Canyon watersheds to the east of the Santa Rita Mountains. The elevation at the confluence of Davidson Canyon Wash and Cienega Creek is 3,325 feet amsl, which is nearly 2,000 feet lower than the Project Area.

The Study Area for the Project extends west to incorporate the full width of the northern Santa Rita Mountain range, north to incorporate Davidson Canyon and lower Cienega Creek, and south and east to incorporate most of the Cienega Creek basin and the Sonoita Plain (Appendix Figure 2-2). This Study Area was defined to encompass areas of potential concern along Cienega Creek and Davidson Canyon. The proposed Rosemont Open Pit and the other main Project facilities are located in the upper Davidson Canyon watershed (Appendix Figure 2-2).

2.1 Previous Studies

Rosemont and other investigators have conducted numerous scientific studies both within the Project Area and throughout the Study Area. Some of these studies date back to earlier development planning efforts in the 1970s and 1980s. Engineering design studies related to the Project facilities have also been completed. Scientific studies of aquatic resources, groundwater resources, surface water resources, riparian vegetation, geology, geochemistry, climate, stream flow, and springs have been completed for the Project. The U.S. Geological Survey (USGS), the University of Arizona (UA), the Arizona Department of Water Resources (ADWR), the Arizona
Geological Survey (AZGS), the Pima Association of Governments (PAG), and the Bureau of Land Management (BLM) have also completed current and historical studies. Many of these various studies are discussed in further detail in the project setting, seepage and water quality, surface water, groundwater, and aquatic-resources sections.

The following subsections provide an overview of the current and historical physical conditions in the Study and Project Areas. These conditions form the historical context and background conditions upon which the Project will be superimposed in southern Arizona. Determining the significance of potential future impacts due to the Project requires an understanding of the baseline natural variability that has historically influenced surface water, groundwater, and aquatic resources in the region.

### 2.2 Land Use and Hydrography

Arizona is known as the “Copper State” due to its numerous deposits of copper and other metals. Mining claims are prevalent in southern Arizona and there are numerous active copper mining operations in the Project Area (Appendix Figure 2-1). Throughout Arizona’s history, mining has been a major economic industry. In 2010, Arizona’s copper mining industry had a $34.2 billion impact on the U.S. economy and a $12.1 billion impact on Arizona’s economy (AMA 2012). Arizona is the largest copper-producing state in the U.S., accounting for 63% of domestic mined copper. The Project site lies within an old mining district and includes remnants of abandoned mines and dumps from the late nineteenth and early twentieth centuries. These previous mineral exploration and production activities resulted in numerous mine prospects, adits, and access roads that are still present. Historic patented and unpatented mining claims exist throughout the Project Area (Appendix Figure 2-1).

The proposed Project facilities are located on Rosemont and USFS lands (Appendix Figure 2-2). The CNF includes five (5) non-contiguous ranger districts, and the specific district in the Study Area extends from Mount Fagan in the north to the Sonoita Creek watershed in the south. Most of the Study Area is public land administered by the USFS, State of Arizona, Pima County, and the BLM (Appendix Figure 2-2).

The Cienega Creek watershed is subdivided into upper and lower basins. Surface water flow is generally from south to north in the upper basin. The channel turns to the northwest in the lower basin. Davidson Canyon is tributary to lower Cienega Creek (Appendix Figure 2-3). Cienega Creek and Davidson Canyon Wash are the primary drainages in the Study Area. The headwaters for these channels originate in the higher elevation areas in the southern Study Area and along the Santa Rita Mountains.
The Las Cienegas National Conservation Area (LCNCA), which consists of rolling
grasslands and oak-covered hills, covers more than 45,000 acres in upper Cienega
Creek basin and is administered by the BLM. The LCNCA includes upper Cienega
Creek, which has non-contiguous perennial reaches extending from the confluence
with Gardner Canyon Wash, north through a reach where the stream channel
constricts (“The Narrows”) (Appendix Figure 2-3). Ranching and livestock grazing
have dominated the Cienega Creek watershed since the 1880s. The LCNCA was
originally part of the Empire and Cienega Ranches, and four (4) ranchers currently
hold grazing allotments in the LCNCA. There are also three (3) active Forest Service
grazing allotments along the northeastern slope of the Santa Rita Mountains. The
BLM visitor center and working cattle ranches extract groundwater from wells to
support operations in the LCNCA. Mining also occurred on the Empire Ranch and in
many drainages west and southwest of the ranch including the Greaterville Area.

The Cienega Creek Natural Preserve (Preserve) encompasses over 4,000 acres of
land adjacent to approximately 12 miles of the Cienega Creek channel (Appendix
Figure 2-3). Properties composing the Preserve are currently owned by the Pima
County Regional Flood Control District (RFCD) and managed jointly by RFCD and
Pima County Natural Resources, Parks and Recreation Department (NRPR) (Pima,
2012). Cienega Creek, which has non-contiguous stretches of perennial flow
separated by normally dry reaches, is the Preserve’s key feature. Riparian
vegetation consisting of cottonwood, willow, and mesquite trees is commonly
present near the stream channel (Appendix Figure 2-2).

A large section of Cienega Creek and the lower reach of Davidson Canyon Wash have
been designated as Outstanding Arizona Waters (OAW; Appendix Figure 2-3). This
designation provides protection to ensure that outstanding waters will not be
degraded (PAG 2005). The Cienega Creek OAW reach extends approximately 28.3
river miles downstream from the confluence with Gardner Canyon and Spring
Water Canyon to the USGS Pantano Dam gaging station (ADEQ 2012; Appendix
Figure 2-3). The lower Davidson Canyon Wash OAW reach extends approximately
three (3) river miles downstream from an unnamed spring (referred to here as the
Reach 2 Spring) to the confluence with Cienega Creek. Reach 2 Spring is
approximately twelve (12) river miles downstream from the Project.

In addition to historic mining and ranching, modern mines and other development
activities, including the Rosemont Project, have been proposed or are currently in
operation within the Davidson Canyon Watershed. Current active land uses include:
agriculture in the form of vineyards; ranching, including both small family ranches
with a few animals and large commercial ranch operations; domestic homes; and
recreational activities that include heavy off-road vehicle use.

Arizona state land is prevalent throughout the Study Area (Appendix Figure 2-2).
State-owned lands are largely undeveloped with the exception of ranching activities,
but they often surround in-holdings of private land that have been developed. The
in-holdings within the Study Area contain low-density residential homes, with some
agriculture and ranching activities. At least one limestone quarry has a current lease on state land.

### 2.3 Climate

The southern Arizona climate is typical of a semi-arid continental desert with hot summers and temperate winters. The Project Area is in the Santa Rita Mountains at elevations exceeding 5,000 feet amsl. The higher elevation climate in the Project Area is milder than at the lower elevations across the region. Summer daily high temperatures in the Project Area are above 90 degrees Fahrenheit (°F) with significant cooling at night. Higher temperatures and less nighttime cooling occur at the lower elevations. Winter in the Study Area is typically drier with mild daytime temperatures and overnight temperatures that are typically above freezing. Winter can have occasional low intensity rainstorm patterns that can last for multiple days (Tetra Tech 2010c). Average precipitation from August to March ranges from 8 to 14 inches. The lowest precipitation months are April, May, and June.

The monsoon season is characterized by afternoon thunderstorms that are typically of short duration, but have high-intensity rainfall. The monsoon season months have the highest precipitation (Figure 2-4). Historically, the start of monsoon season was determined when the average daily dew point was 54 degrees or greater for three consecutive days (NOAA 2012). Since 2008, however, the monsoon season has been defined as June 15 to September 30, which has historically marked the range of the monsoon weather pattern. Based on the dew point criterion, which indicates higher atmospheric moisture and the potential for increased precipitation, the average monsoon start date is in the first week of July (NOAA 2012). Rosemont installed an on-site meteorological station on April 1, 2006. The monitoring program includes data processing, instrument audits, calibrations, and maintenance. The station monitors site-specific weather data including temperature, precipitation, wind speed, and wind direction. Pan evaporation was added to this station in mid-2008. The station is located at the approximate center of the proposed Open Pit at an elevation of 5,350 feet amsl (AEC 2006). There are eight (8) meteorological stations located within an approximate 30-mile radius of the Project site with longer periods of record than the Rosemont station, and these data were used to determine climate conditions in the Study Area (Appendix Figure 2-5). These climatic conditions are important because they influence groundwater recharge, stormwater runoff, stream flow, riparian vegetation, evapotranspiration (ET), and spring discharge.

#### 2.3.1 Precipitation

Precipitation in southern Arizona typically varies with elevation and may also vary depending on topographic influences that can create rain-shadow effects. The rain-shadow effect is due to moisture from the Gulf of Mexico being blocked by the Rocky and the Sierra Madre Mountain ranges. This results in dry and hot conditions in southern Arizona. Higher elevations tend to have higher precipitation than lower
elevations as illustrated in Appendix Figure 2-5. Mountain ranges may have over 25 inches of annual precipitation, while lowland areas typically have less than 15 inches per year.

Due to the short period of record from the Rosemont weather station, an analysis of available historical precipitation data was completed. This analysis resulted in an average annual precipitation estimate of 17.7 inches per year for the Project Area (Tetra Tech 2010d). The average monthly precipitation measured at weather stations within an approximately 30-mile radius of the Project site is presented in Table 2-1 (WRCC 2012)

Figure 2-4. Average Monthly Temperature, Precipitation and Pan Evaporation at Nogales Weather Station.
<table>
<thead>
<tr>
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</tr>
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<tbody>
<tr>
<td>January</td>
<td>1.30</td>
<td>1.58</td>
<td>1.47</td>
<td>1.38</td>
<td>1.07</td>
<td>1.07</td>
<td>1.12</td>
<td>1.12</td>
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<tr>
<td>February</td>
<td>1.16</td>
<td>1.72</td>
<td>1.02</td>
<td>1.14</td>
<td>0.86</td>
<td>0.98</td>
<td>0.84</td>
<td>0.84</td>
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<tr>
<td>March</td>
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<td>0.44</td>
<td>0.28</td>
<td>0.37</td>
<td>0.22</td>
<td>0.22</td>
<td>0.44</td>
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<tr>
<td>April</td>
<td>0.44</td>
<td>0.52</td>
<td>0.28</td>
<td>0.22</td>
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<td>0.37</td>
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<td>0.17</td>
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<td>0.42</td>
<td>0.54</td>
<td>0.45</td>
<td>0.54</td>
<td>0.51</td>
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</tr>
<tr>
<td>July</td>
<td>4.42</td>
<td>4.05</td>
<td>4.14</td>
<td>4.36</td>
<td>4.36</td>
<td>4.64</td>
<td>4.19</td>
<td>4.19</td>
<td>4.64</td>
</tr>
<tr>
<td>August</td>
<td>4.05</td>
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<td>3.74</td>
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<td>September</td>
<td>2.19</td>
<td>2.19</td>
<td>1.63</td>
<td>1.57</td>
<td>1.57</td>
<td>1.44</td>
<td>1.44</td>
<td>1.44</td>
<td>1.44</td>
</tr>
<tr>
<td>October</td>
<td>0.84</td>
<td>0.84</td>
<td>0.89</td>
<td>0.89</td>
<td>0.89</td>
<td>0.89</td>
<td>0.89</td>
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</tr>
<tr>
<td>November</td>
<td>1.02</td>
<td>1.02</td>
<td>1.27</td>
<td>1.27</td>
<td>1.27</td>
<td>1.27</td>
<td>1.27</td>
<td>1.27</td>
<td>1.27</td>
</tr>
<tr>
<td>December</td>
<td>1.40</td>
<td>1.52</td>
<td>1.18</td>
<td>1.39</td>
<td>1.39</td>
<td>1.29</td>
<td>1.39</td>
<td>1.39</td>
<td>1.39</td>
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<table>
<thead>
<tr>
<th>Data source</th>
<th>Tetra Tech (2010d)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monsoon months are shaded.</td>
<td></td>
</tr>
</tbody>
</table>
Average monthly temperature and precipitation data indicate the seasonal variability in the Study Area (Figure 2-4, Table 2-1). Winter temperatures are mild with relatively low precipitation and summers are hot with increased precipitation during the monsoon season. However, multiple day winter storms can result in significant precipitation that can produce groundwater recharge.

Figure 2-6. Annual Precipitation at Nogales Weather Station with Periods of Drought.

2.3.2 Temperature

Average annual temperature data indicate the seasonal temperature variability in the Study Area (Figure 2-7). A previous climate study of the Rosemont area was commissioned by Anamax Mining Company (UA 1977). The average monthly minimum temperatures at the Rosemont site usually occurred in January and were approximately 36°F; maximum monthly temperatures usually occurred in June and were above 90°F (UA 1977). These results are consistent with the temperature data collected at the on-site weather station since April 2006. The long-term temperature record in Figure 2-7 indicates an overall warming trend in southern Arizona since the 1950's.
2.3.3 Evaporation

Evaporation is an important climatic parameter at mine sites. The post-closure Pit Lake water balance estimates are heavily influenced by assumptions about water evaporation from the Pit Lake. A high evaporation rate due to high temperatures and low humidity is expected to result in a depressed Pit Lake stage that creates a terminal hydraulic sink condition. Potential net infiltration through waste rock and tailings facilities also depends in part on evaporation.

Pan evaporation data have been historically collected at the UA and Nogales 6 N meteorological stations. Pan evaporation at the Rosemont meteorological station was added in June 2008. Average monthly pan evaporation for the three (3) stations is provided on Figure 2-4. An annual average pan evaporation of about 71.5 inches was estimated for the Rosemont site based on correlation with data from the UA and Nogales 6 N stations (Tetra Tech 2010d). Pan evaporation is approximately 30% higher than open water evaporation due to measurement conditions. Therefore, annual evaporation on the Pit Lake surface is expected to be 50 inches per year, which greatly exceeds the average annual precipitation of 17.7 inches per year.
2.4 Climate Variability

Groundwater level decreases due to the Project are predicted to take hundreds of years to materialize at distant ecologically sensitive areas along Cienega Creek. A review of climate variability is important because the climate far into the future is likely to be different than today’s conditions. Variations in climate have resulted in significant changes to the regional ecosystem in the past, and similar changes are likely over the next 1,000 years. The small magnitude of predicted Project impacts should be considered in the context of the natural environmental changes that can occur due to baseline climate fluctuations.

Climate variability can be discussed in terms of the last 100 or so years, when temperature and precipitation data have been collected, and in terms of the past millennia, by relying on proxies to reconstruct the climate. Future climate is predicted by numerical models.

Over 100 years of instrumented weather records from Patagonia and Nogales stations provide an indication of the natural climate conditions and variation that can be expected at the Rosemont site. In that period there have been recurring cycles of drought and above average precipitation conditions (Figure 2-6). Annual precipitation data on Figure 2-6 illustrates this cyclic variability and the occurrence of droughts since 1899. The definition of a drought varies depending on the study, but the term generally applies to prolonged periods of below average precipitation, which may be accompanied by higher temperatures. Significant recent droughts in the southwest occurred at the turn of the twentieth century, from 1953 to 1957, and at the turn of the twenty-first century (Figure 2-6). Drought conditions have persisted from 1996 to the present in the southwest, with the driest conditions from 2002 to 2004. Understanding past climate changes helps to understand the possible future climate impacts on biodiversity due to climate variations (Overpeck and others 2005). Although there has been considerable climate variability during the past 100 years, it is likely that this variability underestimates the more distant historic past and the potential future variability (Overpeck and others 2005).

2.4.1 Historical Droughts

Droughts in the southwestern U.S. are conspicuous within the data recorded over the past 100 years. The most notable droughts occurred in the late 1890’s through the early 1900's, the 1950s, and the most recent, and possibly still ongoing, drought of the early 2000's (Figure 2-6, Swetnam and Betancourt 1998, Fye and others 2003, Seager 2007, Quiring and Goodrich 2008). Several other droughts analogous to the 1950’s drought, which is regarded as the worst of the twentieth century, also likely occurred during the past 500 years (Weiss and others 2009). Tree-ring records reveal that the 2000’s drought was one of the 10 most severe droughts in the southwestern U.S. since the 1500’s (Piechota and others 2004). These droughts suggest a recurrence interval of roughly 50 years in the southwest U.S. (Fye and others 2003, Hidalgo 2004, Quiring and Goodrich 2008).
Paleoclimatic data provide evidence that twentieth-century droughts are not representative of the full range of drought variability that has occurred over the last 2,000 years. The collection of dendroclimatic reconstructions for the Great Plains region suggests that the severe droughts of the twentieth century are not unprecedented in the past four (4) centuries. When all proxy data, including historical accounts of eolian activity, are considered, it is likely that droughts of a magnitude at least equal to those of the 1930’s and 1950’s have occurred with some regularity over the past 400 years.

There is also evidence for two (2) major multi-decadal droughts of the late thirteenth and/or sixteenth centuries that were of a much greater duration and severity than twentieth century droughts (Woodhouse and Overpeck 1998). The most recent of these “megadroughts” occurred throughout the western U.S. in the second part of the sixteenth century (Woodhouse and Overpeck 1998). This drought is believed to be the most severe drought of the past 500 years (Meko and others 1995, Stahle and others 2000). Prominent multi-decadal drought and pluvial periods in western North America over the last 1,200 years identified by Conroy and others (2009) are provided in Table 2-2. Since the year 855 there have been nine megadroughts with an average duration of 48 years.

Table 2-2. Prominent Multi-decadal Drought and Pluvial Periods in Western North America (Conroy and others 2009)).

<table>
<thead>
<tr>
<th>Drought</th>
<th>Pluvial</th>
</tr>
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<tbody>
<tr>
<td>Years</td>
<td>Duration (years)</td>
</tr>
<tr>
<td>855–887</td>
<td>32</td>
</tr>
<tr>
<td>943–1042</td>
<td>99</td>
</tr>
<tr>
<td>1122–1179</td>
<td>57</td>
</tr>
<tr>
<td>1215–1290</td>
<td>75</td>
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<tr>
<td>1375–1408</td>
<td>33</td>
</tr>
<tr>
<td>1433–1482</td>
<td>49</td>
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<tr>
<td>1567–1595</td>
<td>28</td>
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<tr>
<td>1849–1893</td>
<td>44</td>
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<tr>
<td>1948–1966</td>
<td>18</td>
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</tbody>
</table>

2.4.2 Future Climate

Climate conditions naturally fluctuate over time and as shown there is evidence for dramatic changes in the past. As will be discussed in subsequent sections, recent data indicate declining groundwater level in a few wells and declining stream-flow trends in response to the current drought conditions. In the future, decreases in
water levels, spring flows, riparian vegetation, and stream flows can be expected periodically due to climate variability.

### 2.5 Hydrogeology

The bedrock forming the Santa Rita Mountains consists of a crystalline metamorphic core flanked by Paleozoic and Mesozoic sedimentary rocks including carbonates, shales, and limestones locally metamorphosed and metasomatized (Appendix Figure 2-8) (Wardrop 2005). These and similar rocks across the watershed are collectively termed bedrock. Permeability in the bedrock is primarily due to secondary fractures, since the bulk rock is typically metamorphosed or highly consolidated with minimal storage and permeability. This bedrock is typically covered by unconsolidated to semi-consolidated basin-fill deposits, recent alluvium, and unconsolidated deposits in the low lying drainage channels. These surficial deposits typically have higher storage and permeability, with the capacity to transmit more water than the underlying bedrock (Tetra Tech 2010a).

The bedrock topographic highs define the watershed boundary for Davidson Canyon (Appendix Figure 2-2). Due to the generally low permeability of the bedrock, and the focusing of water toward the interior of the watershed, it is assumed that the groundwater sub-basin follows the watershed boundary. Although groundwater inflows to the Davidson Canyon sub-basin are not believed to be significant, there could be inflows in the upper-most reaches where the divides are less pronounced. Groundwater observed in Davidson Canyon is predominately the result of recharge occurring within the watershed (Tetra Tech 2010a).

The Paleozoic rocks in the Study Area include limestone, dolomitic limestone, and dolomite, along with lesser amounts of sandstone, conglomerate, shale, and siltstone. Limestone units are the host rock for copper mineralization in the Rosemont area and mineralizing fluids severely altered the limestone rocks that created the ore body. Many of the limestone rocks in the Project Area have been altered and/or metamorphosed to skarn or marble (M&A, 2010).

No evidence of an extensive karst system in the Rosemont area carbonate rocks has been observed during the extensive drilling program for geotechnical, hydrogeologic and orebody characterization. Small isolated cavities, on the scale of inches, have been observed in a few core holes (Cornoyer 2010). Mineralization fluids and metamorphosing heat that created skarn and marble have further reduced the permeability of rocks in the Project Area.

Except at shallow alluvium wells constructed in Barrel Canyon Wash, all of the rock units encountered during drilling in the Project Area (M&A 2009a) are moderately to strongly lithified. In the southeast area of the proposed pit, upper excavated levels will intercept strongly cemented basin-fill deposits. In the cemented basin-fill deposits, groundwater flow typically occurs in the pore space between sediment grains; however, this pore space has been largely filled by cementation. Hydraulic
connectivity within and between the larger bedrock complex and cemented basin-fill deposits system tends to be low and limits the lateral drawdown extent (M&A 2010).

Basin-fill deposits and alluvium cover the bedrock units to various depths in the Study Area. Basin-fill deposits in upper Cienega Creek are more spatially extensive and occur to greater depths. These deposits cover the deeper Paleozoic limestone units. Unconsolidated and poorly cemented basin-fill deposits tend to have greater water storage capacity (per unit volume) than bedrock units. More groundwater flow is possible through the shallow unconsolidated sediments than through the well lithified basin fill that extends from the surface to the underlying bedrock.

### 2.5.1 Geologic Structures

Geologic mapping by the Arizona Geologic Society (AZGS) delineated several geologic structures, including faults and dikes, in the pit area and throughout upper Davidson Canyon (Appendix Figure 2-8; Ferguson 2009, Ferguson and others 2001, Spencer and others 2001). An aquifer testing program was conducted by Montgomery and Associates, Inc. (M&A) in 2008 and 2009 (M&A, 2009a, M&A 2009b). One of the objectives of the aquifer testing program was to determine if these geologic structures were barriers or conduits to groundwater flow. Areas of limited groundwater flow were observed where wells were pumped dry at low pumping rates.

The north-south trending “Backbone Fault” is present along the ridge of the Santa Rita Mountains and through the western pit area (Appendix Figure 2-8). This faulting appears to have created a higher conductivity zone due to increased fracturing. This may enhance north-south groundwater flow in the immediate Open Pit area. However, the Precambrian granodiorite unit to the west of the fault has low conductivity, which would impede groundwater flow to the west (M&A 2010). Thermal and mineral alteration in the pit area may have reduced the rock permeability by sealing fractures and faults.

The Davidson Canyon fault zone consists of a western fault that is concealed by alluvium and an eastern fault that is partially exposed in the northern piedmont of the Empire Mountains (Appendix Figure 2-8; Ferguson and others 2001). These faults are poorly understood (Ferguson and others 2001), but their importance to groundwater flow has been demonstrated from groundwater flow modeling (Tetra Tech 2010b, M&A 2010). Water-level contours indicate that groundwater flow is focused toward the Davidson Canyon surface water drainage (Appendix Figure 2-9; M&A 2010). The orientation of the Davidson Canyon fault zone is likely to be roughly parallel to the groundwater flow direction, suggesting that there is some degree of enhanced flow in the fault zone. The width of an enhanced flow zone cannot be accurately determined based on the available information. Observed water levels suggest that the fault zone is more permeable than the surrounding bedrock, is near the alluvial stream channel, and extends from below the confluence
of Barrel and Davidson Canyon Washes to the confluence of Davidson Canyon Wash and Cienega Creek. A permeable fault zone would tend to direct bedrock groundwater flow towards the Davidson Canyon alluvial stream channel area.

Numerous quartz-porphyry dikes have formed in the Empire Mountains (Ferguson 2009) and Mount Fagan areas (Ferguson and others 2001). These dikes may create barriers to groundwater flow due to their low permeability, relatively young geologic age that bisects older rocks, orientation transverse to flow, and tendency to seal fractures in the surrounding bedrock. One of the longest, thickest, and most continuous dikes perpendicularly intersects Davidson Canyon Wash downstream of the confluence with Barrel Canyon Wash (Appendix Figure 2-8). Faulting in areas where it is concealed by alluvium may have disrupted this dike, but this cannot be verified due to the lack of surface exposure.

2.5.2 Bedrock Fractures

Lithified bedrock permeability and storage in the Project Area and in most of the region is dominated by fractures. In the Project Area, the degree of hydraulic connection between these fractures and the spatial extent of this connection determines the long-term groundwater inflow to the pit, the magnitude and timing of groundwater drawdown away from the pit, and the groundwater-related environmental impacts to ecologically sensitive areas. Drawdown will preferentially propagate to areas with higher fracture permeability when there is a hydraulic connection over long distances. Conversely, if the hydraulic connection is limited in spatial extent, drawdown propagation will be limited, regardless of the permeability of the disconnected fractures.

Numerous 12- and 24-hour single well tests and a 30-day hydraulic test using five (5) pumping wells, 46 observation wells/piezometers, four (4) springs and a dam were conducted by M&A (2009). The results indicated that there are zones within select wells that are permeable and capable of producing water. A 2-foot water-level drawdown response to pumping was observed between wells PC-5 and PC-7, which are 3,541 feet apart in the proposed pit area. This was the greatest distance between a pumped well and an observed response in the 30-day test. The Flat Fault, a low angle fault that has been observed in several wells in the proposed pit area, was interpreted as being the structure responsible for the hydraulic connection between PC-5 and PC-7 (M&A 2010).

The permeability in several wells was quite low, resulting in minimal groundwater flow to the well. This suggests that a limited set of fractures is hydraulically connected, and this connection does not extend over large distances. Groundwater flow to wells and the Open Pit will initially be predominately from fracture storage. As long-term pumping depletes the water stored in the fractures, flow to wells and the Open Pit will be controlled by the matrix material and precipitation recharge.
More heavily fractured and faulted bedrock areas exist in the Backbone Fault, the Flat Fault, and the Davidson Canyon Fault zones. These areas have higher permeability and hydraulic connections over larger areas than the surrounding bedrock. In the Project Area, hydraulic connections due to the Backbone and Flat Faults appear to exist at a scale of less than 5,000 feet. Outside of these more intensely fractured fault zones the hydraulic connections between permeable fractures are less likely. High water levels in the pit area suggest that poor hydraulic connections exist between the pit area bedrock and down-gradient areas.

2.5.3 Groundwater Flow

Groundwater-level data are currently being collected by Rosemont in the Project Area and by other entities (e.g., PAG, ADWR, and the BLM) in Davidson Canyon, the Preserve, and LCNCA. Monthly water-level monitoring by Rosemont has been ongoing since 2006, and hydrogeologic characterization wells were installed in 2008 with regular water-level data collection beginning after their installation. These water-level data are used to characterize the horizontal and vertical hydraulic gradients throughout the Study Area, which determine flow directions. These data are also used to constrain groundwater flow modeling and to determine the groundwater system conditions, including confined and unconfined pressures and surface water and groundwater interactions. Hydrogeologic analyses provide valuable information on how rock characteristics vary and how geologic structures, such as faults, fractures, and dikes, impact the groundwater system.

Groundwater levels are highest in the pit area and along the crest of the Santa Rita Mountains, with water levels generally decreasing as the topography decreases. Groundwater flow is from the topographically high areas to the low areas, and follows the gradient defined by the water-table contours as indicated by the arrows on Appendix Figure 2-9. The volume of groundwater flow through the pit area is limited by the low permeability bedrock and the connectivity of the fractures, but there is flow to down-gradient areas. From the Open Pit area, the primary groundwater flow paths are toward Davidson Canyon.

The Santa Rita Mountains and the Open Pit area are in a large hydraulic gradient area. Areas with large hydraulic gradients are indicated by closely spaced contours and these areas are outlined on Appendix Figure 2-9. Large hydraulic gradients occur where there are low permeability rocks that restrict groundwater flow to lower elevations, such as in the Project Area. These characteristics will tend to limit drawdown propagation away from the Open Pit. Large groundwater-level drawdown will occur within a few miles of the pit area, but the drawdown decreases rapidly with distance.

The downward hydraulic gradients near the proposed Open Pit (M&A 2009) indicate that recharge is occurring in this area. Steeply dipping bedrock units may have enhanced permeability along exposed bedding planes and fractures that allow precipitation to infiltrate into the groundwater system.
Confined groundwater conditions are also known to exist at depth in the Open Pit area. Higher water pressures are created by infiltrating precipitation that results in recharge and high water levels. Wells that exhibit confined pressures and flowing conditions are located in or near the Flat Fault, which has enhanced permeability. Low permeability volcanic units overlay the Flat Fault (Appendix Figure 2-10) creating a cap, or confining layer, that creates the confined groundwater pressure. Penetrating this cap with wells allows groundwater to rise and even flow at the surface.

Water table or unconfined conditions tend to exist at shallow depths across the Study Area. Unconfined, shallow fractured bedrock and unconsolidated basin fill and alluvium are open to surface atmospheric conditions. Confined and unconfined groundwater conditions are important because they influence the distances over which drawdown is observed. Confined pressure changes can propagate long distances if there is a laterally continuous hydraulic connection. Lowering an unconfined water table however, will not propagate as far.

2.5.4 Groundwater Flow Paths

Conceptually, there are three (3) primary flow paths (deep, shallow, and alluvial stream channel) in the Davidson Canyon and Cienega Creek groundwater flow systems (Figure 2-12). Deep flow paths, if they exist, may originate in the high-elevation, bedrock recharge areas in the Santa Rita Mountains. Groundwater may be flowing slowly through the laterally and vertically extensive low permeability bedrock that occurs throughout the Study Area. Shallow groundwater flow paths are shorter and can occur at any elevation. Precipitation infiltrating through bedrock or alluvium can reach the water table and flow down-gradient. If these waters stay near the water table they are considered to have shallow flow paths. These shallow flow paths can result in groundwater discharging at the ground surface, particularly in areas with steep topography (Figure 2-12). The water may also intersect alluvial filled stream channels that are incised into the bedrock, where the water may or may not discharge at the surface.
Figure 2-12. Conceptual Model of Groundwater Flow Paths, Ephemeral Springs, and Perennial Springs.

Alluvial stream channel flow paths occur when stormwater runoff infiltrates into the recent alluvium that is bounded by low permeability bedrock. The magnitude, intensity, and duration of precipitation and runoff determine if the water infiltrates. Riparian vegetation can also consume this shallow water and prevent it from reaching the groundwater system. The water may completely or partially saturate the channel alluvium, and flow down-gradient in the shallow subsurface or discharge at the surface in the form of a spring. Low permeability bedrock obstructions and constrictions in the alluvium can contribute to forcing the groundwater to the surface (Figure 2-12).

The deep, shallow, and stream-channel flow paths can have distinct geochemical properties. However, these flow paths can mix, which may reduce the distinction between the flow paths and water sources. A high degree of mixing can complicate data interpretation. When deep and shallow groundwater mix, the resulting water may have a different geochemical signature than stormwater infiltration along stream channels.

2.5.5 Groundwater Trends and Fluctuations

Groundwater-level trends provide information on the groundwater system and how it responds to changes in climate, riparian vegetation, water development,
stormwater flow, and other stresses. The Project Area and the Cienega Creek Natural Preserve (CCNP) have the most abundant long-term water-level data that can be used to assess trends.

The most recent drought, which started in 1996, peaked in severity from 2002 to 2004 and continues today. These dry conditions have likely resulted in less recharge to the groundwater system. Some wells (7 of 32) in the Project Area have declining water-level trends (Figure 2-13) that may be a response to this decrease in precipitation recharge (Figure 2-6). Although the entire drought period has not been monitored, between 2008 and 2012 water levels have declined approximately 2 to 6 feet in these wells. This overall decline occurred even though water levels rose in response to an abnormally wet January 2010 when 3.49 inches of precipitation was measured (Figure 2-13).

![Figure 2-13. Selected Project Area Wells Showing Recent Groundwater Level Declines](image)

Two wells in the Preserve also show declining water-level trends (Figure 2-14). The Jungle and Empirita 2 wells had a slight downward water-level trend from 1994 to 2010. Water levels in these wells declined approximately five (5) to seven (7) feet over 16 years. The depth to water in the Cienega well is less than 20 feet and there is a distinct seasonal trend that is likely due to seasonal changes in riparian
vegetation evapotranspiration and groundwater recharge. A more subtle, longer-term trend in the Cienega well may be due to drought conditions and/or the increase in riparian vegetation.

Wells located in the Preserve are located near the Cienega Creek channel and are also potentially influenced by recharge from infiltration of stormwater runoff. Wells PS-1 and Del Lago in particular appear to have responses to stream flow that infiltrates and recharges the groundwater system (PAG 1998; Figure 2-14).

![Figure 2-14. Monthly Depth to Water at PAG Wells Located Along Cienega Creek and Davidson Canyon](image)

Management practices have resulted in several changes since 1986, when the Preserve was established, including retiring water rights, eliminating cattle grazing, and re-vegetation projects. These practices have allowed native riparian vegetation to expand throughout the area. A consequence of the increase in riparian vegetation density and extent was a corresponding increase in evapotranspiration (ET). An increase in plants that are using groundwater and intercepting shallow surface water infiltration that would otherwise become recharge can result in declining water levels. Drought conditions since 1996 would also be expected to decrease water levels, stormwater runoff, and stream flow.

It is not possible to attribute the water-level trends in the Preserve to a single cause due to the complex interaction between the natural processes and management
practices. Over the relatively short period of time that conditions have been monitored in the Preserve, it is clear that there is significant natural variability in riparian vegetation, water levels, and stream flow. Stream flow is discussed in detail in subsequent sections.

Only limited water-level data are available in public databases for the CVNCA. BLM monitoring data, if any exists, has not been made public. Therefore, long-term trends and natural variability for the CNVCA cannot be determined.

Water levels measured between 2007 and 2009 for the Rosemont groundwater monitoring program were analyzed to determine the range of fluctuations (M&A 2010b). These short-term groundwater level fluctuations ranged from 0.71 to 33.07 feet in 52 wells, with an average fluctuation of 7.1 feet.

Long-term water-level fluctuations were based on data from the Anamax groundwater monitoring program for the period 1975 through 1982 (UA 1977), from the Rosemont groundwater monitoring program for the period 2006 through 2009, and from historic monitoring data obtained from the ADWR Groundwater Site Inventory (GWSI) database (ADWR 2010). The long-term (37 to 55 years) groundwater-level fluctuations ranged from 0.70 to 69.04 feet at 14 wells, with an average fluctuation of 19.7 feet. Groundwater fluctuations in the Davidson Canyon area have been observed to range from four (4) to 25 feet (M&A 2010b).

The water-level fluctuations observed in the available data likely underestimate actual fluctuations. Measurements are intermittent and have occurred over relatively short periods of time. Extreme water-level and flow conditions have likely not been observed due to the incomplete data record.

Natural climatic variations result in corresponding variations to groundwater levels within the Davidson Canyon watershed and Cienega Creek basin. Spring flow and surface water flow can be sensitive to these water-level changes that occur as a result of drought and climate variability.

### 2.6 Streams

Stream flow in the Davidson Canyon and Cienega Creek watersheds occurs due to stormwater runoff, groundwater discharging to the stream channel, and as a combination of these two (2) sources. Groundwater and surface water interactions occur in alluvial stream channels where groundwater comes in contact with surface water. In Davidson Canyon, all stream flow appears to be the result of stormwater runoff; shallow groundwater flow in the alluvial channel is due to stormwater infiltration.

Streams either gain water from inflow of groundwater (gaining stream; Appendix Figure 2-15 A) or lose water by outflow to groundwater (losing stream; Appendix Figure 2-15 B). Losing streams can be connected to the groundwater system by a continuous saturated zone or can be disconnected from the groundwater system by
an unsaturated zone (Appendix Figure 2-15 C). These groundwater and surface water connections can also vary on a seasonal or annual basis depending on the overall climatic conditions.

An important characteristic of streams that are disconnected from groundwater is that groundwater-level declines do not affect the stream flow (Winter and others 1998). The nature of the groundwater connection to the stream is an important distinction when evaluating the potential for the Project to decrease stream flows in specific reaches. Stream reaches that are supported by groundwater will be impacted if drawdown lowers the water table below the streambed. Predicted water-level declines that may impact streams are discussed in Section 6 of this report.

Groundwater supports stream flows in gaining reaches. The groundwater component of stream flow is called base flow. Stream flow that is predominately supported by groundwater, with minimal precipitation and runoff influences, is most likely to occur during April and May due to the low spring-time precipitation and typical lack of stormwater runoff. Alternatively, the highest stream flows and spring discharges occur during the summer monsoon season due to the highest precipitation and highest stormwater runoff. However, stream flows can also occur in response to winter rain events.

2.6.1 Cienega Creek

The Cienega Creek watershed can be divided into upper and lower sub-basins. Upper Cienega Creek is upstream of the bedrock outcrop where the stream channel narrows (“The Narrows”) and the geomorphology changes from a broad alluvial basin to a constricted bedrock channel (Appendix Figure 2-3). Upper Cienega Creek includes the BLM’s LCNCA (Appendix Figure 2-2). Lower Cienega Creek extends from “The Narrows,” through Pima County’s Preserve, and ultimately flows into Pantano Wash in the Tucson basin (Appendix Figure 2-2).

The broad alluvial basin in the upper Cienega Creek watershed collects stormwater runoff and funnels it through “The Narrows” into lower Cienega Creek. Stormwater runoff infiltrates into the alluvium and recharges the groundwater system. Surface discharge occurs where the groundwater intersects the land surface due to topography or bedrock outcrops. When the groundwater level drops below the stream-channel bottom, the surface flow continues until it is lost to ET or infiltrates into the unsaturated channel sediments.

Stream flow along Cienega Creek is interrupted, with several perennial reaches separated by intermittent and ephemeral reaches. Perennial reaches in lower Cienega Creek are associated with the constriction of floodplain alluvium deposits by consolidated rock units, which forces shallow, alluvial groundwater to the surface. These gaining conditions are assumed to be at the upstream end of the perennial reach. At some point downstream of the bedrock constrictions, the
surface water flow starts infiltrating back into the alluvial deposits. Stream flow can also be diminished by groundwater losses to ET due to the riparian vegetation. Surface flow normally will end when these losses exceed the available flow. However, in the case of Cienega Creek, the surface flow ends at Pantano Dam where much of the flow is diverted to irrigation use through a surface water right.

The wet and flowing length of the perennial reaches of Cienega Creek tends to vary seasonally and annually (Pima 2012). PAG has been monitoring the wet and flowing reaches of lower Cienega Creek every June since 1999. Between 1999 and 2009, the perennial stream lengths have varied from 1.5 miles to just over 4.6 miles (Pima 2012). Groundwater is likely only supplying part of the typically flowing reaches. The percentage of flowing stream channel has varied from 16 to 35% between 1999 and 2009. The long-term trend indicates that the length of flowing reaches has decreased 80% between 1984 and 2010 (Appendix Figure 2-16). Monitoring well data in the Preserve indicates that groundwater is disconnected from lower Cienega Creek flow in several areas. Stream reaches in lower Cienega Creek near the monitoring wells are predominately dry and the highest observed groundwater levels in the wells are as much as 80 feet below the adjacent stream bed elevation (Appendix Figure 2-17; Table 2-3). During 2011, which was the driest year that flows have been monitored in the Preserve, 13 percent of the stream channel was flowing (Appendix Figures 2-16 and 2-17). With the exception of flow at the Pantano Dam, the flowing reaches during 2011 did not have nearby wells to determine the depth to water. Measured water levels near non-flowing reaches, however, were below the stream channel.

The depth to groundwater in the Cienega well is consistently near the stream channel elevation (Figure 2-13 and Appendix Figure 2-17). However, water levels in the Cienega well drop below the stream channel and stream flow ceases during dry years (Table 2-3, Appendix Figure 2-17. The observed depth to groundwater in monitoring wells adjacent to other reaches of lower Cienega Creek indicate that the groundwater level is consistently well below the stream channel bottom (Table 2-3, Appendix Figure 2-17). In some areas with shallow groundwater it is likely that a temporary groundwater and surface connection exists when precipitation, lower ET, and/or stormwater runoff raises groundwater levels to the stream channel elevation.

The Pantano dam reservoir has been filled with sediment deposited during stormwater runoff events, creating an area of artificial water storage in the channel alluvium. Persistent flow at Del Lago is possibly the result of the dam forcing this shallow, subsurface flow to the surface. This is the same process that forces shallow water to the surface at bedrock constrictions in other parts of Cienega Creek.

Perennial reaches in the upper Cienega Creek basin have not been studied as extensively as lower Cienega Creek basin (Appendix Figure 2-3). There are limited wells and water-level measurements near the stream channel in upper Cienega Creek. However, it is assumed that the depth to groundwater is relatively shallow in
these reaches and that groundwater is supporting the perennial reaches. Drawdown in the upper Cienega Creek basin has the potential to reduce stream flow.

2.6.2 Davidson Canyon

Davidson Canyon is located at the bottom of a watershed with a drainage area large enough to produce relatively large magnitude stormwater flow. Stream-channel recharge may be occurring due to this stormwater runoff and shallow groundwater flow paths may intersect the alluvial channel. Groundwater levels in the alluvial stream channels at lower elevations in Davidson Canyon are relatively shallow. These conditions are favorable for temporary groundwater and surface water interactions, but there is no persistent connection under the current conditions.

The Pima County well (D-16-17 31dcb) is the nearest well to the Reach 2 Spring, which is located approximately ¾-mile upstream and marks the upstream start of Davidson Canyon’s OAW Reach (Appendix Figure 2-3). The depth to groundwater at the Pima County well persistently ranges from seven (7) to 15 feet below the stream channel (Figure 2-18). Given these fairly consistent groundwater levels and the ephemeral, short duration, low discharge, limited surface-length expression of spring flow at the Reach 2 Spring, the groundwater system is unlikely to have more than an occasional, temporary connection with the surface water system.

A temporary connection between the Davidson Canyon groundwater and surface-water systems is possible during wet periods and long duration stormwater runoff events. Large volumes of infiltrating stormwater runoff can saturate the alluvium and connect to the shallow groundwater. Groundwater levels that ultimately rise to the surface are expressed as stream flow or spring discharge after the stormwater flow event has ended. Bedrock constrictions in the alluvial channels can force this shallow, alluvial channel groundwater to the surface (Figure 2-14). The Reach 2 Spring and Escondido Spring in lower Davidson Canyon appear to be examples of this type of disconnected groundwater and surface-water interaction with an occasional, temporary connection. If the Project lowers groundwater levels this temporary connection may occur less frequently.

<table>
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<th>DATE</th>
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<th>Empirita 2(1)</th>
<th>Davidson #2 (2)</th>
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<th>PN-2(3)</th>
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<td>DTW(5)</td>
<td>Dry or Flow</td>
<td>DTW(5)</td>
<td>Dry or</td>
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<td>(feet)</td>
<td></td>
<td>(feet)</td>
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(1) Inconsistently accessible
(2) Measured quarterly
(3) Monitored by ADWR
(4) Difference between fiscal year averages. “+” is a rise in water level and “−” is a drop in water level.
(5) Depth to Groundwater

Source: Pima 2012
2.6.3 Stream Discharge

Stream gage data in the Study Area illustrate the nature of stormwater runoff and perennial flows. Stormwater runoff occurs primarily during the monsoon season from mid-June or early July through September. Afternoon monsoon thunderstorms can result in short duration and high intensity rainfall. These conditions are favorable for generating runoff in the many, normally dry, drainage channels in the region. Davidson Canyon Wash and Cienega Creek are the major stream channels that convey this runoff, which typically lasts a few hours to a few days.

Historically, there have been five (5) USGS stream gages in the Davidson Canyon and Cienega Creek watersheds (Appendix Figure 2-19). The longest period of record belongs to that gage at the Pantano Wash near Vail, with data starting in 1959. From 1968 to 1975 there were gages on Cienega Creek near Pantano and on Davidson Canyon near Vail. More recently, gages were installed on Cienega Creek near Sonoita in 2001 and on Barrel Canyon near Sonoita in 2009. Monthly stream flow measurements have also been collected at the Marsh Station by PAG (Appendix Figure 2-16).

The Cienega Creek gages near Sonoita and Vail monitor reaches that flow nearly continuously. These gages have recorded only 31 and 60 days without flow during the period of record (0.8 and 0.4%) (Table 2-4). Conversely, days with no recorded
flow at the other USGS gages range from 72 to 98% of the record. Hydrographs at all of the stream gages illustrate the highly variable flows related to stormwater runoff (Appendix Figure 2-19). Average monthly stream flows are presented in Table 2-5 for these gages. Daily stream flows are presented on Appendix Figure 2-19. The dramatic increases in stream flow during the monsoon season are evident in Tables 2-5 and on Appendix Figure 2-19. Increases in stream flow can also occur during the winter months when there is sufficient precipitation.

The groundwater-supported component of stream flow is referred to as base flow. While base flow can occur all year, the best estimate of its magnitude is the lowest average monthly discharge at the stream gage, which usually occurs during May or June when stormwater runoff is small or non-existent (Table 2-5, Appendix Figure 2-19). Historically, base flow estimated for other studies has ranged from one (1) to three (3) cubic feet per second (cfs) in upper Cienega Creek (M&A 1985, PAG 1998) and about 1 cfs in lower Cienega Creek (PAG 2009). The lowest average monthly flow for May and June that is representative of groundwater supported base flow at the Sonoita gage is 0.44 cfs (Table 2-5). The Pantano Wash gage near Vail has a lowest monthly average of 1.1 cfs in May (Table 2-5), but water levels in the Del Lago #1 well indicate that bedrock groundwater is not the source.

The length of flowing channel, which is an indicator of stream flow, in lower Cienega Creek has been decreasing since monitoring began in 1984 (Appendix Figure 2-16). Using 1984 as the baseline flow condition, the flowing length has decreased almost 90 percent. Monthly stream discharge at the Marsh Station in lower Cienega Creek also indicates a downward trend in discharge between 1994 and 2009 (Appendix Figure 2-16).

Streams and reaches that are normally disconnected from the groundwater system, such as in Barrel Canyon and Davidson Canyon, do not have a perennial base flow component. The Davidson Canyon gage near Vail has non-zero average discharge for all months. However, the sporadic flows indicate that the water source is stormwater runoff and not groundwater (Table 2-5).
Table 2-4. Daily Stream Flow Discharge Statistics.

<table>
<thead>
<tr>
<th>Site Name</th>
<th>Site Number</th>
<th>Period of Record</th>
<th>Days in Record</th>
<th>Maximum Discharge (cfs)</th>
<th>Minimum Discharge (cfs)</th>
<th>Number of Days With No Discharge</th>
<th>Percent of Days With No Discharge</th>
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<td>2009 - 2012</td>
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<td>2001 - 2012</td>
<td>3,885</td>
<td>534</td>
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<td>Pantano Wash near Vail, Arizona</td>
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<td>1959 - 1974; 1989 - 2012</td>
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</table>

NOTES:
1) Stream discharge data was obtained from the United States Geological Survey's (USGS) online Water Information System.
2) cfs = Cubic feet per second.
3) NA = No data was available.
4) Average baseflow index was obtained from the USGS Stream gages-NHD Locations database.
Table 2-5. Average Monthly Discharge in Cubic Feet Per Second in Cienega Creek and Davidson Canyon Wash

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<th>Site Number</th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
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<tr>
<td>Davidson Canyon Wash near Vail, Arizona</td>
<td>9484590</td>
<td>0.11</td>
<td>0.18</td>
<td>0.20</td>
<td>0.15</td>
<td>0.11</td>
<td>0.07</td>
<td>2.5</td>
<td>3.4</td>
<td>2.1</td>
<td>0.10</td>
<td>0.14</td>
<td>0.23</td>
</tr>
<tr>
<td>Pantano Wash near Vail, Arizona</td>
<td>9484600</td>
<td>5.4</td>
<td>5.2</td>
<td>3.2</td>
<td>1.8</td>
<td>1.1</td>
<td>1.6</td>
<td>18</td>
<td>19</td>
<td>8.8</td>
<td>2.6</td>
<td>2.0</td>
<td>4.3</td>
</tr>
</tbody>
</table>

NOTE: Stream discharge data was obtained from the USGS’ online Water Information System Time-Series: Monthly Statistics database (waterdata.usgs.gov). The USGS calculated average discharge using daily data.
2.7 Springs

Springs occur when groundwater discharges at the ground surface. Springs can be important sources of water for humans, livestock, and wildlife. Springs can receive water from shallow or perched groundwater sources, or from deeper, regional groundwater sources. The source of the discharging water is important because springs that are not hydraulically connected to the regional groundwater system under normal conditions will not be impacted due to Project operations (Figure 2-15). Groundwater-level decreases will not impact perched or stormwater runoff springs, but springs sourced from regional groundwater may be impacted by Project related drawdown depending upon the interconnection of the fractures in the rock matrix in the area of the spring. This report will differentiate between “local” and “regional” springs.

Springs that are disconnected from the regional groundwater system will be called local springs, to reflect that the water source is within the subwatershed where the spring occurs, and spring flow is directly related to infiltrating precipitation or stormwater runoff conveyed to the spring through shallow flow paths disconnected from the underlying groundwater system. Characteristics of local springs include variable temperature that approximates the ambient air temperature, intermittent flows following precipitation and runoff events, extended periods (several consecutive months) with zero discharge, short subsurface residence time, lack of riparian vegetation, and lack of perennial aquatic resources.

Local springs can be located in alluvium-filled drainage channels that collect infiltrating stormwater runoff. The discharge characteristics of these local springs depend on the size of the watershed, runoff duration, volume of alluvium, channel geometry, and spring location within the watershed. The duration of local spring flow can be for days or months depending on the site-specific characteristics. The onset of flow is also highly variable. Flow can begin within hours of precipitation and runoff if the storm event is large enough, or it can take months before the water that infiltrated significantly upstream of a spring to migrate through the alluvial sediments and surface as spring discharge at a bedrock constriction or at a topographically steep stream channel reach.

Regional springs, on the other hand, tend to have perennial flow, consistent base flow rates, and consistent water temperatures that can be warmer or colder than ambient air temperature depending on the depth of the flow paths and the seasonal air temperature. Flow paths and groundwater residence times for regional springs also tend to be longer than for local springs. In general, water temperature and chemistry in regional spring samples tends to correlate with values for samples from nearby deep groundwater wells when both reflect deeper groundwater flow paths. These flow paths result in longer residence times, allowing the water more time to chemically equilibrate with the sub-surface rocks (Figure 2-14).

Regional and local springs occur throughout the Study Area. Many observed springs have minor discharge, with flows commonly less than 1 gpm (0.002 cfs). However,
the discharge at many springs is so low that flowing water has not been observed and it is more appropriate to call them seeps. On a regional scale, these seeps and springs are not significant to the water balance, but they may be locally important to humans, livestock, and wildlife.

### 2.7.1 Spring Monitoring

Rosemont has been collecting spring samples to monitor water quality, pH, electrical conductivity, and flow since April 2008. Water-quality data have been collected at 16 of the 22 routinely monitored springs (Appendix Figure 2-20). Eight (8) of the springs are without water quality data because of typically dry conditions or conditions with insufficient flow to obtain a sample.

Spring flows and physical parameters for 20 of the routinely monitored springs have been reported in M&A (2009a). These 20 springs and 2 additional springs have continued to be monitored since the M&A report in 2009. Helvetia Spring and Rosemont Spring (Appendix Figure 2-20) were the only springs with observed perennial flow over the duration of monitoring. All other springs have been observed to be dry, with no surface flow, during some of the site visits.

In addition to the routine spring monitoring, Rosemont has conducted field surveys intended to locate springs within 12 miles of the proposed pit that are identified from information sources including USGS topographical maps, the USGS Geographical Name Information System (GNIS) database, the ADWR - Statement of Claimant database (Pearce 2007), and published reports (M&A 2009a, Tetra Tech 2010a, WestLand 2007, WestLand 2011). A discussion of the results of these surveys is provided in Section 7.4 of this document. However, historical climate data indicate that the Project Area is currently in a period of relatively dry conditions (Figure 2-6), and some of these potential springs could not be located in the field. It is likely that many of the springs identified by previous studies and maps reflect wetter periods when either groundwater levels were higher or there was more stormwater runoff infiltrating to perched aquifers. Natural climate variation has likely resulted in the disappearance of many of these springs, and springs that currently have observable damp conditions or discharge presumably had higher discharge during historical periods with wetter conditions. Persistently lower precipitation has resulted in lower groundwater levels that have decreased spring flows to their current levels.

Natural climate variations will continue in the future and will result in changes to spring flows. Wetter climate conditions result in more springs and higher discharges. Dry climate conditions result in fewer springs and lower discharges. Dry conditions since 1996 have likely resulted in flow ceasing at many springs, and continued dry conditions may cause springs that currently discharge to also go dry. The proposed Project impacts will be superimposed on the background climate variability. As a practical matter, it may not be possible to determine if future spring discharge changes are due to Project-related drawdown or due to climate variability.
2.8 Riparian Vegetation and Evapotranspiration

Evapotranspiration (ET) refers to the transport of water into the atmosphere from surfaces, including water, soil (soil evaporation), and vegetation (transpiration). Riparian areas along Cienega Creek and Davidson Canyon are the most significant source of water losses to ET, although evaporation from open water and shallow groundwater also occurs (Appendix Figure 2-2).

Increased ET in the riparian vegetation reaches of Davidson Canyon Wash and Cienega Creek may be influencing groundwater levels and stream flow. The expansion of riparian vegetation since the establishment of the Preserve and the implementation of current management practices favorable to riparian vegetation may be partly responsible for the declining stream discharge and flowing reach lengths (Appendix Figure 2-16).

Prolonged high temperatures result in greater ET demand and can exacerbate the impact of drought (low precipitation) conditions (Weiss and others 2012). As recently as April to September 2011, the combination of high temperatures and low moisture impacted southern Arizona (Weiss and others 2012). Temperatures were more than 2.7 °F above average for many parts of the Southwest. While both the 2000’s and 1950’s droughts induced significant vegetation mortality in ecosystems from deserts to forests (Weiss and others 2009), observations indicated that pinon pine die-off during the 2000’s drought was significantly greater in magnitude and extent than during the 1950’s drought, despite more total precipitation during the years 2000–03 than 1953–56. Warmer temperatures during the 2000’s drought, coupled with low precipitation, appeared to cause higher vegetation water stress (Weiss and others 2009).

Riparian vegetation typically goes through periods of expansion and die-back as water availability waxes and wanes. Specifically, as water availability decreases, natural die-back reduces vegetation water consumption and therefore total ET.

2.9 Groundwater Pumping

All water use within the Cienega Creek Basin (note that Cienega Creek Basin, as defined by ADWR, is differentiated from more general discussions of the Cienega Creek basin in this document) is from groundwater sources, with no recorded surface water diversions noted by ADWR (2006). Where the specific area defined by ADWR is However, a surface water right at the Pantano Dam can divert up to 100 percent of the flow in lower Cienega Creek (ADWR 2006). Average-annual water demand in the Cienega Creek Basin was 1,250 acre-feet (AF) between 2001-2006, which included 500 AF of municipal demand, less than 300 AF of industrial demand, and 500 AF of agricultural demand (ADWR 2009). Municipal, industrial, and agricultural groundwater use has remained fairly consistent since 1991. Approximately 170 acres of vineyards, most located in the Elgin area, have been reported in the Cienega Creek Basin (ADWR 2006). These estimates of water demand do not include pumping in the Davidson Canyon watershed or in the
western part of the Preserve and that surrounding area, because these are outside of the ADWR Cienega Creek Basin boundary.

Groundwater pumping in the upper Cienega Creek Basin was estimated by Knight (1996) to be 400 to 500 AF/yr. Most of the pumping was from wells in the Sonoita-Elgin area. In the LCNCA, which is managed by the BLM, groundwater is currently extracted for cattle ranching, but no pumping estimates have been obtained. Groundwater pumping at Empirita Ranch, in the lower Cienega Creek Basin, was estimated by M&A (1985) to be 340 AF/yr. However, Empirita Ranch pumping was retired in 1991 when Pima County purchased the Empirita Ranch properties for the Preserve.

Domestic groundwater users are likely tapping the regional groundwater system in the Davidson Canyon watershed to supply water to their homes, ranches, and small businesses. The ADWR well registry database indicates that there are over 300 wells (monitoring wells excluded) within the Davidson Canyon watershed. As of 2005, there were 1,874 registered wells within Cienega Creek Basin with a pumping capacity of less than or equal to 35 gpm and 169 wells with a pumping capacity of more than 35 gpm (ADWR, 2006). In the absence of actual discharge rates from these wells, the magnitude and spatial distribution of impacts on the hydrologic system due to this pumping cannot be accurately assessed.

### 2.10 Summary

Land use in the Study Area has historically and presently included mining, ranching, limited agriculture, domestic homes, and recreational activities including off-road vehicle use. Land ownership and management consists of private, county, state, and federal entities. The BLM manages the LCNCA in upper Cienega Creek basin and Pima County manages the Preserve in the lower basin.

The Project Area is located in the desert southwest, which is known for its hot and dry conditions. The area has experienced numerous droughts, including droughts in the last century with a recurrence interval of approximately 50 years. Drought conditions have persisted from 1996 to present, as well as in periods of several years in the late 1800’s and 1950’s. Droughts over the past 2,000 years, including megadroughts lasting decades, have been shown to be more severe and longer lasting than the droughts occurring over the past 100 years.

Current climate conditions have resulted in a trend of declining water levels, spring flows, and stream flows. Water levels in seven (7) Project Area wells and two (2) lower Cienega Creek wells appear to be declining due to current drought conditions. Stream flows in lower Cienega Creek also appear to be declining due to the current drought and/or the expansion of riparian vegetation allowed by changes in management practices on adjacent land. Future stream conditions in upper and lower Cienega Creek will be impacted by the continuing and future droughts that can impact flows. Currently flowing springs have discharges less than one (1) gpm, and most historically identified springs exhibit dry with occasional damp conditions.
All spring occurrences in the Project Area appear to be tenuous and more springs are likely to go dry if the current drought conditions continue.

Predicted impacts from the Project are described in subsequent sections. Analyses of impacts to water resources, particularly at the distant, ecologically sensitive areas in Davidson Canyon and Cienega Creek, show that Project impacts are small relative to the natural variability typical of the Project’s regional setting. Water levels in wells near lower Cienega Creek, for example, can vary over ten (10) feet under current conditions; while Project-related drawdown is predicted to be less than one (1) foot in that area. Larger water-level fluctuations have also been observed in Davidson Canyon in the recent past. Climate changes in the future may result in even greater background variability and in systemic changes to the hydrologic conditions.

2.11 References


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3  PROJECT SETTING

The Rosemont Project is located in the upper reaches of the Davidson Canyon watershed on private property and on federal land managed by the CNF. The Project Area consists of a group of patented and unpatented mining claims and fee land covering most of the historic Rosemont and Helvetia Mining Districts. The Project has been designed to avoid environmental impacts to the extent practicable by minimizing land disturbance and water use, minimizing impacts to surface and groundwater resources, and utilizing state-of-the-art processing and reclamation practices. This section describes how these goals were incorporated into the Project design.

The expected life of the Project includes two years of construction and pre-production excavation, 20 to 25 years of production, and three to eight years of closure activities, totaling between 25 to 35 years. From its inception, the Project design process has focused on incorporating environmental goals into facility siting, water supply, water conservation, and concurrent reclamation:

- **Facility Siting to Minimize Land Disturbance:** Typical open pit copper mines have separate waste rock, tailings, and heap leaching facilities covering multiple drainage basins. To reduce the Project footprint and minimize environmental impacts, the proposed Project layout consists of a single Landform, developed as a consolidated facility and contained within a single drainage basin. The Phased Tailings layout of the Project, which mirrored the Project MPO in terms of footprint, included placing material in both the Barrel and McCleary drainages (Appendix Figure 3-1), producing a footprint of about 2,870 acres as documented in the DEIS (USDA 2011). In the DEIS, the USFS has indicated a preference for the Barrel Alternative (Appendix Figure 3-2), which covers about 2,447 acres and keeps the McCleary Canyon drainage open (USDA 2011). If this alternative is ultimately implemented, it is expected to reduce environmental and water resource impacts by confining development to a single tributary to Davidson Canyon to the greatest extent practicable.

- **Water Supply Optimization:** The Project will require approximately 5,000 acre-feet of water per year on average. Fresh water for the Project will be supplied from wells in the Santa Cruz aquifer near Sahuarita, located 15 to 20 miles west of the Santa Rita Mountains. The groundwater will be transported to the Project site via a pipeline and booster pump system. Rosemont has secured water extraction permits from the ADWR for up to 6,000 acre-feet per year for 20 years. To offset the effects of the withdrawals, Augusta Resource Corporation (the parent company of Rosemont) has entered into an agreement with a local water company to purchase and recharge a volume of water, delivered through the Central Arizona Project (CAP), equivalent to 105% of the volume required for the Project. Sufficient water recharge will take place to offset groundwater pumping over the life of the Project. This water import program began in 2009. To date, 45,000 acre-feet (equivalent to approximately nine (9) years of average
Project water use) have been purchased and recharged within the Santa Cruz aquifer, primarily near Marana.

- **Tailings Disposal Design to Maximize Water Conservation and Minimize Land Disturbance:** Water is a critical resource in an arid climate. Therefore, Rosemont has incorporated important water conservation elements into the Project design. The most significant of these conservation elements is the use of a dry stack tailings placement method. This method will consume only about 8 gallons of water for every pound of copper produced, compared to 15 to 30 gallons per pound typically required at other copper mines in the region. At most copper mines and other mines that produce tailings, the tailings slurry (the solids and process water from flotation, typically 40 to 50% solids) is disposed in an impoundment created behind a tailings dam. The tailings solids settle to the bottom and the tailings water on top is reused, evaporated, and/or discharged. At Rosemont, tailings will be dewatered using a filtering process to reduce the process water content to under 18% by weight, and the filtered water will be recycled into the process stream. Since more water is being recycled, this results in a lower fresh water requirement and minimizes evaporative and other losses. The filtered tailings will be stacked behind waste rock buttresses. Not only does dry stack tailings design consume less water than conventional methods, it also results in a smaller footprint (since tailings are stacked) and reduced land disturbance. In addition, dry stack tailings facilities can be reclaimed concurrently, which minimizes exposed tailings surfaces that have caused dust problems at other mines. Operation of a dry stack facility is more costly than a tailings impoundment due to the costs of filtering and transporting tailings, but the environmental benefits are significant.

- **Concurrent Reclamation to Minimize Land Disturbance:** Rock excavated from the Open Pit will be used to construct a series of perimeter buttresses around the dry stack tailings facilities. These buttresses will provide stormwater control, reduce the visual impact of the operation from State Route 83, and allow reclamation and re-vegetation to begin early in the life of the Project. Excavated topsoil will be salvaged and used as a vegetation growth medium as soon as the perimeter buttresses are established. Similar waste rock buttresses will be constructed to encompass the waste rock facilities so that perimeter berms are created early in the life of the project, and topsoil placement and revegetation can begin on the outside berm surfaces. Waste rock will continue to be deposited behind and within the perimeter berms during the life of the mine. As the tailings and waste rock placement progresses, the outer surface of the perimeter facilities will be incrementally reclaimed and re-vegetated.

Through multi-year grants to researchers at the University of Arizona, Rosemont has worked to identify seed mixes and re-vegetation techniques that will facilitate rapid re-vegetation of the site with native plants that thrive under the climate and rainfall conditions prevalent at the Project site. Concurrent reclamation will allow Rosemont to optimize reclamation techniques and get an early start on reclamation, maximizing the opportunity for successful
reclamation, and effectively minimizing the extent of land disturbance during operations.

3.1 Facility Design

The Project consists of five (5) major features: the Open Pit, the Plant Facilities, the Dry Stack Tailings Facility, the Heap Leach Facility, and the Waste Rock Storage Area. Discussions throughout this document will describe the relationship between these Project features and water and aquatic resources, both in the immediate Project Area and in the surrounding Study Area. Therefore the following sections describe the Project facilities in some detail. Additional information is available in more than 500 reports and technical references, the most comprehensive being the MPO (WestLand 2007) and the Aquifer Protection Permit (APP) Application (Tetra Tech 2009).

3.1.1 Open Pit

The proposed Project would develop the Rosemont deposit as an open pit mine. Approximately 67% of the 1,848 million tons (Mt) of material excavated would be waste rock, with the remaining 33% of the material divided between sulfide ore (29%) and oxide ore (4%). Mining operations will excavate about 300,000 to 315,000 tons per day (tpd) of material from 50-foot high benches using large shovels and haul trucks. At the completion of mining, the Open Pit will be about 6,500 feet in diameter at the rim and about 2,900 feet deep, with a bottom elevation of about 3,050 feet amsl. The Open Pit will extend below the local groundwater table. Therefore dewatering will be required during operations to maintain pit-slope stability and safe working conditions. This dewatering will remove all water flowing into the pit, including direct precipitation and pit-wall runoff, the small amount of surface water runoff that may enter the pit from adjacent undisturbed areas between the pit and the diversion channel or runoff from operations areas, and groundwater inflow (Figure 3-3). The water removed from the pit will be sent to the milling operations to offset some of the Project's water demand.
Groundwater monitoring indicates that current groundwater levels in the pit area are high, with depth-to-water (DTW) ranging from 20 to 130 feet below the ground surface. Groundwater flow is primarily from the Santa Rita Mountain highlands towards the lower elevations north and east of the Project Area. Primary groundwater flow paths coincide with Davidson Canyon (Figure 3-4). Smaller volumes of groundwater flow from the Santa Rita Mountain highlands and then towards the east via upper Cienega Creek. The Open Pit will alter current groundwater conditions and flow paths by lowering the groundwater level in the immediate Project Area to the elevation of the bottom of the pit during dewatering operations. A steep gradient for the groundwater surface in the immediate vicinity of the Open Pit will form, creating a “capture zone” around the Open Pit. This is analogous to a watershed divide for surface water flow. The perimeter of this capture zone is a groundwater divide, within which groundwater flows towards the pit, and beyond which groundwater continues to flow down-gradient towards lower elevations, such as down Davidson Canyon. Any infiltration occurring inside the capture zone, from any source including spills and precipitation, will flow towards the pit. Modeling undertaken to predict groundwater conditions resulting from excavation of the Open Pit, during both the operational and post-closure periods, is
discussed in detail in the Groundwater Section of this report, including the predicted drawdown, groundwater inflows to the Open Pit, evaporation, and other water-balance components.

At the end of mining operations, when dewatering ceases, the Open Pit will begin to fill with inflow from groundwater, surface runoff, and precipitation. A pit lake will form and stabilize when inflows equal evaporation losses. This stabilization process is predicted to take hundreds of years because the low permeability of the rock surrounding the Open Pit limits groundwater inflow rates, and the climate combines low precipitation with high evaporation rates. At equilibrium, estimated groundwater inflows of 100 to 200 gpm to the Pit Lake are expected to be equivalent to evaporation. Based on current evaporation and rainfall estimates, the water surface elevation of the Pit Lake is expected to rise for about 700 years, until the lake is over 1,200 feet deep. Drawdown will slowly propagate away from the Open Pit during the post-closure period, ceasing when the groundwater system reaches a new equilibrium condition.

Rosemont has chosen models appropriate for the applications; however, the limitations of the models should be acknowledged. While the groundwater models and inputs are highly precise, the ability of these models to accurately simulate large-scale, realistic situations may be limited, especially with increasing time into the future. The models do provide the best assessments available and in many cases provide a very conservative estimate (i.e., an estimate that is expected to overestimate, rather than to underestimate) of the potential impacts.
At some other mines around the world, pit lakes have been observed to concentrate contaminants and/or develop acidic conditions. Therefore, the Rosemont Pit Lake was modeled to assess the risk of potential chemical environmental hazards over a period of 200 years. Results of this modeling are discussed in the Seepage Section of this report. The modeling indicates that the lake will not become acidic (pH < 7.0) and water chemistry will be of good quality when compared to the existing groundwater or to the numeric Aquifer Water Quality Standards (AWQS) established in Arizona. At the conclusion of Project operations the Pit would remain closed to the public.

### 3.1.2 Plant Facilities for Processing Sulfide Ores

The Plant Facilities are located on the northeast side of the Open Pit and consist of the administrative, ore processing, and support facilities for the mine. Two types of ore will be mined at Rosemont; oxide ore, in which the copper-bearing minerals are present as oxides, and sulfide ore, in which the copper-bearing minerals are sulfides. The ore types require different processing methods. The oxide ore processing facilities include the Raffinate Pond for Heap Leaching and the Solvent Extraction – Electrowinning (SX-EW) Plant. These are discussed in Section 3.1.4, below. Facilities for sulfide ore processing include the Process Water/Temporary Storage
(PWTS) Pond, the Settling Basin for the temporary storage of unfiltered tailings, and the crushing, milling, flotation, thickening, and filtering facilities. Following is a more detailed description of this process.

The sulfide ore in the Rosemont deposit contains approximately 0.5% copper as well as other valuable elements. The ore will be processed by grinding the material in a water slurry to the consistency of fine-grained sand, to allow the valuable copper-bearing minerals to be separated from the host rock through a process called flotation. The products of flotation are a concentrate containing most of the copper-bearing minerals, and tailings. Tailings are the non-copper bearing by-product of this milling process.

Run-of-mine (ROM) sulfide ore will be hauled to the Primary Crusher and reduced in size to less than six (6) inches. Crushed ore will be transferred via conveyor to the covered Coarse Ore Stockpile and from there to the Grinding and Classification Circuit to be further ground to the consistency of fine-grained sand, and then mixed with water from the PWTS Pond to form a slurry (about 70% water by weight). The Grinding and Classification Circuit product will gravity flow to the Flotation and Regrind Circuit, where a series of flotation cells will separate the copper minerals from the host rock. The products of the Flotation and Regrind Circuit will be a mineral slurry, known as concentrate, consisting of about 30% copper, and tailings. The concentrate will be dewatered in a large tank referred to as a thickener, where the slurry will segregate. Thickener overflow (water) will be pumped to the reclaim water system. Thickener underflow (about 60% concentrate) will be pumped to the filters for further dewatering. Filtered concentrate (15-20% moisture content by weight) will be transported via conveyor belt to the enclosed Concentrate Storage facility and loaded into licensed highway trucks for transport to a smelter. The tailings will also undergo a filtration and dewatering process (Section 3.1.3) prior to disposal in the Dry Stack Tailings Facility.

At closure, all of the plant facilities will be removed. The site will be re-graded and stabilized to prevent erosion, and reclaimed.

3.1.3 Dry Stack Tailings Facility

The tailings material remaining from sulfide ore processing (about 98% of the original mass) will be dewatered using thickeners and filters and placed in the Dry Stack Tailings Facility. Typically, tailings slurries are either not dewatered or are dewatered using only thickeners, resulting in a slurry that contains 40-50% water. For the Rosemont Project, a filtration process similar to that used for the concentrate will further dewater the tailings. The relatively dry material coming out of the Tailings Filter Plant will have a moisture content under 18% by weight. The filtered dry stack method is more process-intensive than using traditional tailings ponds to settle solids, but was selected as a very effective water conservation strategy, as an important element for water quality protection, and to facilitate concurrent reclamation. The filtration process will eliminate fluid discharge from the tailings facilities to the greatest extent practicable by removing free liquid from the tailings before they are placed. The greatly improved geotechnical
characteristics of this material allow it to be stacked higher, thereby reducing the ultimate footprint of the facility. The Dry Stack Tailings Facility will receive filtered tailings, without free liquid, at a nominal rate of 75,000 tpd throughout the mine life. The facility as proposed in the MPO was designed to hold just over 543 million tons of tailings over the mine life. Tailings will be stacked behind large containment buttresses constructed from chemically benign waste rock.

### 3.1.4 Heap Leach Facility

Heap leaching is used to remove copper from oxide ore. Oxide ore mining will be conducted during the first seven (7) years of operations. The oxide ore lies only near the surface of the Open Pit. Leaching of the ore mined in the first seven (7) years of operations will be completed, and closure of the Heap Leach Facility is planned, by Year 10 of operations. As proposed in the MPO, approximately 50 million tons of oxide ore will be leached over the life of the mine. Excavated oxide ore will be transported by haul trucks directly to the Heap Leach Facility located near the Open Pit and placed in 30-foot lifts on a lined pad equipped with a solution collection system. The leaching process consists of applying a weak sulfuric acid solution known as Raffinate to the surface of the stacked ore. The barren (copper-free) Raffinate pumped from the double-lined Raffinate Pond located at the Plant Site will percolate through the ore and liberate copper ions, creating a Pregnant (copper-bearing) Leach Solution (PLS) that drains to the base of the pad and flows through the collection system to the double-lined PLS Pond. The copper-laden PLS will be pumped from the PLS Pond to the SX-EW Plant where the copper will be extracted from solution and electroplated to produce nearly pure copper cathode plates. In the event of a process upset or large storm, the PLS Pond is designed to overflow into a lined pond (referred to as the Heap Stormwater Pond) where the solution will be temporarily stored and recovered.

The Heap Leach Facility is designed to meet and exceed Prescriptive Best Available Demonstrated Control Technology (BADCT) guidelines for environmental protection established by the Arizona Department of Environmental Quality (ADEQ) (ADEQ 2004). The Heap Leach Pad liner system includes: a low-permeability geosynthetic clay liner (GCL); a linear low-density polyethylene (LLDPE) liner; a network of solution collection pipes; and 3 feet of high permeability crushed drainage rock. The Raffinate and PLS Pond liner systems include: a GCL; a high-density, polyethylene (HDPE) secondary liner; a leak detection system consisting of a geonet drainage layer; and an HDPE primary liner. The Heap Stormwater Pond will be lined with a GCL and an HDPE liner.

During operation, runoff and seepage from the Heap Leach Pad will be collected in the double-lined PLS Pond located at its base, and, for large storm events, in the Heap Leach Stormwater pond. After leaching is complete, the Heap will be allowed to drain for up to three (3) years. At this point, the heap leach pile, the Raffinate Pond, and the PLS/Heap Stormwater Pond will be closed in accordance with Prescriptive BADCT criteria established by ADEQ (2004). The spent ore pile will be covered with waste rock and graded to minimize meteoric infiltration into the spent ore. Seepage modeling considered several alternatives ranging from a one (1) foot
thick soil layer to 25 feet of waste rock, as well as combinations of waste rock and soil. Additional details about this modeling are discussed in the Seepage Section of this report. The modeling indicated that a 5-foot thick waste rock layer with a 1-foot soil layer will prevent infiltration as effectively as 20 feet of waste rock.

Modeling indicates that the drainage flow rate at the end of the three (3) year period will be less than ten (10) gallons per minute and will continue to decline thereafter. If drain-down from the spent ore has ceased after the three (3) year period, the ponds at the base of the pad will be closed by removing the plastic liners and filling the excavations with waste rock (as prescribed in BADCT for pond closure). However, if drain-down from the Heap is different than predicted and continues, Rosemont has proposed to convert the former PLS and Heap Stormwater Ponds into an engineered, passive, biological treatment system.

If biological treatment is necessary, the design of the treatment system will be tailored to the specific drain-down chemical composition and seepage flow rate at the time of closure, but would include the following steps. Flow from the closed heap will be delivered in series to the former PLS Pond and then to the Heap Stormwater Pond, which will have been converted to primary and secondary treatment basins, respectively, using the existing leachate collection piping. The treatment process would filter the seepage through treatment materials which could include crushed limestone, manure, straw, wood chips, etc. Both basins (the former PLS Pond and the former Heap Leach Stormwater Pond) would be mounded with crushed limestone and then covered with geotextile before being covered with waste rock (or dry stack tailings in the case of the Barrel Alternative). Rosemont will also install a monitoring/recovery well to regularly test the treated water for compliance with AWQS. If the samples indicate that the fluid does not comply with AWQS, it will not be released through infiltration, but instead will be pumped out after the polishing step for reuse in the process if operations are ongoing or for additional treatment if necessary.

Treatment of the heap drain-down solutions is further discussed in the Projected Seepage And Water Quality Impacts section below, and also in Tetra Tech (2010a) and Tetra Tech (2011).

3.1.5 Waste Rock Storage Area
The Waste Rock Storage Area southeast of the Open Pit within the Barrel Canyon drainage will store ROM waste rock in excess of the volume required to construct project facilities. Waste rock, consisting of overburden and non-ore bearing rock, will be used to construct buttresses for the Dry Stack Tailings Facility and used to cover the Heap Leach and Dry Stack Tailings Facility areas as part of final reclamation. Less than 4% of the waste rock has the potential to form acid rock drainage, and this material will be carefully placed within the Waste Rock facility to utilize the high buffering capacity of the vast majority of the material present in the Rosemont waste rock. Additional information about the geochemistry of the non-ore bearing waste rock is provided in the Seepage Section of this report. Approximately 1.2 billion tons of waste rock will be disposed in the Waste Rock
Storage area over the life of the mine. During operations, the outer surfaces of the Waste Rock Storage Area will be re-graded, contoured, and re-vegetated for concurrent reclamation.

### 3.2 Stormwater Management

In general, stormwater will be managed by diverting runoff from adjacent undisturbed areas around the Project facilities to the greatest extent practical. Due to the configuration of the canyon and the large volume of tailings and waste rock that will be placed, it is not possible to completely divert runoff around the waste rock and tailings areas. Therefore, flow-through drains were designed as part of the Project to convey runoff under the landform. The flow-through drains are an integral part of the Project’s stormwater management design. They protect Project facilities during large storm events and prevent contact between tailings and stormwater, while minimizing the loss of surface flows in downstream systems. The drain designs incorporate a geotextile wrap to separate the rock drain from the overlying tailings. (Tetra Tech 2010b). Comments received during the EIS process have caused Rosemont to incorporate a geotextile –LLDPE consolidated material into the designs, as well as to examine the phasing to ensure the drains are protected from runoff that would not be appropriate for discharge.

Water management features have been designed to ensure that stormwater that contacts process materials will not be discharged from the site. As described below, runoff from the outer slopes of the buttresses, or final landform areas, will be allowed to leave the site pursuant to an Arizona Pollutant Discharge Elimination System (AZPDES) permit. Runoff that is not eligible for discharge under regulatory programs (e.g., from the Heap Leach Facility or from other Project process or mining areas) will be contained within the Project boundary and the water will be reused onsite. Rosemont developed a Site Water Management Plan (Tetra Tech 2007a) and a Site Water Management Update (Tetra Tech 2010c) to describe designs for managing storm flows and sediment yield both during the active mine life and as part of the long-term reclamation plan. This plan and its update include stormwater management provisions for the Open Pit, the Plant Site, the Dry Stack Tailings Facility, the Heap Leach Facility and the Waste Rock Storage Area.

The Open Pit, Plant Site, and Heap Leach Facility are designed as closed systems, with all direct rainfall and local runoff contained. In the Open Pit, any rainfall or runoff will be collected and pumped into the process circuit during active operations. Stormwater flows from the Plant Site will be directed into the PWTS Pond complex which is located down-gradient of the Plant Site. All water directed to the PWTS Pond will be incorporated into the sulfide ore processing circuit, thus reducing the Project’s requirement for process water from well sources. All precipitation falling on the Heap Leach Pad will be captured by the solution collection system and incorporated into the oxide ore processing circuit.

The Dry Stack Tailings Facility will be constructed in uniform lifts placed behind waste rock buttresses that will be constructed incrementally higher than the dry stack tailings. The buttresses will not only contain the tailings, but will facilitate
concurrent reclamation and the application of Best Management Practices (BMPs) including channels, settling ponds, and other sediment control devices as needed between the toe of the facility and the Compliance Point Dam to reduce down-gradient sediment loading before water is discharged. Stormwater management at the Waste Rock Storage Area will be similar to the Dry Stack Tailings Facility. Perimeter buttresses, concurrent reclamation, and appropriate BMPs will progress up the outer slopes as the facility is constructed. BMPs will limit erosion potential while direct runoff is conveyed to sediment ponds.

The Compliance Point Dam will serve as a final sampling point for monitoring stormwater releases. If necessary, additional BMPs can be implemented at this location. The Compliance Point Dam is designed as a porous rock-fill check dam located in Barrel Canyon downstream of its confluence with McCleary Canyon. The embankment will be approximately six (6) feet tall, creating a final sediment pond for the Project with a storage capacity of approximately two (2) acre-feet. It will be constructed using chemically benign waste rock as an unlined embankment. Normally, the area behind the embankment will be dry. During storm events, water will be slowed, or retained, and then released through the porous structure. Stormwater flows during large storm events are expected to overtop the embankment and proceed downstream. Rosemont will regularly inspect the dam as part of the AZPDES program. If the dam is damaged or destroyed by a storm event, it will be repaired or rebuilt as necessary. The Compliance Point Dam will be dismantled after reclamation activities have stabilized the surface of the Landform.

Upon final closure and reclamation, stormwater on the landform will be conveyed off-site through a combination of channels, drop chutes, and other structures. Flows will be directed to Perimeter Containment Areas and flow-through drains, or to other channels, both natural and constructed. Based on comments received during the DEIS and at the CNF’s request, the design elements of the site water management plan will be reviewed to minimize ponding and avoid relying on the flow-through drains post closure by maximizing diversions. The design of the water management system and structures will minimize the potential for erosion and protect the natural drainage downstream of the Project.

3.3 Regulatory Setting

Unregulated historical mining activities, including both mine development and closure, have resulted in adverse environmental effects. These effects were poorly understood and often poorly addressed during the course of mine operations and after closure, leaving “legacy” environmental impacts that have required (and continue to require) significant after-the-fact expenditures for remediation of tailings ponds, waste piles, and surface and groundwater.

Beginning in the late 1960s and accelerating in the 1970s and beyond, the Federal government, in partnership with state governments, began to establish a body of laws and regulations designed to address the potential negative environmental impacts of mining and other industries, with particular focus on better planning and up-front prevention and mitigation measures. During this same time frame,
environmental science, environmental monitoring, engineering, and preventive design techniques have advanced tremendously. A new mine like the Rosemont Project, developed under modern laws and regulations and using the best practices now available for evaluation and design, bears little resemblance from an environmental perspective to other regional copper mines developed in the 1960s or earlier. Rosemont is required to obtain numerous Federal and State permits and approvals that impose comprehensive analysis, monitoring, and adaptive management requirements designed to protect the environment, and in some cases mitigation activities to offset environmental impacts. In addition, the USFS can apply additional stipulations in approving the MPO and will require financial assurance to cover the costs of reclamation and closure. The DEIS described the many approvals and permits that will be required for the Project. Described in more detail below are the two significant State permits associated with water quality: the Arizona Pollutant Discharge Elimination System (AZPDES) permit and the Aquifer Protection Permit (APP), both administered by the ADEQ. ADEQ issued the Rosemont Copper Project APP in April 2012.

3.3.1 Arizona Pollutant Discharge Elimination System (AZPDES)

The National Pollutant Discharge Elimination System (NPDES) is a permit-based program designed to regulate the discharge of pollutants into waters of the U.S. Section 402 of the Clean Water Act prohibits the discharge of any pollutant from a point source into waters of the U.S. unless the discharge has a NPDES, or state-authorized equivalent, permit. EPA approved the AZPDES program and therefore ADEQ is authorized to issue AZPDES permits for point source discharges to waters of the U.S. in accordance with the NPDES program.

There are two (2) basic types of AZPDES permits: individual and general. An individual permit is generally issued for a single facility for a multi-year period. Individual permits are developed to be site-specific, i.e., customized for a specific facility’s discharge practices. General permits are developed for classes of facilities. General AZPDES permits required for this Project include the Multi-Sector General Permit (MSGP) for Stormwater Discharges Associated with Industrial Activity (Arizona has a mining-specific Multi-Sector permit with conditions tailored specifically to mining); the De Minimis General Permit for defined, short-term discharges to a waters of the U.S. (i.e., such as discharge of groundwater from an aquifer test); and the Construction General Permit (CGP). A Notice of Intent (NOI) must be submitted to ADEQ, and a site-specific Stormwater Pollution Prevention Plan (SWPPP) developed and implemented, in order to obtain an AZPDES general permit. General AZPDES permits (including the MSGP and the CGP) contain detailed inspection and monitoring requirements.

Rosemont’s Project design is intended to allow the facility to qualify for the Arizona Mining MSGP. Rosemont plans are being developed consistent with the site water management goals specified by the CNF, and Rosemont will implement a SWPPP pursuant to the General Permits listed above. The SWPPP will include the techniques described in section 3.2 and the selected Best Management Practices
(BMP) as well as monitoring, and reporting to ensure that stormwater discharges are in compliance with the Permit requirements.

### 3.3.2 Arizona Aquifer Protection Permit

Arizona’s APP Program is administered by ADEQ under Arizona Revised Statutes (A.R.S.) Title 49, Chapter 2, Article 3, and Arizona Administrative Code (A.A.C.) Title 18, Chapter 9, Articles 1 through 4. The APP application requirements are specified in A.R.S. §49-243.A and A.A.C. R18-9-A201 through A208. The purpose of the APP Program is to protect Arizona’s groundwater and prevent further degradation to aquifers in areas already exceeding AWQS. The APP Program gives ADEQ the authority to regulate facilities that could have discharges to groundwater, including surface impoundments, leach piles, ore and waste rock stockpiles, and tailings storage facilities. Rosemont submitted an APP Application for the Rosemont Copper Project to ADEQ on March 3, 2009. ADEQ issued the APP to Rosemont on April 3, 2012.

The APP Program regulates the design, construction, operation, and closure of all facilities that may discharge pollutants to an aquifer. The Program requires an applicant to make several demonstrations relevant to ensuring the long-term protection of groundwater resources, including: technical capability, financial capability, compliance with AWQS at designated points of compliance, and implementation of BADCT to minimize discharges.

The demonstrations for technical and financial capability required Rosemont to submit detailed information to ADEQ concerning Project personnel and financing. Under the APP, Rosemont will be required to show, through groundwater monitoring at eight (8) specified point of compliance (POC) wells, that its operations are not causing or contributing to conditions exceeding an AWQS (or not causing any worsening of existing water quality if an AWQS is exceeded at the time of permit issuance). BADCT requirements specify that the Project be designed, constructed, and operated to ensure the greatest degree of discharge reduction, and therefore groundwater protection, achievable, considering a variety of factors enumerated in statute (including consideration of site-specific conditions). ADEQ has developed Prescriptive BADCT criteria for several types of mining facilities, including process and non-stormwater ponds, heap leach pads, and tailings impoundments. Prescriptive BADCT criteria are designed to be conservative and are based on the premise of minimizing discharge beyond the engineered containment, and their implementation is largely independent of site-specific characteristics (ADEQ 2004). In addition to the BADCT requirements applied to the design of Project features, Rosemont must implement a rigorous program for monitoring groundwater quality at the eight (8) designated POCs.

### 3.4 Reclamation Approach

Rosemont has carefully designed the Project with closure in mind, including the use of state-of-the-art up-front design to facilitate both concurrent reclamation techniques, and reclamation at the end of the mine life. The footprint of the facilities
was minimized and restricted to a single drainage through careful design and
detailed planning efforts, by closely coordinating waste rock and tailings
construction and operational needs. Minimizing the visual impacts of the mine was
also a major goal in the mine’s design. The reclamation approach is described in
detail in the Reclamation and Closure Plan (Tetra Tech 2007b) and the Reclamation
Concept Update (Tetra Tech 2010b). The Reclamation and Closure Plan must be
approved by both the USFS (under the MPO Approval) and by the Arizona State
Mine Inspector (ASMI). ASMI approved the reclamation plan in 2009.

Activities at the site will culminate in a large landform, which will be a consolidated
and contoured earthen structure consisting of the Waste Rock Storage Area, the
encapsulated Heap Leach Facility, and the Dry Stack Tailings Facility, also
encapsulated with waste rock. Encapsulation of the Heap Leach and Dry Stack
Tailings facilities provides these facilities with a deep and benign rock cover that
serves to isolate the environment from the underlying materials by minimizing or
eliminating stormwater infiltration. Encapsulation also stabilizes the final slopes
and protects them from erosion, and assists in providing a growth medium for re-
vegetation.

The Dry Stack Tailings Facility and the Waste Rock Storage Area are designed to
facilitate closure and reclamation. By placing clean waste rock buttresses along the
eastern perimeter of the landform early in the mine life and using dry stack tailings
technologies, the Project design will enhance the effectiveness of concurrent
reclamation. The perimeter buttresses will stabilize soils, enhance revegetation,
and allow reclamation to begin early in the mine life.

At the cessation of mining operations, final reclamation will include demolition and
closure of the Plant Site and final re-grading and re-vegetation of the landform. The
spent oxide ore and dry stack tailings will be completely encapsulated with a thick
waste rock shell capped with a soil layer to facilitate revegetation, and will thereby
be isolated from the surrounding environment. The reclamation concept will result
in diverse habitats and allow the final landform to support the post-mining land use
(ranching and wildlife habitat) by controlling stormwater and erosion. The design is
intended to allow access to all areas of the reclamation while incorporating
landscaping and aesthetic considerations. Rosemont will monitor reclamation
success and revise reclamation techniques as needed to improve the effectiveness of
reclamation. If new reclamation practices are developed during the life of the mine,
Rosemont is committed to working with Federal and State agencies to revise the
Reclamation and Closure Plan to incorporate these techniques as needed.

Stormwater will be managed during reclamation and discharged under the AZPDES
permit. After the site is reclaimed, stormwater can discharge freely so long as it is
determined that the stormwater meets the required standards.

The DEIS and supporting information predicted that water treatment is unlikely to
be required at closure or farther into the future for runoff from the landform or in
the Open Pit. The analyses supporting these conclusions are described in section 4.
Rosemont will monitor surface and ground water during operations and for a period
following complete reclamation to ensure that permit conditions and applicable water quality standards are being met. If conditions differ from those predicted, Rosemont will respond accordingly to ensure protection of the environment. This response could include rerouting and infiltration of water, water treatment, and other techniques depending upon the problem.

The Reclamation and Closure plan describes post-closure monitoring and incorporated costing to cover reclamation repair in the post-closure period. The original plan anticipated a three (3) year post-closure period. However, the APP has specified a longer post-closure monitoring period that may be reduced if specific targets are met. An adaptive management process, including the post-closure monitoring measures, will be developed.

3.5 Summary

The Project and its individual facilities have been “designed for closure” from its inception. Rosemont will implement state-of-the-art tailings operations and reclamation practices to avoid environmental impacts. Facility designs have accomplished the goal of minimizing the footprint, minimizing water use and maximizing water recycling, minimizing the contact between water and waste materials, protecting surface and groundwater resources, minimizing and mitigating impacts on wildlife, and mitigating view concerns to the extent possible. Incorporating reclamation planning as part of the mine design, using water conserving processes such as dry stack tailings, and incorporating landform designs that facilitate consolidation of waste materials and concurrent reclamation are all part of Rosemont Copper’s plan to practice good stewardship of natural resources and the environment.

3.6 References


4 FACILITY SEEPAGE AND WATER QUALITY

This section focuses on issues of water balance and water quality as they relate to the Project Area. The section includes a discussion of the testing, planning, and evaluation effort that has been invested in understanding the potential for water-quality impacts and designing Project features to avoid and minimize impacts. It summarizes and provides references to the body of reports and studies that were prepared by top consultants and peer reviewed by other consultants working independently for the USFS. The Project has been designed to protect water quality by:

- minimizing the volume of impacted water generated by the Project;
- minimizing the potential for contamination of water; and
- eliminating the potential for the release of impacted water to surface water or groundwater.

Rosemont’s strategy for minimizing seepage (and thereby protecting water quality) is straightforward. First, Arizona’s arid climate, with low rainfall and high evaporation, reduces both the creation and the potential for release of impacted water. Second, the compact footprint of the Project, in conjunction with the use of Dry Stack Tailings, co-located waste storage sites, and concurrent reclamation, is designed to minimize seepage to a level far below typical mines with conventional tailings ponds. Both the volume of water in contact with waste rock and tailings and the length of time water is in contact with these materials will be minimized. Third, the “host rock” environment at the site is benign in terms of its potential for water-quality degradation after it is exposed by mining activity. These factors collectively minimize the extent to which water-quality degradation can occur.

The Open Pit/Pit Lake will create a long-term hydraulic sink that will direct groundwater in the Project Area toward the pit. Seepage within this capture zone that reaches the groundwater will migrate back toward the Pit and prevented from flowing down gradient. Finally, although the Pit Lake will gradually concentrate minerals as water evaporates over time, modeling shows that water quality in the lake will meet all applicable water quality standards.

Water quality impacts from Project seepage are expected to be minor and largely confined to the mine facilities’ footprint. This section provides information that supports that conclusion, describing the assessments that: quantify anticipated seepage and runoff from Project facilities, characterize the chemical quality of water that contacts mine rock and tailings, and describe the predicted environmental impacts and consequences.

4.1 Infiltration Modeling

The conceptual models developed for the Project Waste Rock Storage Area, Heap Leach Facility, and Dry Stack Tailings Facility are similar to models developed for other facilities of this type throughout the mining industry. The conceptual models include the fundamental system water-balance components including:
In an environment with a net negative water balance, such as the arid southwestern United States, evaporation is one of the most important components of the system. Evaporation and transpiration were calculated in the models using the following climate, soil, and vegetation factors:

- Air temperature
- Soil temperature
- Relative humidity
- Solar intensity (from latitude)
- Soil temperature
- Soil moisture content
- Leaf area index
- Plant root depth
- Plant wilting point
- Wind speed and
- Measured pan/modelled actual evaporation

The combination of the factors listed above provides a reasonable estimate of water evaporation and transpiration from the system. Infiltration into waste rock was based in part on the unsaturated hydraulic conductivity of the material at a given time. In the model calculations, precipitation that was not evaporated, transpired (via plant uptake), or infiltrated was attributed to runoff. Model output tracks the amount of rainfall that:

- Runs off the facility,
- Evaporates or is transpired by plant growth, or
- Infiltrates into the sub-surface.

Infiltration and seepage models were developed for the major Project features, which included the Waste Rock Storage Area, the Dry Stack Tailings Facility, and the Heap Leach Facility. The models simulated a variety of hydrologic scenarios and included sensitivity analyses that, although not detailed in the DEIS, were available for review in the reference material. The results of these investigations are summarized here.

Infiltration and seepage models developed for the Waste Rock Storage Area and the Heap Leach Facility by Tetra Tech, Inc. (Tetra Tech) are detailed in Tetra Tech (2012). The models were developed using VADOSE/W (GEO-SLOPE 2007), an accepted two-dimensional unsaturated flow computer code. The following climatic conditions were simulated:
• Average (annual) climate conditions derived from a 50-year record at the Nogales, AZ weather station;
• Daily measurement climatic conditions for a 50 year record from the Nogales, AZ monitoring station;
• Daily measurement climate conditions for a 10-year record from the University of Arizona weather station;
• Daily measurement climatic conditions for a 50-year record from the Nogales weather station;
• A 100-year, 24-hour storm event (4.75 inches of rain in a 24-hour period); and
• A multi-day storm event (actual precipitation from a winter storm event that occurred from September 29, 1983 to October 5, 1983, and produced approximately 6 inches of rain in seven days).

This range of climatic conditions accounts for the dominant observed conditions, but also investigates the potential effects of episodic intense and multiple-day precipitation events that characterize the region.

4.1.1 Waste Rock Infiltration

The Waste Rock Storage Area will be constructed southeast and east of the Open Pit, and at the head of the Barrel Canyon drainage (Appendix Figures 3-1 and 3-2). Waste rock that is excavated from the Open Pit during the recovery of copper ore will be placed in this facility, which will have a footprint of about 1,370 acres and contain about 756 million tons of material. The remaining 633 million tons of waste rock will be used for various construction purposes, including for buttresses for the Dry Stack Tailings Facility. At the direction of the USFS, the Waste Rock facility design incorporates slopes that efficiently shed stormwater and avoid ponding on either the top or benches at closure.

The physical properties of ROM materials, which dictate their hydraulic properties, were measured for andesite and arkose waste rock samples under standard laboratory conditions and procedures. The hydraulic properties determined for ROM rock are equivalent to a coarse material with a broad distribution of sizes (poorly sorted) from gravel (0.1 inches) to large boulders (greater than 12 inches). At depth, ROM rock is consolidated by the weight of the overlying material. The relatively consolidated ROM was represented in modeling using a permeability that was one order of magnitude less than the unconsolidated waste rock material. This assumption was determined to be valid for the Rosemont Project based on experience and observation of conditions at similar facilities with heights and materials of this type at currently operating mines. This consolidation condition was also used to simulate the Heap Leach Facility material to represent its condition after leaching and burial by waste rock.

The modeling approach consisted of a series of linked infiltration and seepage models to simulate the progressive development of the Waste Rock Storage Area
over time. The models were used to evaluate the performance and the feasibility of different reclamation designs. Specifically, model components were assembled to represent the following periods of time during the development of the Waste Rock Storage Area:

- Beginning of mine life to approximately Year 3;
- Year 4 to approximately Year 6;
- Year 7 to end of mine life; and
- Closed facility with various reclamation soil layers placed on outer waste rock surface to determine feasible reclamation alternatives.

The reclamation scenarios simulated included:

- One (1) foot thick soil with hydraulic conductivity of $10^{-5}$ centimeter per second (cm/sec);
- Three (3) foot thick hydraulic conductivity $10^{-5}$ cm/sec soil;
- Two (2) foot thick hydraulic conductivity $10^{-5}$ cm/sec soil with a one (1) foot gravel layer on the soil surface;
- Closed facility with no reclamation soil layer placed on the outer waste rock surface; and
- Closed facility with ponding on the benches to manage runoff.

Modeling results for all climatic conditions and for all reclamation designs indicated that no seepage is anticipated from the Waste Rock Storage Area (Tetra Tech 2012). Simulated evaporation rates greatly exceed precipitation for average conditions as well as for simulations using the 10-year daily weather record data, with both showing an overall net loss of water under these conditions. Model simulations do indicate that under the 100-year, 24-hour storm event and the multi-day storm event, some water would infiltrate the surface of the facility. However, the stormwater infiltration in the model simulation was evaporated due to the predominantly arid conditions and the considerable time that typically elapses between such major storm events.

Specific results of unsaturated modeling of the Waste Rock Storage Area are presented in Tables 4-1 through 4-3. These tables summarize the annual water balance for the Waste-Rock facility for each of the climatic conditions simulated (average, 100-year-24-hour storm, multi-day storm).

Table 4-1 depicts the water balance for average climate conditions, which was consistent with, and similar to, the 10-year and 50-year daily record result. It should be noted that the negative storage and evapotranspiration values represent losses from the system (i.e., reduction of water). The tabulated results indicate that there was no increase in water storage due to infiltration for all the modeled reclamation scenarios. Several of the scenarios resulted in appreciable loss of moisture and all showed substantial ET.
Model results for storm events are provided in Tables 4-2 and 4-3. The 100-year, 24-hour event resulted in significant runoff, as would be expected and commonly observed in the desert southwest for heavy rainfall on dry sediments. The longer lasting, less intense multi-day storm event provided a slower rate of rainfall, allowing the surface of the waste rock to slowly wet and accommodate greater infiltration (storage) as the storm event progressed. This simulation resulted in lower runoff than that generated by the 100-year, 24-hour storm.

**Table 4-1. Unsaturated modeling results for 50-year average annual climate conditions for the Waste Rock Storage Area.**

<table>
<thead>
<tr>
<th>Reclamation Scenario</th>
<th>Storage</th>
<th>Runoff</th>
<th>Evapotranspiration</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Reclamation Soil</td>
<td>0%</td>
<td>0%</td>
<td>-101%</td>
</tr>
<tr>
<td>Mixed Reclamation Soil &amp; Gravel</td>
<td>0%</td>
<td>0%</td>
<td>-101%</td>
</tr>
<tr>
<td>Vegetated Reclamation Soil &amp; Gravel</td>
<td>-2%</td>
<td>3%</td>
<td>-98%</td>
</tr>
<tr>
<td>3-Foot Reclamation Soil</td>
<td>-14%</td>
<td>0%</td>
<td>-116%</td>
</tr>
<tr>
<td>Vegetated 3-Foot Reclamation Soil</td>
<td>-36%</td>
<td>0%</td>
<td>-140%</td>
</tr>
<tr>
<td>1-Foot Reclamation Soil</td>
<td>0%</td>
<td>0%</td>
<td>-101%</td>
</tr>
<tr>
<td>Vegetated 1-Foot Reclamation Soil</td>
<td>-2%</td>
<td>3%</td>
<td>-98%</td>
</tr>
</tbody>
</table>

¹Negative numbers indicate a loss to the system.

**Table 4-2. Unsaturated modeling results for 100-year, 24-hour storm event on Waste Rock Storage Area.**

<table>
<thead>
<tr>
<th>Reclamation Scenario</th>
<th>Storage</th>
<th>Runoff</th>
<th>Evapotranspiration</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Reclamation Soil</td>
<td>5%</td>
<td>91%</td>
<td>-5%</td>
</tr>
<tr>
<td>Mixed Reclamation Soil &amp; Gravel</td>
<td>5%</td>
<td>91%</td>
<td>-5%</td>
</tr>
<tr>
<td>Vegetated Reclamation Soil &amp; Gravel</td>
<td>0%</td>
<td>91%</td>
<td>-9%</td>
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<tr>
<td>3-Foot Reclamation Soil</td>
<td>1%</td>
<td>94%</td>
<td>-5%</td>
</tr>
<tr>
<td>Vegetated 3-Foot Reclamation Soil</td>
<td>1%</td>
<td>94%</td>
<td>-5%</td>
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<tr>
<td>1-Foot Reclamation Soil</td>
<td>1%</td>
<td>94%</td>
<td>-5%</td>
</tr>
<tr>
<td>Vegetated 1-Foot Reclamation Soil</td>
<td>1%</td>
<td>94%</td>
<td>-5%</td>
</tr>
</tbody>
</table>

¹Negative numbers indicate a loss to the system.
Table 4-3. Unsaturated modeling results for multi-day storm event for the Waste Rock Storage Area.

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Storage as a percent of precipitation</th>
<th>Runoff</th>
<th>Evapotranspiration¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Reclamation Soil</td>
<td>3%</td>
<td>87%</td>
<td>-10%</td>
</tr>
<tr>
<td>Mixed Reclamation Soil &amp; Gravel</td>
<td>3%</td>
<td>87%</td>
<td>-10%</td>
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<tr>
<td>Vegetated Reclamation Soil &amp; Gravel</td>
<td>0%</td>
<td>82%</td>
<td>-18%</td>
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<tr>
<td>3-Foot Reclamation Soil</td>
<td>10%</td>
<td>79%</td>
<td>-10%</td>
</tr>
<tr>
<td>Vegetated 3-Foot Reclamation Soil</td>
<td>10%</td>
<td>80%</td>
<td>-10%</td>
</tr>
<tr>
<td>1-Foot Reclamation Soil</td>
<td>2%</td>
<td>88%</td>
<td>-10%</td>
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<tr>
<td>Vegetated 1-Foot Reclamation Soil</td>
<td>1%</td>
<td>88%</td>
<td>-10%</td>
</tr>
</tbody>
</table>

¹Negative numbers indicate a loss to the system.

Following storm events, model conditions return to average and the waste rock returns to a net water removal balance. The net result is an expected absence of seepage from the Waste Rock Storage Area.

4.1.2 Dry Stack Tailings Infiltration

The Dry Stack Tailings Facility will consist of two separate areas referred to as Phase 1 and Phase 2. Phase 1 is designed to accommodate about 343 million tons of dry stack tailings and the Phase 2 stack capacity is about 253 million tons. Dry stack tailings are estimated to be placed at a rate of about 75,000 tons per day.

One of the most important observations from the seepage analyses of these dry stack tailings is that saturated conditions within the Dry Stack Tailings Facility are not expected to develop. Under the scheduled stacking plan, given the fine-grained properties of the tailings and the compaction that will occur near the buttress and generally, due to the weight of the tailings, overall unsaturated conditions are expected to prevail. In profile, modeling shows that lower moisture contents are present along the perimeter (rockfill) and at the surface of the facility, and higher moisture contents are present towards the center and bottom of the facility. This reflects long-term drainage as the tailings moisture content falls from the as-placed moisture content of less than 18 percent (by dry weight) to the field capacity of approximately 11 percent (by dry weight). The model results show that recharge to the tailings from precipitation is negligible to non-existent. By 150 years after mining, the Dry Stack Tailings Facility is expected to lie within the Open Pit groundwater capture zone that was predicted by M&A (2010).

The estimated seepage rate increases as the dry stack facility is constructed, reaching a peak rate of 8.4 gallons per minute for the entire facility, for the average climatic conditions, at production Year 18. This maximum rate is followed by a gradual decrease as the moisture content of the tailings decreases over time. Figure
4-1 illustrates the rate of drain down for the Dry Stack Tailings Facility under the 
average climatic conditions (AMEC 2009, Tetra Tech 2012). This drain down occurs 
slowly under unsaturated conditions and continues for an estimated 500 years.

![Drain Down Curve for Dry Stack Tailings Facility](image)

**Figure 4-1. Drain down Curve for Dry Stack Tailings Facility (AMEC 2009).**

Additional modeling runs were conducted using the 50-year daily climate record, 
producing a drain down curve for the Dry Stack Tailings Facility that is generally 
consistent with the simulation of average annual conditions. An exception is 
present for a storm event occurring in the climatic record from January 1968, which 
resulted in a brief increase in drain down rate. These modeling results are available 
in *Infiltration, Seepage, and Fate and Transport Modeling Report - Revision 2* (Tetra 
Tech 2012).

### 4.1.3 Heap Leach Infiltration

The Heap Leach Pad will be constructed southeast of the Open Pit (Figure 3-1) and 
within the Barrel Canyon drainage. Oxide ore will be placed on the Heap Leach Pad 
during the first seven (7) years of mining. After leaching operations and a drain 
down period are completed, the closed heap and the ponds located at the base of the 
heap will be covered. The outer surface of the waste rock cover will be contoured 
and graded to prevent stormwater from ponding above the closed heap facilities. 
Following placement of the waste rock cover, seepage will be limited to the residual 
-drain-down solution, as evaporation will prevent precipitation from infiltrating 
through the overlying material and into the spent leach ore.
In order to simulate the Heap Leach Facility material, the relatively consolidated ROM was represented in modeling using a permeability that was one order of magnitude less than the unconsolidated waste-rock material. This assumption was determined to be valid for the Rosemont Project based on experience and observation of conditions at similar facilities with heights and materials of this type at currently operating mines. This consolidation condition was used to simulate the Heap Leach Facility material to represent its condition after leaching and burial by waste rock.

Unsaturated flow modeling of the Heap Leach Facility (Tetra Tech 2012) considered the same climatic scenarios simulated for the Waste Rock Storage Area just described. In the case of the Heap Leach Facility, the application of the leaching solution was included in the modeling to provide the basis for the start of the drain down period. The operating Heap Leach Facility was not modeled. As with the Waste Rock Storage Area, a series of linked infiltration and seepage models were built based on the Heap Leach Facility operational and reclamation designs:

- Operating Heap Leach Facility (year 1 to 7);
- Drain-down of the spent ore within the heap [approximately three (3) years] (year 7 to 10)]; and
- Closed Heap Leach Facility reclamation scenarios with:
  - Five (5) feet of waste rock with and without a one (1) foot soil layer on the surface;
  - Ten (10) feet of waste rock with and without a one (1) foot soil layer on the surface;
  - Fifteen (15) feet of waste rock with and without a one (1) foot soil layer on the surface;
  - Twenty (20) feet of waste rock with and without a one (1) foot soil layer on the surface; and
  - Twenty-five (25) feet of waste rock with and without a one (1) foot soil layer on the surface.

Based on model output, the combination waste rock/soil layer options are more protective than the waste rock only scenarios. A five (5) foot waste rock thickness with a one (1) foot soil layer performs as effectively as the scenarios with thicker waste rock only or with thicker waste rock coupled with a soil layer. If only waste rock were used, the model indicates that the thickness would need to be at least 20 feet in order to eliminate precipitation infiltration into the spent ore. For the average climate condition, once the waste rock is placed over the spent ore, the dominant component of the system becomes evaporation, which results in water being drawn up and out of the facility.

In addition to average climate conditions, closure scenarios were also modeled using the two design storm events (100-year, 24-hour storm and recorded multi-day precipitation, Table 4-4). The 100-year, 24-hour storm represents a short, but intense storm event that has a high potential for above average runoff. The multi-day storm represents a higher than average infiltration condition.
Table 4-4. Comparison of Modeled Storms to Average Climate Conditions

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Storage$^1$</th>
<th>Runoff$^1$</th>
<th>Evaporation$^1$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Climate Conditions</td>
<td>-60%</td>
<td>-2%</td>
<td>&gt; -100%</td>
</tr>
<tr>
<td>100-year, 24-hour Storm Event</td>
<td>1%</td>
<td>94%</td>
<td>-5%</td>
</tr>
<tr>
<td>Multi-Day Storm Event</td>
<td>2%</td>
<td>88%</td>
<td>-10%</td>
</tr>
</tbody>
</table>

$^1$Negative numbers indicate a loss to the system.

When these storm simulations are compared to the model results associated with the average climate conditions, both result in increased runoff and storage. There is some increased infiltration. However, the models show that any precipitation that does infiltrate into the upper portion of the waste rock covering the heap leach will be removed from the facility through evaporation following the storm event as conditions return to average, resulting in a net withdraw of water from the facility. Therefore the heap drain down, addressed below, will be the main consideration for management at this facility.

4.2 Water Quality

Copper mine development unavoidably leads to the production of waste rock and tailings, generally from an open pit, although underground mining for copper may also occur. Pit walls, waste rock, tailings, and spent ore (from heap leaching) may, depending upon facility configuration, release chemical constituents to water that contacts them, both during operation and post-closure. Therefore, it is imperative that Project design and operation minimize the amount of contact water and control the movement and disposition of impacted water. In addition, heap leaching of copper ore requires and produces acidic solutions that cannot be discharged, as they have levels of chemical constituents that are undesirable in the. Rosemont has designed the Project to prevent and minimize chemical impacts to local and regional water quality.

Currently, except for the residuum of historic mining activities, there is no Open Pit, nor Waste Rock Storage Area, nor Heap Leach Facility, nor Dry Stack Tailings Facility located in the Project Area. Rain is either shed as surface runoff, infiltrates into the shallow subsurface, or recharges groundwater. This water partially dissolves minerals contained in the rock, which is composed of un-mined ore and waste rock, resulting in the observed baseline chemical quality of groundwater and surface water at the site. Ore deposits are by definition locations of anomalously high concentrations of chemical elements. At metal mines, one metal is often the primary resource, with other constituents present in much lower, non-economic concentrations. The baseline chemical quality of groundwater samples ranges considerably from clearly potable, to non-potable (not for human consumption).

The existing water quality of stormwater sampled downstream of the Project Area has been monitored and characterized by Rosemont (Tetra Tech 2010c). Surface water quality standards apply to the storm flow in washes directly downstream of the proposed Project Area (e.g., Barrel Canyon). These water quality standards are
in place to protect wildlife and aquatic species that may rely on the sporadic presence of water in these washes, as well as to protect the limited human uses of the washes that may occur. A more strict set of surface water quality standards exists for the OAW reach downstream in Davidson Canyon. Because water is present more regularly in portions of the OAW stretch of Davidson Canyon, more species are presumed to be present and longer term exposure is assumed, with the result that lower concentrations of pollutants are allowed. These standards for perennial flows are in place to provide year-round protection for wildlife and warm-water aquatic species with a lower threshold of toxicity than applies to intermittent flows. For several constituents, numeric surface water quality standards vary based on the hardness of the water.

Rosemont has conducted baseline stormwater sampling from 2007 to present. Some of the samples collected to determine the baseline quality of the stormwater exceed applicable surface water quality standards that apply to the Barrel Canyon Wash for arsenic, cadmium, copper, and lead (Tetra Tech 2010c).

Water-quality monitoring for stormwater discharges from the Project will occur at the Compliance Point Dam, to characterize runoff released downstream. Water quality monitoring will continue until site stabilization and reclamation activities have established a condition that will allow Rosemont to cease monitoring pursuant to AZPDES requirements.

4.2.1 Assessment of Acid Rock Drainage Potential

The water quality issue of greatest concern at mining operations is the potential for acid rock drainage (ARD). ARD is an acidic (low pH) iron sulfate solution that is derived from the oxidation of sulfide minerals (e.g., pyrite, FeS₂) in the presence of water. ARD will often contain a range of trace metals, some of which have the potential to cause acute or chronic effects to aquatic life above certain concentration levels, and therefore are regulated. Many of these constituents are found within, or closely associated with, sulfide minerals. The extent to which ARD impacts the environment depends upon many factors, especially the availability and volume of water that can transport ARD off-site and the presence of neutralizing minerals naturally contained in the adjacent rock.

If sufficient acid-neutralizing rock types (e.g., limestone containing the mineral calcite, also known as calcium carbonate CaCO₃) are present, the rate of sulfide mineral weathering or oxidation and leaching is minimized; the acidic solution produced is rapidly offset, and a neutral to slightly alkaline solution pH results. This pH modification is critical for two reasons. First, if pH conditions are buffered at neutral to alkaline, any metals released from sulfide minerals are removed from the water by precipitation as a generally stable solid material. Metals generally have high solubilities under acidic conditions, but quite low solubilities under alkaline or neutral pH conditions. Second, the formation of metal solids, particularly iron oxides, may act to coat sulfide minerals immediately, inhibiting their further oxidation. This can be expected to occur most in settings like the Project Area,
where limestone is abundant and rapidly adds alkalinity to water contacting sulfide minerals.

As discussed in more detail below, less than 4% of the waste rock that will be produced at the Rosemont Mine will be potentially acid generating. Mine models have been developed to track the acid generating potential and neutralizing capacity of waste rock during all stages of Project operations and closure. The Waste Rock Storage Area will be carefully constructed to blend various rock types that are encountered during mining, so that an environmentally protective net neutralization potential is maintained. Therefore neither runoff from the Waste Rock Storage Area nor the minimal amount of seepage produced is expected to include water with constituent concentrations that exceed water-quality standards. Only highly alkaline waste rock will be placed on the outside perimeter of the Waste Rock Storage Area to further protect against any acidic runoff.

Static acid-base accounting (ABA) and humidity cell testing (HCT) are the standard short-term and long-term tests used to estimate the potential for ARD to occur and rates of ARD occurrence.

4.2.1.1 Static ABA Testing

ABA is a method by which the acid potential (AP, also known as acid-generating potential or AGP) and neutralization potential (NP, also known as acid-neutralization potential or ANP) of mine rock are measured and compared. AP is determined by measuring the concentration of acid-producing sulfide sulfur that is present in a rock type. NP is determined by measuring the amount of acid that a rock type can neutralize, per mass of the rock. The difference in NP and AP is called the Net Neutralization Potential (NNP) and is equal to NP-AP. Rock with an NNP greater than 20 is generally regarded as having little or no potential to form ARD. The ratio of NP to AP is also used to gauge ARD potential. As stated in the Arizona Mining BADCT Guidance Manual (2004): “Ratios of ANP/AGP [NPR] can also be used to assess the acid generation potential (e.g., ANP/AGP ratio of 1:0 is equivalent to an NNP of zero). If the ratio of a sample’s neutralization potential and acid production potential is greater than 3:1, then there is a low risk for acid drainage to develop and the material can generally be considered non-acid generating. For ratios between 3:1 and 1:1, uncertainty arises and additional testing is usually necessary using kinetic test methods as described under the Tier #2 protocols. Those samples with a ratio of 1:1 or less are more likely to generate acid.” Overall, rock with an NPR greater than 3 or with an NNP greater than 20 is generally considered inert with respect to the formation of ARD.

4.2.1.2 Humidity Cell Testing

HCT is a method used to determine the rate at which acid production may occur. Rock samples are subjected to a chemical environment that provides excess oxygen and water so that the oxidation of sulfide minerals is not impeded. Material solids are exposed to humidified oxygenated air and rinsed once a week, and the chemical composition of the rinse solution is tracked over time. Depending upon the rock
characteristics, some HCT test samples will become acidic and some will not. These results are used to refine ABA evaluations of ARD potential and estimate the time that may be required for an ARD-forming rock to exhaust any NP that is present. The steady-state water quality from HCT is often used as one basis for estimating potential future contact water quality.

Overall, the waste rock associated with the Rosemont Project is substantially net acid consuming. ABA analysis was completed on a total of 226 samples of waste rock submitted for analyses, with more samples taken of the more abundant rock types. Table 4-5 summarizes the classification of the waste rock samples into categories (unlikely, likely or uncertain potential to generate ARD) according to NNP or NPR values. These samples were collected throughout the anticipated pit volume, but are more focused toward the center where exploration and development drilling has been most active.

A significant majority of the waste rock samples are characterized as unlikely to produce ARD (Table 4-5). Conversely, very few are characterized as likely to generate ARD. About 25% of waste rock samples can be considered uncertain with respect to producing ARD. The rock types having the greatest potential to produce ARD are andesite and Bolsa quartzite, which together only comprise 6% of all waste rock estimated at the site, and not all samples of either rock type showed the potential to produce ARD.
### Table 4-5. Rosemont Waste Rock ABA Classification (NPR/NNP reporting basis).

<table>
<thead>
<tr>
<th>Lithology</th>
<th>Percent Unlikely or Non-Acid Generating</th>
<th>Uncertain Acid Generation</th>
<th>Likely Acid Generating</th>
<th>Lithology Percent Of Waste Rock</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abrigo</td>
<td>100%/100%</td>
<td>0%/0%</td>
<td>0%/0%</td>
<td>9.24</td>
</tr>
<tr>
<td>Andesite</td>
<td>55%/69%</td>
<td>31.5%/26%</td>
<td>13%/3%</td>
<td>3.99</td>
</tr>
<tr>
<td>Arkose</td>
<td>87%/72%</td>
<td>11%/28%</td>
<td>2%/0%</td>
<td>44.38</td>
</tr>
<tr>
<td>Bolsa</td>
<td>40%/13%</td>
<td>20%/80%</td>
<td>40%/7%</td>
<td>1.9</td>
</tr>
<tr>
<td>Colina</td>
<td>91%/100%</td>
<td>9%/0%</td>
<td>0%/0%</td>
<td>1.31</td>
</tr>
<tr>
<td>Concha</td>
<td>100%/100%</td>
<td>0%/0%</td>
<td>0%/0%</td>
<td>2.77</td>
</tr>
<tr>
<td>Earp</td>
<td>93%/93%</td>
<td>7%/7%</td>
<td>0%/0%</td>
<td>2.4</td>
</tr>
<tr>
<td>Epitaph</td>
<td>100%/100%</td>
<td>0%/0%</td>
<td>0%/0%</td>
<td>2.21</td>
</tr>
<tr>
<td>Escabrosa</td>
<td>100%/100%</td>
<td>0%/0%</td>
<td>0%/0%</td>
<td>1.86</td>
</tr>
<tr>
<td>Horquilla</td>
<td>100%/100%</td>
<td>0%/0%</td>
<td>0%/0%</td>
<td>7.08</td>
</tr>
<tr>
<td>Glance</td>
<td>100%/100%</td>
<td>0%/0%</td>
<td>0%/0%</td>
<td>0.03</td>
</tr>
<tr>
<td>Martin</td>
<td>100%/100%</td>
<td>0%/0%</td>
<td>0%/0%</td>
<td>2.62</td>
</tr>
<tr>
<td>Overburden</td>
<td>100%/33%</td>
<td>0%/67%</td>
<td>0%/0%</td>
<td>0.03</td>
</tr>
<tr>
<td>QMP</td>
<td>88%/22%</td>
<td>12%/78%</td>
<td>0%</td>
<td>1.06</td>
</tr>
<tr>
<td>Scherrer</td>
<td>100%/40%</td>
<td>0%/60%</td>
<td>0%/0%</td>
<td>0.69</td>
</tr>
</tbody>
</table>

The Rosemont mine plan calculates the total number of tons of each type of waste rock to be mined on a yearly basis. This production information can be combined with ABA results to characterize the overall aggregate ABA of all mine rock produced during the mine life by calculating a weighted average of AP, NP, and NNP (Geochemical Solutions 2012). Figure 4-2 graphs the aggregate, weighted average NNP for the Rosemont waste rock for each year of production, and the running average of NNP. The values plotted for annual production reveal the range in NNP, while the running average tracks the overall NNP of all waste rock produced. It is significant that throughout the entire production period, the minimum NNP for any single year is about +70, far in excess of the +20 value that defines unlikely ARD development. More significantly, the running average stays consistently above +200. Therefore, by standard professionally accepted criteria, ARD is not a concern for waste rock produced from the Rosemont pit.

Simulated tailings samples were also subject to ABA testing. The lowest NNP values for any of the tailings samples were for tailings generated from the Earp rock type at 138 T CaCO$_3$/kT, well over the +20 T CaCO$_3$/kT value that defines unlikely ARD development. The highest value was for Horquilla at 539 T CaCO$_3$/kT. Horquilla is expected to comprise 47.5% of the material mined as ore, while Earp represents nearly 17%. Tailings samples have consistently shown no potential for ARD formation, which makes sense since most of the sulfide minerals are removed with the flotation concentrate (Tetra Tech 2010h).
Figure 4-2. Aggregate Weighted Average NPP for Rosemont Waste Rock.

Based on ABA test results, the majority of Rosemont waste rock types are not expected to produce ARD, and hence, kinetic testing (i.e. extensive humidity cell testing) was not warranted. For those rock types that ABA tests indicated are likely or uncertain to generate ARD (see Table 4-5), some HCT work was appropriate.

Sample test periods for HCT are rarely less than 20 weeks, unless leach solutions very rapidly turn acidic and reach a steady chemical composition. There are no specific requirements for total test time (ASTM 2007). Instead, as discussed in ASTM (2007), the test duration is dependent upon the objective of the testing. Rosemont HCT work was conducted for 35 weeks, and was conducted using waste rock samples primarily of andesite and arkose. One sample of the Bolsa Quartzite was selected for testing as it was deemed likely to produce ARD and, unlike all other samples, had no NP. The other samples selected were of uncertain or likely ARD potential.

Other than the Bolsa quartzite sample, all HCT samples produced somewhat alkaline pH values of about 8 standard units (S.U.) (pH less than 7 S.U. is acidic; pH of 7 S.U. is neutral). The Bolsa HCT resulted in acidic conditions, with pH values around 3.4 S.U. By the end of 35 weeks, all HCT tests had reached steady-state conditions for effluent water quality, and the tests were terminated.

Owing to the abundant NP and very slow sulfide mineral oxidation in the Rosemont waste rock samples, the HCT tests would generally have had to run for years to
consume the available NP present and produce low pH solutions for those few samples that have a likely potential to generate ARD. Even waste rock samples that can be characterized as likely to generate ARD contain appreciable NP.

The observation that the rate of NP depletion due to sulfide weathering in HCT tests can be very slow relative to the total amount of NP in the sample is not unique. For example, results are reported for an HCT (ASTM, 2007; Minnesota Department of Natural Resources, unpublished data) with AP = 206 and NP = 14 (from calcium carbonate only, the mineral in limestone). This sample HCT remained at alkaline pH for over two years before depleting calcium carbonate, despite a very high concentration of pyrite (AP). Rosemont waste rock that can be categorized as likely to generate ARD at a minimum still contains NP equal to about 20. Given the very limited amount of Rosemont waste rock that can be considered likely or uncertain to generate ARD (see Figure 4-2), running HCT protocols until all NP is consumed is not warranted and would not provide information that would impact the Project design.

Rosemont HCT tests were run until steady-state chemical quality of the effluent solutions was reached. For almost all HCT tests, steady water quality was reached after ten (10) weeks, but the tests were continued for another 25 weeks (6 months). Ultimately, HCT tests for the proposed Rosemont Project proved more useful for gauging the chemical quality of water contacting waste rock, which is discussed below, than for assessment of ARD generation potential.

4.2.2 Chemical Loading

Water contacting waste rock at Rosemont, or any other mine, can be expected to dissolve chemical constituents. The amount and concentrations of chemicals that are released depends upon geochemical processes and environmental factors. The simplest process occurs when minerals originally in the rock simply dissolve in water, as gypsum (calcium sulfate) dissolves in water. Another process is one in which a mineral originally present in the rock can be altered to form another material that then dissolves in water. An example of this is when pyrite (iron sulfide) oxidizes to release iron, sulfate, and various trace elements (e.g., arsenic), which are then picked up by contact water. This is how ARD is generated. In the absence of oxidation, pyrite is relatively insoluble.

These two basic processes can, and often do, occur simultaneously during testing and natural weathering of mine rock. For the rock types present at Rosemont, calcite (calcium carbonate, limestone) originally present in the rock dissolves on contact with water to produce calcium and alkalinity (in the form of bicarbonate, HCO$_3^-$). Pyrite, if present, oxidizes to produce acidity, iron, and sulfate. At the alkaline pH levels maintained by rapidly dissolving calcite, pyrite oxidizes very slowly (Williamson and Rimstidt 1994, Langmuir 1998). The acidity produced is rapidly neutralized, and the neutral pH causes most metals to precipitate as solids, removing them from the solution. Some of these precipitated solids (particularly iron hydroxides) act to coat any remaining pyrite to some extent, further slowing its oxidation (Humicki and Rimstidt 2003).
In aggregate, reactions like these dictate the chemical quality of water contacting mine materials (e.g., pit walls, waste rock and tailings). For Rosemont rock, the significant excess of limestone (calcite) acts as a strong buffer to maintain the pH of contact water in the range of 7.5 to 8, where many trace elements have limited solubility. Additionally, even if some of the waste rock exhausts its supply of NP and produces low pH water, this water will eventually contact other waste rock materials having abundant NP (see Figure 4-2). Overall, the pH buffering of the abundant calcite at the Rosemont site exerts strong influence on ultimate water chemical quality.

Several tests are routinely used to gauge chemical release from mine rock. Each of these is discussed below.

4.2.2.1 Humidity Cell Tests
HCT can be used as one tool to develop water quality estimates for contact water at mine sites. Using HCT tests to gauge the maximum chemical concentrations in contact water is most valuable when limited or no NP is present, which could be at the beginning of the test, or at some later time when NP is depleted. For sulfide mineral-containing rock with limited pH buffering by NP, chemical loading to contact water is often directly related to the rate at which sulfide minerals oxidize. With increasing amounts of NP, as in the case of Rosemont waste rock, the chemical products of any sulfide mineral (pyrite) oxidation are tempered by the dominant alkalinity maintained by the limestone, which prevents significant metal loading.

4.2.2.2 Synthetic Precipitation Leaching Procedure
In cases where alkaline pH is buffered, HCT may not offer any substantial advantage in estimating chemical quality of contact water. For the Rosemont Project, this was recognized relatively early during geochemical characterization (Tetra Tech 2007). Although HCTs were completed on sulfide mineral-containing waste rock that had been deemed likely to uncertain to generate ARD, Synthetic Precipitation Leaching Procedure (SPLP) was chosen for assessing contact water quality. Support for this choice is presented below. SPLP is also the method of choice for assessing contact water used by the Arizona Department of Environmental Quality, as described in Appendix B of the Arizona Mining Best Available Demonstrated Control Technology (BADCT) Guidance Manual (2004).

In SPLP testing, test material is combined with water in a closed container, agitated for 18 (+/- 2) hours, and then the solution is analyzed for a range of dissolved chemical constituents. In cases where the sulfide mineral oxidation rate is not driving ultimate water quality and pH buffering is substantial, SPLP offers a useful approach.

In field settings, the proportion of water contacting rock (water-rock ratio) is often small, with the proportion being at most one-to-one, and often smaller. SPLP, in contrast, combines 20 parts water with 1 part rock. It has been suggested that the chemical concentrations reported for the SPLP test should be increased to effectively decrease the water-rock ratio to a value more consistent with common
field conditions. This makes sense when the test is dissolving highly soluble materials. An example of this scenario is table salt mixed in quartz sand. The more of the solid used in the SPLP-type test, the more salt dissolves and the higher the resulting concentrations of sodium and chloride in solution. For materials with limited solubility, like the Rosemont rock types, however, adjusting reported SPLP concentrations would be inappropriate. An example here is calcium carbonate, which dissolves rapidly, but only to a limited extent. Changing the water-rock ratio will have limited or no effect on solution concentrations.

4.2.2.3 Meteoric Water Mobility Procedure

The Meteoric Water Mobility Procedure (MWMP) has similarities to both HCT and SPLP. Like HCT, the MWMP is conducted in a column, but only provides for a single application of leach water, like the SPLP. The water that percolates through the rock sample is collected and chemically analyzed. There is only one flush of water and no weekly rinsing occurs as in the HCT. Unlike SPLP, a given mass of water contacts an equal mass of rock, so that the water-rock ratio is 1 compared to 20 for SPLP. The ratio is usually about 1 to 1.5 for HCT tests.

The MWMP was originally developed to test ROM material such as waste rock in field settings. It dictates that 5 kg of solid be used for testing, compared to 1-1.5 kg in HCT tests and 0.1 kg in SPLP. This comparatively large amount of material is a strength of the MWMP; it uses a sample of uncrushed/unsieved material that includes a wide range of grain sizes. Rock samples are crushed for use in the SPLP and HCT tests. MWMP tests were conducted on 20 Rosemont mine rock samples, but because of limitations on the amount of sample material available as well as the need to meet BADCT requirements for testing, the use of MWMP was limited in comparison to SPLP (60 tests) and ABA (226 tests).

4.2.2.4 Chemical Loading Summary

Many samples of Rosemont waste rock have been tested to characterize the potential chemical quality of contact water; HCT, SPLP, and MWMP have all been used. Table 4-6 reports the number of samples of each rock type tested, by each method, as well as the percentage of total waste rock for each rock type (Tetra Tech 2010d, 2010f).
Table 4-6. Number of Rosemont Waste Rock Samples Submitted for Leach and ABA Testing.

<table>
<thead>
<tr>
<th>Rock Type</th>
<th>Tons of Material</th>
<th>Percent of Material</th>
<th>No. ABA Tests</th>
<th>No. SPLP Tests</th>
<th>No. MWMP Tests</th>
<th>No. HCT Tests</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arkose</td>
<td>546,336,000</td>
<td>44.38</td>
<td>55</td>
<td>8</td>
<td>8</td>
<td>4</td>
</tr>
<tr>
<td>Tertiary</td>
<td>141,227,000</td>
<td>11.47</td>
<td>5</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Abrigo</td>
<td>113,815,000</td>
<td>9.24</td>
<td>6</td>
<td>5</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Horquilla</td>
<td>87,141,000</td>
<td>7.08</td>
<td>26</td>
<td>8</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Glance</td>
<td>80,841,000</td>
<td>6.57</td>
<td>4</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Andesite</td>
<td>49,118,000</td>
<td>3.99</td>
<td>38</td>
<td>4</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>Concha</td>
<td>34,107,000</td>
<td>2.77</td>
<td>6</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Martin</td>
<td>32,304,000</td>
<td>2.62</td>
<td>7</td>
<td>4</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Earp</td>
<td>29,577,000</td>
<td>2.40</td>
<td>14</td>
<td>6</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Epitaph</td>
<td>27,150,000</td>
<td>2.21</td>
<td>16</td>
<td>6</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Escabrosa</td>
<td>22,859,000</td>
<td>1.86</td>
<td>10</td>
<td>4</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Bolsa</td>
<td>23,447,000</td>
<td>1.90</td>
<td>13</td>
<td>6</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Colina</td>
<td>16,145,000</td>
<td>1.31</td>
<td>11</td>
<td>4</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Quartz</td>
<td>13,047,000</td>
<td>1.06</td>
<td>9</td>
<td>2</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Scherrer</td>
<td>8,542,000</td>
<td>0.69</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Pre-</td>
<td>4,203,000</td>
<td>0.34</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Undefined</td>
<td>941,000</td>
<td>0.08</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Overburden</td>
<td>391,000</td>
<td>0.03</td>
<td>6</td>
<td>2</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td><strong>Total Amounts</strong></td>
<td><strong>1,231,173,000</strong></td>
<td><strong>100</strong></td>
<td><strong>226</strong></td>
<td><strong>60</strong></td>
<td><strong>20</strong></td>
<td></td>
</tr>
</tbody>
</table>

Rosemont data for tests of the same waste rock type with SPLP, HCT, and MWMP methods are available, which provides an opportunity to compare the results obtained by each method for a range of water to rock ratios. When average test results are compared for each rock type tested by all three methods, there is no significant difference. In other words, despite having three different water-rock ratios, the tests produced comparable solute loadings, suggesting that pH buffering by Rosemont mine rock plays a strong role in regulating the chemical composition of contact water regardless of dilution. Where potential sulfide mineral oxidation and ARD concerns exist, HCT is commonly regarded as most suitable to gauge contact water quality from the waste rock. However, results from SPLP testing are consistent with longer-term HCT results for Rosemont waste rock samples tested. Therefore, SPLP is an appropriate method of estimating the chemical loading of contact water for rock types encountered at the Project.
SPLP, supplemented by relevant HCT and MWMP data, was selected to estimate the chemical quality of water after contact with Rosemont waste rock. Owing to the pH buffering effects of the high NP Rosemont mine rock, the rates of sulfide mineral oxidation are relatively muted and the SPLP test was selected early on in the program for characterizing contact water. Although the water-rock ratio of the SPLP test is high and may be inconsistent with some field conditions, the effect of this water-rock ratio on the resulting chemical quality of the contact water was minimal for the high NP Rosemont waste rock.

Average HCT results, along with average SPLP and MWMP results for arkose and andesite waste rock types are presented in Figures 4-3 and 4-4 (Tetra Tech 2010g). These figures were not included in the text of the DEIS, but were available in the reference material. The figures include key major and trace elements including: Ca, Mg, SO\textsubscript{4}, As, Cu, Se, and Mn. Overall, the SPLP results are consistent with long-term HCT results, or higher in concentration. The applicability of SPLP testing data to gauge contact water quality for Rosemont waste rock is unusual, and is related to the uncommon style of the deposit. In Arizona, copper deposits are predominantly hosted in so-called crystalline rock. These deposits are associated with volcanic, granite-like rock types that are typically a silicate-based mineralogy. They have very limited calcium carbonate associated with them. By contrast, the Rosemont deposit is hosted in sedimentary limestone (calcium carbonate). The style of mineralization at Rosemont is very uncommon in Arizona, and, because the limestone host rock provides a much more benign water chemistry setting than does silicate-based host rock, direct comparison with previously developed mineral deposits is difficult. The Rosemont conditions are much more rapidly neutralizing and, therefore, naturally protective of water quality than conditions at many other mine sites.
Figure 4-3. Comparison of HCT, SPLP, and MWMP Results For Arkose.
Figure 4-4. Comparison of HCT, SPLP, and MWMP Results For Andesite.
4.3 Predicted Environmental Water Quality Impacts

4.3.1 Pit Water

The Open Pit was described in the Project Setting section in some detail, including the imperative that inflows to the pit from unimpacted surface runoff and groundwater are pumped out to dewater the pit during mining. At the end of mining, dewatering will stop and the local groundwater will re-establish a post-mining steady-state condition. A pit lake will form at a rate that is determined by the balance of water inputs from groundwater and rain, and water removed through evaporation. As described in Tetra Tech (2010d), Tetra Tech (2010f), and M&A (2010), groundwater inflow and evaporation are the dominant components affecting the formation of the Pit Lake. The relative magnitude of other contributions of water to the Pit Lake, either directly to the lake surface or running off Pit walls, is very small. At its ultimate condition, the lake surface is estimated at a maximum elevation of 4279 feet amsl (Tetra Tech 2010e).

Groundwater in the vicinity of the pit will flow towards the pit from all directions and will not re-enter the regional aquifer. Water will only be removed from the Pit Lake by evaporation after dewatering has ended. This condition is referred to as a terminal sink or by ADEQ in their APP permit program as a hydraulic sink.

As a hydraulic sink, the Pit Lake will draw groundwater towards it from all directions, but not beyond a limited area. This area from which groundwater is drawn towards the pit is called the capture zone. Any solutions infiltrating the ground surface and reaching groundwater within this capture zone will flow toward the Pit Lake, where the chemical load will be captured. The estimated ultimate groundwater capture zone 1,000 years after mining ceases is illustrated in Figures 6-10 and 6-14 (M&A 2010, Tetra Tech 2010e, 2010f). The Tetra Tech model (Tetra Tech 2010e) predicts that some, but not all, of the facilities are within the ultimate capture zone (Appendix Figure 6-14). The capture zone predicted in the M&A model increases over time to encompass most of the facilities (Figure 6-10). A capture zone that encompasses all of the Project facilities would provide additional protection for regional groundwater.

As the Pit Lake forms, various chemical constituents dissolved from pit walls by groundwater and conveyed by unimpacted surface runoff will enter the pit. Because the groundwater flow inputs are high compared to the very limited inputs from rain, concentration of chemicals naturally in the groundwater is responsible for the majority of the chemical loading in the Pit Lake. Although the chemicals associated with flow to the pit do not leave, water is removed from the Pit Lake by evaporation.

Over time, as chemical constituents in groundwater continue to report to the Pit Lake and water evaporates, concentrations of those chemical constituents will increase. This process is called evapo-concentration. Major constituents such as calcium, bicarbonate, and sulfate will increase to a maximum, or saturation, limit. When the saturation limit for calcite (calcium carbonate, CaCO$_3$) or gypsum (calcium sulfate, CaSO$_4$·2H$_2$O) is reached, their concentrations will no longer increase because
the minerals begin to precipitate out of solution as solids. Other trace elements may or may not eventually reach a limit of saturation. Calculations estimating the evolution of Pit Lake water quality predict eventual precipitation of calcite and gypsum (Tetra Tech 2010d). Arsenic removal from Pit Lake water through scavenging by precipitating iron oxides was also simulated in the modeling results. Other trace constituents did not reach saturation or precipitate through scavenging.

As an anticipated hydraulic sink, the Pit Lake is not expected to result in any negative environmental consequences. Instead, the terminal nature of the Pit Lake provides an additional, large-scale measure for protecting the regional aquifer (although groundwater is not expected to be impacted due to very low seepage from facilities). Because the surface of the Pit Lake will be constantly exposed to the atmosphere, calculations of the estimated chemical evolution of Pit Lake water quality assumed the top of the lake to be fully oxidized. Although short-term variations in chemical quality within the Pit Lake may occur due to turnover (reversal of vertical gradients), oxidation at the surface of the lake is anticipated to dominate the long-term water quality conditions.

It is important to note that predictive modeling of water quality for trace metals is inherently difficult and uncertain owing to their low concentrations. Because of this, it is inappropriate to directly compare trace constituent concentrations with established numerical standards, although Rosemont has used the numerical standards to provide context for the results in prior sections. Rather, the significant observation is that most constituent concentrations are anticipated to be quite low. Considerations related to excessive loading are not warranted at this stage of development, but monitoring Pit Lake water quantity and quality, during operations and at the end of operations prior to closure, will be an important part of site-wide monitoring. Those monitoring results can then be compared to the model described above. There is no indication from testing, modeling or other site investigation that the model analysis could be incorrect, but the monitoring data will provide some of the detail required for the final closure plan that will be presented to ADEQ under the APP.

4.3.2 Waste Rock Seepage and Runoff

Potential water quality impacts from the Waste Rock Storage Area could occur as a result of seepage or runoff. Both of these potential pathways were analyzed as described below.

4.3.2.1 Waste Rock Seepage

As previously described, unsaturated flow modeling of the Waste Rock Storage Area predicted no seepage to groundwater. The modeling did indicate that temporary, shallow infiltration into the facility is possible as the result of significant storm events. However, average climate conditions are anticipated to result in withdrawal of this infiltration through the effects of evaporation and transpiration by plants in the arid periods between sporadic storm events. This overall negative water
balance for the Waste Rock Storage Area provides the initial layer of protection against groundwater impacts.

While infiltration modeling predicts that seepage from the Waste Rock Storage Area will not occur, the geochemical testing results indicate that concentrations of metals in any seepage that does occur will be low and will comply with groundwater quality standards. Therefore, even if seepage were to intersect groundwater, negative impacts to groundwater outside the area covered by the APP are highly unlikely. In addition, the Waste Rock Storage Area will lie within the area of steep groundwater gradients produced by dewatering of the Open Pit during the operational period, and within the capture zone that is expected to be well-established at closure. Any seepage that occurs within this zone will report to the Pit Lake and will not affect the regional groundwater system. Groundwater quality impacts are not anticipated.

4.3.2.2 Waste Rock Runoff

As indicated by unsaturated flow modeling, single large or multiple day storm events will result in nearly 90% of the storm precipitation being shed from the Waste Rock Storage Area as surface runoff (see Tables 5.2 and 5.3 of Tetra Tech 2012). This stormwater will have very limited contact time with waste rock, and its chemical composition may reasonably be expected to approximate SPLP testing results for waste rock with a low sulfide mineral content. Waste rock SPLP testing data for a range of waste rock types were compared against the surface water quality standards that apply in the washes directly downstream from the Project. The SPLP effluent was below all the water quality standards that apply to Barrel Canyon wash directly below the Project. Only effluent associated with the quartz-monzonite porphyry (QMP) type waste rock had concentrations that exceeded any of the water quality standards applicable further downstream. In this instance, the warm-water aquatic and wildlife standard applicable to the OAW reach of Davidson Canyon was exceeded for copper (Tetra Tech 2010c). However, the anticipated volume of QMP waste rock comprises just over 1% of the waste rock that will be generated by the mine, and placement of this type of waste rock can be managed to limit exposure to surface run off. Moreover, the warm-water aquatic and wildlife standard applies only in the OAW, over 10 miles downstream from the potential discharge point. Therefore, the runoff from the Waste Rock Storage Area is not expected to increase copper concentrations in Davidson Canyon and runoff is expected to be in compliance with surface water quality standards. As discussed in section 3, runoff will be regulated under an AZPDES General permit, which includes development of a stormwater pollution prevention plan and implementation of BMPs.

4.3.2.3 Waste Rock Summary

Both the infiltration modeling results and geochemical testing results indicate that the environmental consequences of water contacting the Waste Rock Storage Facility will be low. Models have determined that there will be a negative water balance, even in response to high rain events, which indicates that seepage to
groundwater is not anticipated. In the event that seepage to groundwater was to occur, the geochemical testing has shown that results will be in compliance with the APP for protection of groundwater. Further, the Pit Lake creates a capture zone which encompasses the Waste Rock Storage Area and provides additional protection.

Finally, predicted water quality from stormwater contacting the waste rock meets the appropriate surface water quality standards in all but one sample. Appropriate waste rock management and selective placement will ensure that Rosemont does not impact the water quality downstream of the Project.

4.3.3 Dry Stack Tailings

As with the Waste Rock Storage Area, there are two sources of water associated with the Dry Stack Tailings Facility that could result in impacts to water resources: run-off and seepage. These impacts are discussed in the following sections.

4.3.3.1 Dry Stack Tailings Seepage

Potential impacts due to seepage were evaluated by assessing the potential for seepage to occur, estimating the chemical quality of such seepage, and analyzing the potential for such seepage to reach regional groundwater.

Unlike the Waste Rock Storage Area, the Dry Stack Tailings Facility is constructed from material that contains moisture in excess of its field capacity. As such, it will drain under the effects of gravity from its placed moisture content to a lower moisture content. Unsaturated flow modeling of the Dry Stack Tailings Facility indicates that the solids will drain from a placed moisture content of about 18% to a field capacity of about 11%. The seepage that results will reach a maximum initial flow of about 8.4 gallons per minute for the entire facility, and will gradually decrease, ceasing in about 500 years.

Modeling calculations indicate that infiltration of rain into the Dry Stack Tailings Facility will be negligible, although seepage rates can increase temporarily in response to storm events. The negligible infiltration is a function of the fine-grained nature of the crushed and ground tailings material and the compaction that will occur with placement and facility construction. In addition, the 500-year drain-down estimate suggests that any rain that does in fact infiltrate will not appear as seepage for hundreds of years.

Like the Waste Rock Storage Area, most of the Dry Stack Tailings Facility will lie above the ultimate groundwater capture zone predicted by the M&A model (see Figure 6-10). Within this zone any seepage that may occur would ultimately flow via groundwater to the open pit. If the capture zone does not encompass the entire facility it is possible that the seepage will reach the groundwater and flow down gradient.

Water entrained in the dry stack tailings that comprises drain-down has been chemically analyzed and modeled (Table 4-7) (Tetra Tech, 2007a, Tetra Tech 2012).
Modeling and analytical results indicate that seepage constituent concentrations will be below the AWQS for regulated constituents (ADEQ 2008). This makes sense since flotation separates the vast majority of the sulfide-containing minerals and removes them from the tailings, leaving, in the case of Rosemont, a tailings product that is relatively free of minerals that have the potential to generate ARD.

Table 4-7. Tailings Drain-Down Water Modeled and Analysis

<table>
<thead>
<tr>
<th>Constituent</th>
<th>2007 Entrained Tailings Water Analyses</th>
<th>2010 Tailings SPLP Analyses Range</th>
<th>2012 Entrained Tailings Water Analyses</th>
<th>2010 PHREEQC Modeled Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH (standard units)</td>
<td>--</td>
<td>7.85 - 9.48</td>
<td>NA</td>
<td>5.87</td>
</tr>
<tr>
<td>Alkalinity, total (as CaCO₃)</td>
<td>--</td>
<td>NA</td>
<td>8.3 ³</td>
<td>7.4 ³ 0.206</td>
</tr>
<tr>
<td>TDS</td>
<td>--</td>
<td>NA</td>
<td>NA</td>
<td>863 810</td>
</tr>
<tr>
<td>Aluminum</td>
<td>--</td>
<td>&lt; 0.08</td>
<td>&lt; 0.08 - 0.7</td>
<td>&lt; 0.08 ND</td>
</tr>
<tr>
<td>Antimony</td>
<td>0.006</td>
<td>0.00351</td>
<td>&lt; 0.005 - 0.006</td>
<td>&lt; 0.003 ND</td>
</tr>
<tr>
<td>Arsenic</td>
<td>0.05</td>
<td>0.0071</td>
<td>&lt; 0.02 ⁶</td>
<td>&lt; 0.025 ND</td>
</tr>
<tr>
<td>Barium</td>
<td>2.0</td>
<td>0.0176</td>
<td>0.005 - 0.05</td>
<td>0.0248 0.017</td>
</tr>
<tr>
<td>Beryllium</td>
<td>0.004</td>
<td>NA</td>
<td>&lt; 0.002 ⁶</td>
<td>NA NA</td>
</tr>
<tr>
<td>Calcium</td>
<td>--</td>
<td>22.8</td>
<td>9.8 - 193</td>
<td>277 188</td>
</tr>
<tr>
<td>Chloride</td>
<td>--</td>
<td>1.5</td>
<td>&lt; 0.200 - 0.628</td>
<td>14.8 3.98</td>
</tr>
<tr>
<td>Cadmium</td>
<td>0.005</td>
<td>&lt; 0.002</td>
<td>&lt; 0.002 ⁶</td>
<td>&lt; 0.002 ND</td>
</tr>
<tr>
<td>Chromium, total</td>
<td>0.10</td>
<td>NA</td>
<td>&lt; 0.006 ⁶</td>
<td>NA NA</td>
</tr>
<tr>
<td>Copper</td>
<td>--</td>
<td>&lt; 0.01</td>
<td>&lt; 0.01 - 0.17</td>
<td>&lt; 0.01 ND</td>
</tr>
<tr>
<td>Fluoride</td>
<td>4.0</td>
<td>1.09</td>
<td>0.63 - 1.12</td>
<td>0.79 2.37</td>
</tr>
<tr>
<td>Iron</td>
<td>--</td>
<td>&lt; 0.06</td>
<td>&lt; 0.06 - 1.2</td>
<td>&lt; 0.06 ND</td>
</tr>
<tr>
<td>Lead</td>
<td>0.5</td>
<td>&lt; 0.0075</td>
<td>&lt; 0.0075 ⁶</td>
<td>0.0094 ND</td>
</tr>
<tr>
<td>Magnesium</td>
<td>--</td>
<td>1.49</td>
<td>0.2 - 8.5</td>
<td>5.67 19.61</td>
</tr>
<tr>
<td>Manganese</td>
<td>--</td>
<td>0.017</td>
<td>&lt; 0.004 - 0.10</td>
<td>0.0102 ND</td>
</tr>
<tr>
<td>Mercury</td>
<td>0.002</td>
<td>&lt; 0.0002</td>
<td>&lt; 0.0002 - 0.0007</td>
<td>&lt; 0.0002 ND</td>
</tr>
<tr>
<td>Molybdenum</td>
<td>--</td>
<td>NA</td>
<td>0.03 - 0.18</td>
<td>0.072 0.076</td>
</tr>
<tr>
<td>Nickel</td>
<td>0.10</td>
<td>&lt; 0.01</td>
<td>&lt; 0.01 ⁶</td>
<td>&lt; 0.01 ND</td>
</tr>
<tr>
<td>Nitrate</td>
<td>10.0</td>
<td>NA</td>
<td>NA</td>
<td>NA NA</td>
</tr>
<tr>
<td>Nitrate + Nitrite</td>
<td>10.0</td>
<td>NA</td>
<td>&lt; 0.10 - 0.120</td>
<td>0.219 0.001</td>
</tr>
<tr>
<td>Potassium</td>
<td>--</td>
<td>3.24</td>
<td>0.84 - 1.97</td>
<td>15.2 9.35</td>
</tr>
<tr>
<td>Selenium</td>
<td>0.05</td>
<td>&lt; 0.04</td>
<td>&lt; 0.04 ⁵</td>
<td>&lt; 0.04 0.006</td>
</tr>
<tr>
<td>Silver</td>
<td>--</td>
<td>&lt; 0.005</td>
<td>&lt; 0.005 ⁶</td>
<td>&lt; 0.005 ND</td>
</tr>
<tr>
<td>Sodium</td>
<td>--</td>
<td>10.3</td>
<td>1.4 - 4.1</td>
<td>9.83 26.5</td>
</tr>
<tr>
<td>Sulfate</td>
<td>--</td>
<td>50.5</td>
<td>6.88 - 43.2</td>
<td>591 ND</td>
</tr>
<tr>
<td>Sulfide</td>
<td>--</td>
<td>NA</td>
<td>NA</td>
<td>NA NA</td>
</tr>
<tr>
<td>Sulfur</td>
<td>--</td>
<td>NA</td>
<td>&lt; 0.001</td>
<td>559</td>
</tr>
<tr>
<td>Thallium</td>
<td>0.002</td>
<td>&lt; 0.002</td>
<td>&lt; 0.001 - 0.02</td>
<td>&lt; 0.01 ND</td>
</tr>
<tr>
<td>Zinc</td>
<td>--</td>
<td>&lt; 0.01</td>
<td>&lt; 0.01 - 0.05</td>
<td>NA ND</td>
</tr>
<tr>
<td>Uranium</td>
<td>--</td>
<td>NA</td>
<td>&lt; 0.001 - 0.002</td>
<td>NA NA</td>
</tr>
</tbody>
</table>

All units are in mg/L (milligrams per liter) unless otherwise noted.

¹: Tailings sample prepared and analyzed in 2007; results discussed in detail in Tetra Tech (2007a).
²: Range of SPLP analytical results for seven (7) tailing samples prepared and analyzed by SVL Analytical in 2010/2011.
³: One tailing sample analyzed for total alkalinity; remaining six samples were not analyzed for alkalinity.
⁴: 8-12 Year composite tailing sample submitted to SVL Analytical on April 5, 2012.
⁵: PHREEQC Model results discussed and presented in detail in Tetra Tech (2010a).
⁶: Results for all seven tailing samples were reported below this laboratory detection limit.
4.3.3.2 Dry Stack Facility Runoff

The Dry Stack Tailings Facility will be incrementally encapsulated by waste rock as it is constructed. Therefore, there are very limited opportunities for stormwater to come into contact with tailings material.

Rainfall directly contacting dry stack tailings and reporting as runoff to stormwater control structures will be allowed to evaporate or will be pumped to the process circuit. A detailed stormwater management plan for the Dry Stack Tailings Facility was developed by AMEC (2010) for both operational and closure scenarios. In addition to controlling runoff on the tailings surface during operations, diversion channels were specified in order to limit run-on from up-gradient areas from reaching the tailings.

Since the outer surface of the Dry Stack Tailings facility, the perimeter buttress, will be comprised of waste rock, expected stormwater quality from these areas would be the same as for the Waste Rock Storage Area. However, should stormwater runoff from the tailings occur, the tailings SPLP testing data, which is representative of limited water contact time, provides a reasonable characterization of the expected contact water quality. Compared to State of Arizona surface water quality standards, the results of the tailing SPLP testing met all standards applicable to washes directly downstream of the Project, and to the Davidson Canyon OAW reach (Tetra Tech 2010c). As with the Waste Rock Storage Area, concurrent reclamation and Best Management Practices (BMPs) required under the stormwater management plan will further control sediments that could impact water quality.

4.3.3.3 Dry Stack Summary

At the Dry Stack Tailings Facility, models have determined there will limited infiltration even in response to heavy rain events, which indicates that drain-down water from the facility will be the main component of release to the environment. In the event that seepage intercepted groundwater, the geochemical testing has shown that results will be in compliance with the APP for protection of groundwater. Further, the capture zone created by the terminal Pit Lake will underlie much of the tailings facility and will provide additional protection.

Finally, because the dry stack will be encapsulated in waste rock, any stormwater that could runoff will not contact tailings material. The predicted water quality from stormwater contacting the waste rock meets the appropriate surface water quality standards in all but one sample. The use of selected materials for the perimeter buttress will ensure that the Project does not impact water quality downstream of the Project.
4.3.4 Heap Leach Seepage and Runoff

As discussed in Section 3.1.4, during the operating period all runoff and seepage from the Heap Leach Facility will be collected and processed to extract the valuable copper, and remaining solutions will be recycled. At the end of leaching, the solution within the heap leach will continue to drain for an estimated three years and the drain-down solution will be routed back into the mine process circuit for copper recovery, neutralization and reuse. After the three-year drain-down period, seepage flow rates are expected to be minimal. However, if seepage is not minimal, Rosemont is prepared to convert the PLS and Heap Leach Stormwater Ponds into a passive biological treatment system.

The quality of seepage from the heap was estimated based on analysis of solutions produced during metallurgical testing of the leaching process. Some of the parameters in the seepage are predicted to exceed AWQS (see Table 4-8). Rosemont has determined that a biological treatment system will be effective in reducing the concentrations of these parameters to within standards (Tetra Tech 2011). The biological treatment system will establish chemically reducing conditions utilizing sulfate-reducing bacteria. Organic substrates will be added to the pond to provide a food source for these bacteria (e.g., *desulfovibrio desulfuricans*), which occur pervasively in the environment. While consuming supplied organic carbon they also reduce sulfate to sulfide. Sulfide sulfur forms a relatively insoluble metal compound, which removes the metal and sulfide from solution. Calculations have been performed using the geochemical computer code PHREEQC (Parkhurst and Appelo 1999) to estimate the potential water quality that results when drain-down from the spent ore pile is treated by this process. The estimated water quality is shown in Table 4-8. Note that the concentrations reported in Table 4-8 represent computed, theoretical concentrations, not the concentrations that would necessarily be reported by analytical laboratory services. Laboratory reporting is limited to the method detection limit for the testing method employed.

If drain-down is still present three years following the cessation of leaching, this biological treatment system will likely be required to meet applicable water quality standards. The treatment system will be operated until water quality meets applicable standards.
Table 4-8. Simulated Water Quality of Treated and Untreated Heap Leach Drain-down Water Quality.

<table>
<thead>
<tr>
<th>Constituent</th>
<th>Water Quality Standard</th>
<th>Heap Leachate</th>
<th>Passive Limestone Drain</th>
<th>Passive Biological Treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>3.04</td>
<td>6.59</td>
<td>6.31</td>
<td></td>
</tr>
<tr>
<td>Pe</td>
<td>17.6</td>
<td>14.0</td>
<td>-3.27</td>
<td></td>
</tr>
<tr>
<td>Total Alkalinity (mg/L as CaCO₃)</td>
<td>-173</td>
<td>497</td>
<td>1,905</td>
<td></td>
</tr>
<tr>
<td>Total Dissolved Solids (mg/L)</td>
<td>2,848</td>
<td>2,828</td>
<td>1,717</td>
<td></td>
</tr>
<tr>
<td>Silver (mg/L)</td>
<td>0.005</td>
<td>0.005</td>
<td>0.005</td>
<td></td>
</tr>
<tr>
<td>Aluminum (mg/L)</td>
<td>57.7</td>
<td>0.0115</td>
<td>0.127</td>
<td></td>
</tr>
<tr>
<td>Arsenic (mg/L)</td>
<td>0.01</td>
<td>0.003</td>
<td>0.003</td>
<td></td>
</tr>
<tr>
<td>Barium (mg/L)</td>
<td>2</td>
<td>0.013</td>
<td>0.011</td>
<td></td>
</tr>
<tr>
<td>Calcium (mg/L)</td>
<td>442</td>
<td>649</td>
<td>237</td>
<td></td>
</tr>
<tr>
<td>Chloride (mg/L)</td>
<td>5.980</td>
<td>5.981</td>
<td>5.975</td>
<td></td>
</tr>
<tr>
<td>Cadmium (mg/L)</td>
<td>0.005</td>
<td>0.307</td>
<td>0.305</td>
<td></td>
</tr>
<tr>
<td>Chromium, total (mg/L)</td>
<td>0.1</td>
<td>0.034</td>
<td>0.034</td>
<td></td>
</tr>
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In the event of unanticipated under-performance of the treatment system, a secondary level of protection will be available. A riser system consisting of an access well will be constructed as the heap is encapsulated. The riser will allow solutions to be pumped from the treatment pond. These solutions may be routed back to the process circuit. Alternatively, the pumped solutions may be routed to conventional water treatment systems for treatment prior to release. Though additional treatment is unlikely to be necessary, due to minimal flows from the heap and the expected effectiveness of biological treatment, Rosemont is committed to
constructing a treatment system to treat seepage from the Heap Leach Facility if required to protect groundwater quality. Finally, the Heap Leach Facility will lie within the capture zone that will form adjacent to the Open Pit hydraulic sink. As the capture zone develops, any seepage will report to the Open Pit.

In summary, impacts to groundwater quality from the Heap Leach are not expected because: (1) minimal seepage is expected after drain-down, (2) effective treatment of residual drain-down solutions in a biological treatment system will be provided if required, and (3) an access riser will be provided so that additional water treatment can be provided in the event that biological treatment is less effective than anticipated. In addition, because the Heap Leach Facility will be encapsulated, impacts to surface water resources are not anticipated.

4.4 Summary

The arid climate of the Project site, combined with the nature of the rock types (an abundance of limestone and rarity of sulfide minerals, such as pyrite), contributes to the protection of both surface water and groundwater resources in the Project Area. The impact of the Project on surface water and groundwater quality is expected to be minimal.

Infiltration estimates based on an industry standard and commonly accepted computer model (VADOSE/W) predict that the Waste Rock Storage Area and the Heap Leach Facility will produce minimal, if any, seepage to groundwater. Indeed, when the relatively consolidated materials are combined with the development of a viable plant community on reclaimed surfaces, these facilities are estimated to lose water during typical climatic conditions and not develop seepage due to precipitation. Some water is estimated to infiltrate the surface during short, intense storms, or multi-day precipitation events, but this water is expected to be removed through evapotranspiration when typical conditions return.

Although rates of evaporation are high, during large short term or multi-day storm events surface water runoff is anticipated and could be as high as 90% of the precipitation. The resulting water quality after contact with the Waste Rock is estimated by SPLP testing to meet applicable surface water quality standards. This finding is relevant to both the Waste Rock Storage Area and the Dry Stack Tailings Facility, because the exterior buttresses at the Dry Stack Tailings Facility will be constructed of waste rock.

The Dry Stack Tailings Facility is anticipated to slowly drain down as the tailings transition from the placed moisture content to a moisture content near the material’s field capacity. The maximum rate of drain-down is estimated at 8.4 gallons per minute, diminishing with time until drain down is complete in an estimated 500 years. Even though there is seepage expected from the Dry Stack Tailings Facility during active mining, the expected flow rate is very small and the expected quality will be below AWQS standards for regulated constituents.
Laboratory testing of mine waste rock and tailings by professionally accepted methodologies has documented material characteristics that make the majority of the waste rock unlikely to generate ARD. Although less than 4% of the expected mine rock does have the potential to generate ARD, in the aggregate the waste rock at the Project is expected to be overwhelmingly acid consuming. Owing to the abundance of acid neutralizing material, and its planned placement in the Project Landform, any mobile trace metals present in waste rock will be attenuated by adsorption onto solid iron oxides. The overall result is water quality that is expected to consistently meet regulatory standards for groundwater and surface water protection.

The Project’s single landform, Dry Stack Tailing Facility, and stormwater management elements are designed to minimize the formation of potentially contaminated water up front. Additional mitigation measures (biological water treatment and more active treatment) will be implemented to manage seepage if monitoring indicates the need.

### 4.5 References


5 SURFACE WATER RESOURCES

5.1 Introduction

This section focuses on issues of surface water management, erosion, and sedimentation for the Rosemont Project, particularly with respect to the water resources in the broader Study Area surrounding the Project. The intent of this section is to present an overview of the surface water hydrology and fluvial geomorphology in the Study Area prior to the opening of, and subsequent to the completion of, the Project, and to provide substantial detail about the assessment, planning, and evaluation effort invested in determining the changes to surface water behavior that may result due to the Project. Technical analyses quantifying stormwater peak flows, annual total volume of runoff, and annual watershed sediment yield were also performed for alternatives presented in the DEIS.

Construction of the Project facilities will impact surface water and sediment mobilization in the Barrel Canyon drainage. As discussed in the previous section, stormwater is not anticipated to exceed any AWQS for constituents due to the short contact time with waste materials and the neutralizing characteristics of the majority of the waste rock. However, management practices are necessary to reduce the suspended solids (particulate) load of the stormwater. By law, uncontrolled releases are not permitted for any construction activity that includes ground disturbance (See Section 3.3 for stormwater regulatory requirements). The Project has been designed so that all applicable regulatory surface water standards will be met, and regulatory permit conditions will require that Rosemont monitor and report surface water data at the downstream perimeter of the Project site. That regulatory location will be the site of the Compliance Point Dam, a structure designed to facilitate the measurement of stormwater quality leaving the site (Appendix Figure 5-1).

To protect downstream water quality, runoff from precipitation that has contacted any disturbance associated with the Project will be at least detained to reduce the suspended solids in the water that is discharged, and runoff from some Project areas will be completely retained. The following management practices will be used to accomplish this goal:

- **Detention:** Delays the release of surface water runoff, reducing the peak flow rate (discharge) that moves downstream as a result of the storm event. Detention reduces the total volume of water that moves downstream due to increased infiltration. Detention also prevents runoff from proceeding downstream with flow velocities high enough to transport the excessive sediment load that is acquired when runoff contacts disturbed ground.

- **Retention:** Prevents the release of surface water runoff, reducing both the peak flow rate and the total volume of water moving downstream. Runoff from precipitation that has contacted process water including mine drainage,
and runoff from mine areas like the Sulfide Ore Processing Facilities or Heap Leaching Facilities will be completely retained on site.

### 5.2 Hydro-Meteorological Conditions

Surface water hydrology in southern Arizona is driven by precipitation events. Streams in the Study Area typically flow only in response to precipitation events. There are three (3) distinct types of precipitation events that occur in Arizona, and these produce stormwater runoff to varying degrees (ADWR 1985).

- **Convective Thunderstorms**

  Normally occurring in July and August, convective thunderstorms typically occur when moisture that moves into Arizona from the Gulf of Mexico combines with heated air moving in response to the mountainous terrain, producing intense, short-lived precipitation events. Often these storms are accompanied by thunder, lightning, and strong, gusty winds. These convective thunderstorms typically do not exceed one (1) hour, but they may last for up to three (3) hours and on occasion have been known to continue for as long as six (6) hours. Maximum areal coverage for individual storm cells is in the range of 90 to 100 square miles, but the area experiencing the maximum precipitation intensity (sometimes exceeding ten (10) inches per hour) is usually less than a two (2) square-mile central core. Historically, these types of storms have had major impacts upon drainage catchments of less than 25 square miles in areal extent (ADWR 1985).

- **General Summer Storms**

  Normally occurring in August and September, general summer storms typically originate as tropical storms (dissipating cyclonic events) off the west coast of Mexico, and bring damaging winds and flood-producing precipitation into Arizona. Their durations generally range from one (1) to four (4) days, although they have been known to dissipate in as little as six (6) hours and to persist as long as ten (10) days. Maximum areal coverage of general summer storms can easily exceed many thousands of square miles. However, maximum rainfall intensities from these storms are often experienced within multiple isolated cells of less than 100 square miles in area. Historically, major impacts from these storms have generally occurred in drainage catchments ranging in size from 100 to 5,000 square miles (ADWR 1985).

- **General Winter Storms**

  Normally originating over the Pacific Ocean, general winter storms move rapidly eastward through the state. Precipitation from general winter storms is usually of light or moderate intensity, although general winter storms have typically contributed significantly to total precipitation in the wettest years of record, and have produced some of the most damaging floods on the larger watercourses. This has been especially true when warm precipitation has occurred over well-
developed snow packs in the higher elevations of the mountainous regions of the state, producing rapid snowmelt and runoff over large areas. General winter storm durations range from a few hours to several days. Maximum areal coverage can exceed tens of thousands of square miles. The major drainage catchments in the state usually exhibit the most significant impacts from general winter storms, primarily because major catchments are fed by numerous tributaries, which cumulatively drain many thousands of square miles in watershed area (ADWR 1985).

### 5.3 Design Storm Approach

Approximately 50% of the annual precipitation at the Project site occurs during the months of July, August, and September. These summer months are when most convective thunderstorms occur, and conductive thunderstorms are typically the storm type responsible for peak flows and damages in watersheds of less than 25 square miles. It is also during these monsoon months that the bulk of stormwater runoff occurs on the majority of watersheds in southern Arizona (Moosburner 1970, USGS 2009, USGS 2012, ADWR 2009).

The watershed of Davidson Canyon is shown on Appendix Figure 5-1. In the small 8.2 square mile watershed area above the Compliance Point Dam, a high intensity and localized convective thunderstorm would likely produce the maximum flood peak at that location, whereas a general summer storm or general winter storm would likely produce the maximum total runoff volume. However, for the 51.3-square-mile watershed contributing runoff to Davidson Canyon where it meets Cienega Creek, it is more difficult to predict the type of storm that would produce either the maximum flood peak or the maximum total runoff volume. A general summer storm might produce the maximum peak discharge on the Davidson Canyon watercourse, but convective thunderstorms can also produce large peaks on watersheds with contributing drainage areas up to 100 square miles in size.

Because of significant rainfall variability, both spatially and temporally, quantification of the return frequency for runoff emanating from a real-time convective thunderstorm is extremely difficult. Normally, it is assumed conservatively that precipitation from a convective thunderstorm will occur uniformly over the watershed under investigation, even though this rarely occurs for larger watersheds. In fact, the larger the watershed the more likely it is that spatial variation in rainfall will occur, with significant precipitation in some portions of the watershed and little to no precipitation in others. This phenomenon is commonly observed in southern Arizona, including in the region that encompasses the Project.

In designing stormwater management facilities for the Project, modeling of peak discharges from tributary areas was performed using a U.S. Army Corps of Engineers empirical method (Hydrologic Engineering Center Hydrologic Modeling System or HEC-HMS) calibrated using data from the southwestern U.S. In order to overcome the problem of selecting a design “storm type” (i.e., a convective thunderstorm versus a general summer storm) that would characterize both the
spatial and temporal storm variability typical of the region, the hydrologic model for Rosemont used a 24-hour storm distribution with an embedded 3-hour convective thunderstorm rainfall distribution. The convective thunderstorm rainfall distribution was located in the middle of the temporal distribution of the 24-hour general summer storm. Precipitation representative of this conservative 24-hour design storm was then uniformly distributed over the affected watersheds to develop estimates of stream flow.

5.4 Surface Water Hydrology

Like precipitation, stormwater runoff in southern Arizona is highly variable, both spatially and temporally. Data collected by water resources agencies demonstrate this extreme variability (USGS 2009, USGS 2012, ADWR 2009). For example, there are a number of watercourses in southern Arizona for which maximum versus minimum mean-annual discharge has varied by ratios of at least 1,000:1, with a maximum variability for one stream of 15,000:1. Coupled with the high spatial and temporal variability of precipitation events in southern Arizona, these extreme ratios make it difficult to predict annual runoff production in a given year for any southern Arizona watershed.

Based upon USGS (2009) data, the average of measured maximum versus minimum annual runoff within the hydrologic region that encompasses the Davidson Canyon watershed varies by nearly 4,000 percent, which is a 40:1 average maximum versus minimum variability ratio. From February 1968 through Water Year 1981, the USGS operated a stream gage (Davidson Canyon Wash near Vail, AZ 09484590) near the downstream end of Davidson Canyon (USGS 2012). The gage site is located about 0.3 miles upstream (south) from Interstate 10. The watershed area draining to this station is about 50.5 square miles. By comparison, the watershed size of Cienega Creek, at its confluence with Davidson Canyon, is approximately 410 square miles. A duration analysis of the available mean daily flow data (from February 1968 through September 1975) indicates that during the monitored time period Davidson Canyon conveyed flow about 23% of the time at that location, or about 84 days per year; but that the flow exceeded one (1) cfs less than 5% of the time.

Peak flow data for USGS gage 09484590 during the period-of-record indicate that flood hydrology is characterized by sudden, brief, and dramatic flood events. The rising and falling limbs of the flood hydrographs are steep, and the period of peak flow is short. Using the recorded annual flood peaks at the stream gage, a flood-frequency curve was developed, using procedures outlined in U.S. Water Resources Council Bulletin 17B (U.S. Water Resources Council 1981). The resulting flood-frequency curve indicates that the 2-year peak flow is about 1,590 cfs, that the 10-year peak flow is about 6,070 cfs, and that the 100-year peak flow is about 13,900 cfs. As expected, the recorded peak flows were thunderstorm driven, as they typically occurred during the monsoon season, between late July and early September.
As a result of the runoff variability along Davidson Canyon, it is useful to define *ephemeral*, *intermittent*, and *perennial* streams. The definitions below are excerpted from the USEPA (2008):

**Ephemeral:** A stream or portion of a stream that flows briefly in direct response to precipitation, and whose channel is at all times above the groundwater reservoir.

**Intermittent:** A stream where portions flow continuously only at certain times of the year, e.g., when it receives water from a spring, groundwater source, or from a surface source such as melting snow (i.e., seasonal). At low flow there may be dry segments alternating with flowing segments.

**Perennial:** A stream or portion of a stream that flows year-round and is considered a permanent stream, and for which base flow is maintained by groundwater discharge to the streambed. Discharge to the streambed from groundwater would be due to the groundwater elevation adjacent to the stream typically being higher than the elevation of the streambed.

There is a reach along the Davidson Canyon watercourse, defined as perennial by PAG (PAG 2005), which is located about 0.5 miles upstream of the Interstate 10 Bridge crossing. This reach extends for a distance of about 0.8 miles. However, field observations indicate that most or all of this reach should be classified as intermittent based on the definitions presented above. The USGS gage 09484590 site is located approximately 1,000 feet downstream of the “perennial” reach of the watercourse (Appendix Figure 5-1).

### 5.5 Potential Impacts to Davidson Canyon

#### 5.5.1 Hydrologic Calculations

In order to quantify the anticipated reduction in surface flow through Davidson Canyon due to Project development, hydrologic analyses were performed at a series of points along the Davidson Canyon drainage channel from the Rosemont Compliance Point Dam to the confluence with Cienega Creek. The analyses quantify the anticipated reduction in surface flow due to Project development using two (2) separate indices of surface flow: peak flow and average annual runoff volume.

- **Peak Flow:** Estimates of the reduction in peak flow due to the Project are based upon design storm hydrology for a regulatory, or 100-year, storm event (FEMA, HEC-HMS). The reduction in peak flow was calculated by keeping the hydrologic scenario consistent and comparing the maximum estimated discharge for the watershed without, and with, Project stormwater management facilities that reduce the size of the watershed contributing runoff to the peak flow.

- **Average Annual Runoff Volume:** Estimates of the reduction in average annual runoff volume due to the Project are calculated using equations developed from empirical data for precipitation (NOAA Atlas 14) and discharge in semi-
arid and arid regions of the southwestern United States (e.g., Moosburner 1970).

These results are shown in tabular and graphical forms on Appendix Figure 5-1. The drainage areas (DA) and flow values are shown for several concentration points (CP) throughout Davidson Canyon. Hydrologic analyses conducted by Rosemont (Tetra Tech 2010a-c, Tetra Tech 2011) show that the 100-year peak discharge at the Compliance Point Dam in Barrel Canyon wash (Appendix Figure 5-1, CP A) is predicted to be 5,360 cfs, and that the average-annual runoff is predicted to be 912 AF for undeveloped (pre-mining) conditions. For post-mining conditions, the 100-year peak discharge at the Compliance Point Dam in Barrel Canyon Wash is predicted to be 2,842 cfs, and the average-annual runoff is predicted to be 271 AF (a reduction of 47% and 70%, respectively). These predicted reductions in peak flow and average-annual runoff are expected because the drainage area contributing runoff to that point will be reduced to approximately 1.9 square miles from 8.2 square miles as a result of Project development. Analyses assumed that the Phased Tailings alternative would be implemented, resulting in the exclusion of a 0.9-square mile area located down-gradient of the Compliance Point Dam from the contributing watershed at concentration points farther downstream.

Similar hydrologic analyses (Tetra Tech 2010a-c, Tetra Tech 2011) compare runoff from the undeveloped watershed with the post-mining condition at the location just downstream of the SR 83 bridge where Barrel Canyon flows enter Davidson Canyon (Appendix Figure 5-1, CP C). For undeveloped conditions, the 100-year peak discharge is predicted to be 8,358 cfs and the average-annual runoff is estimated at 1,345 AF. For post-mining conditions, the watershed area has been reduced from 15.0 square miles to 7.8 square miles. The predicted 100-year peak discharge is 4,067 cfs and the estimated average-annual runoff is 771 AF (reductions of 51% and 43%, respectively).

For points further downstream, effects as a percentage of flow reduce rapidly with distance. The watershed area that no longer contributes flow due to the Project is a smaller percentage of the total watershed area tributary to Davidson Canyon for points of interest near its mouth. The total drainage area for Davidson Canyon at the site of USGS gage 09484590 is 50.5 square miles. The 100-year peak discharge at this location (Appendix Figure 5-1, CP E) is predicted to be 19,000 cfs, and the average-annual runoff at this location is predicted to be 2,823 AF (Blakemore et al. 1997, FEMA 2011, PCRFCD 2007, USGS 2009). Based upon hydrologic analyses conducted by Rosemont (Tetra Tech 2010 a-c, Tetra Tech 2011), it is predicted that for post-mining conditions at this location the contributing drainage area will be reduced to 43.3 square miles, the 100-year peak discharge would be 17,729 cfs, and the average-annual runoff would be 2,471 AF (reductions of 7% and 12%, respectively).

For both pre-mining and post-mining conditions, the hydrologic evaluation summarized above demonstrates a reduction in both 100-year peak discharge per unit area and average-annual runoff per unit area as the size of the watershed
increases in a downstream direction. This general reduction is characteristic of semi-arid and arid-lands hydrology, and is related to spatial changes in topography, rainfall distribution, and runoff generation for the study areas for which data was used to develop the hydrologic model (Moosburner 1970). These unit-area reductions imply that reductions to flow become less significant with increasing distance downstream, not only because the area removed from the watershed by Project development represents a smaller fraction of the total watershed, but also because the hydrologic data for semi-arid and arid lands show that the rate of increase for both peak discharge and for average-annual runoff is lower than the rate of increase in watershed size as the area under consideration is expanded downstream.

The calculated reduction in the 100-year peak discharge due to Project development becomes relatively minor in nature as the watershed size increases beyond several tens of square miles, for example at the mouth of Davidson Canyon (a 7% reduction). This is the magnitude of reduction that would be expected for a major flood event with a statistical likelihood of occurring once in a 100-year period. Likewise, as the size of the watershed under consideration increases beyond several tens of square miles, the calculated reductions in average-annual runoff due to the Project become relatively minor; particularly compared to the natural annual variability of the hydrologic processes that occur in the Davidson Canyon watershed. It was previously indicated that USGS (2009) data show that the ratio of measured average maximum annual runoff to minimum annual runoff within the hydrologic region that encompasses Davidson Canyon is 40:1. Even the smallest variability in the region is still more than 200%. Given the large variability in the average-annual runoff for Davidson Canyon that is naturally present, the annual runoff value for any given year cannot be reasonably ascribed to be entirely the consequence of the relatively minor change in the hydrologic system that would be created by the Project.

5.5.2 Impacts from Surface Water Reduction

Hydrologic impacts due to watershed changes caused by the Project were predicted using hydrologic modeling. Specific impacts to Davidson Canyon due to watershed changes that would occur upstream of the proposed Compliance Point Dam, were quantified by estimating the expected reduction in the 100-year peak discharge and in average-annual runoff for post-mining conditions. Impacts were quantified for several locations in Davidson Canyon upstream of the confluence with Cienega Creek.

- Post-mining regulatory (100-year) peak discharges emanating from Barrel Canyon were predicted to be decreased by about 51% just upstream of the confluence with Davidson Canyon (drainage area of 15 square miles), but only by about 7% at the mouth of Davidson Canyon near its confluence with Cienega Creek (drainage area of 50.5 square miles), at which point 70% of the watershed is not impacted by the Project (Tetra Tech 2010 a-c, Tetra Tech 2011). In practice, reductions to peak flows will be highly variable, and
will depend upon the spatial and temporal characteristics of individual storm events.

- The reduction in average-annual runoff volumes emanating from Barrel Canyon due to the Project was estimated to be about 43% just upstream of the confluence with Davidson Canyon, and about 12% at the Davidson Canyon confluence with Cienega Creek (Tetra Tech 2010 a-c, Tetra Tech 2011, USGS 2009). The method used to calculate this reduction was conservative in that it considered all of the runoff from the Project site to be removed from the tributary watersheds at points downstream.

The predicted hydrologic changes using average-annual values can help estimate the magnitude of the Project’s impact over time. However, because of the large variability in annual runoff that occurs naturally within the semi-arid regions of southern Arizona, it will be impossible to attribute any observed direct or indirect change in runoff in Davidson Canyon due to the Project without additional data. In fact, due to the large variability in the temporal and spatial distributions of storm systems that occur in the region, significant runoff events will still occur from those portions of the Davidson Canyon watershed that are not impacted by the Project.

Similar calculations were performed below the Davidson Canyon-Cienega Creek confluence (Tetra Tech, 2011). However as you move further from the Project, the watershed area increases and the impacts associated with the Project on these areas becomes smaller approaching the natural variability associated with ephemeral systems.

5.5.3 Existing Fluvial Geomorphologic Characteristics

The processes by which flow creates the physical features of watersheds and channels through erosion and sedimentation are collectively called fluvial geomorphology. The existing morphology of the Davidson Canyon channel and its tributaries provides insights into the processes controlling streamflow and channel development, sediment transport, and groundwater recharge. These processes largely control where ecologically valuable resources develop, and dictate their form. The morphology of the channel, particularly in downstream reaches, is strongly coupled to the bedrock geology of the area. Bedrock outcrops along the channel bed provide grade control along the streambed of the watercourse.

The channel bed slope of the main stem headwater reach of Davidson Canyon Wash flattens as it progresses in the downstream direction, decreasing from about 3.7% in upstream reaches, to about 1.9% at its confluence with Barrel Canyon. Similarly, the slope along Barrel Canyon flattens from about 4.3% in upstream reaches, to about 1.7% above its confluence with Davidson Canyon. Downstream from the confluence with Barrel Canyon, the Davidson Canyon bed slope is relatively constant, at about 1.2%. In these lower-gradient areas, alluvium fills in behind bedrock outcrops sporadically located within the channel. These trapped sand deposits allow for water storage, with water often perching on less permeable bedrock. Sediment deposition upstream of these bedrock outcrops does not indicate a system-wide
sediment imbalance, but rather suggests that a portion of the bed-material sediment load is trapped in localized, low-gradient zones. Sediment deposition also can be observed along transition zones, where energy losses associated with flow expansion result in expansion bars.

The headwater reaches of Davidson Canyon Wash include the main stem and the reach along Barrel Canyon. While these reaches have localized areas that are constricted by bedrock, the channel geometry is typically wide and shallow, and bounded by broad floodplains with moderate to dense grass, brush, and trees. This type of channel geometry indicates that significant sediment storage has occurred in the past both within both the channel and in adjacent overbanks. The sediment supply to the headwater reaches is primarily derived from incision of small tributary channels and toe erosion of alluvial terraces along the main stem, but erosion caused by overland sheet flow may also be a source of sediment.

In the downstream reaches of Davidson Canyon Wash, the valley bottom is relatively wide in areas where the surficial geology is comprised of alluvium; and is somewhat constricted through reaches that have historically incised through bedrock outcrops. The cross-sectional shape of the watercourse similarly varies with the composition of the valley floor. Where the valley bottom is wide, the watercourse consists of a well-defined low-flow channel bounded by low-elevation floodplains that are moderately to densely vegetated, primarily with grasses and brush. Reaches cut through bedrock typically have a poorly defined and irregular cross-sectional shape, with no identifiable floodplain. Lateral migration in the downstream reaches of Davidson Canyon Wash appears to be limited to localized areas, mostly where coarse-grained sediment deposits deflect flow towards the toe of alluvial banks and terraces. Bed material throughout the reaches of Davidson Canyon is generally gravelly sand, with some cobble and boulder-sized clasts present.

Consistent with other ephemeral channels in the southwestern U.S., the presence of relatively large bed material indicates that the observed morphologic and physical characteristics of the channel (i.e., cross-sectional geometry, bed slope, plan form, and sediment balance) are controlled by extreme flow events, since the low-volume base flows likely would not transport significant quantities of sediment. Evidence of channel down-cutting is not readily observable. The persistent longitudinal sediment deposits located along the channel bed indicate that: (1) the bed-material load is significant; and (2) the bed-material sediment supply is in equilibrium with transport capacity or slightly exceeds transport capacity.

The hydraulic conductivity of the alluvium was analyzed, and resultant permeability estimates were quite high, indicating that it is likely that high infiltration rates exist along the Davidson Canyon channel when surface water is present (i.e., there would be high losses to the subsurface system).

Based on the geomorphic characteristics observed in the field, the following conclusions can be drawn:
(1) Base flows are low in magnitude and duration, while high-magnitude flood events (especially peak rates of flow) are driven by monsoon thunderstorms.

(2) The sediment supply to the headwater reaches of Davidson Canyon is somewhat greater than the transport capacity, resulting in sediment storage that occurs along the low-flow channel and along the low-elevation floodplain surface. The resulting sediment supply to the downstream reaches appears to be in balance with the transport capacity.

(3) The physical and morphologic characteristics of the Davidson Canyon Watercourse are not significantly affected by base flows, and are controlled by thunderstorm-driven flood events.

(4) Channel seepage along Davidson Canyon is likely significant due to the shallow alluvial aquifer north of Interstate 10. Recharge would most likely be as a consequence of monsoon-driven surface flows (Tetra Tech 2010f).

5.5.4 Sediment Yield

The fluvial geomorphology of Davidson Canyon is primarily influenced by sporadic flows that typically occur during the summer months of the year (i.e., July through September). During these sporadic flow events, bed-material sediment transport can be significant. Variations in bed-material sediment-transport rates along the watercourse shape the hydraulic geometry of the watercourse from reach to reach. This is a dynamic process, however, varying significantly from year to year and sometimes exhibiting cyclic tendencies within overall stability. Accordingly, quantification of sediment delivery (i.e., the sediment transport that occurs primarily as bed-material sediment load) is extremely difficult to estimate on a reliable basis from one storm event to the next.

Estimated values of average-annual sediment emanating from Barrel Canyon and delivered to the Davidson Canyon channel have been computed (PSIAC 1968, Tetra Tech 2010 d-e). The average-annual sediment emanating from Barrel Canyon that is predicted to be delivered to Davidson Canyon is 17.3 AF for pre-mining conditions and 9.0 AF for post-mining conditions, which suggests a 48% reduction from pre-mining to post-mining conditions based upon a unit average-annual sediment yield of 1.15 AF/yr for each square mile of contributing watershed for both pre-mining and post-mining conditions. The results of other investigations suggest that this estimate of yield per acre may be a conservative (high) value. The PSIA analysis considered specific watersheds that will be impacted by the Project and resulted in a much higher value for unit average annual sediment yield than has been used by the Natural Resources Conservation Service (NRCS), for example, for general planning in the region. An NRCS (1971) map indicates sediment yield of only 0.2 to 0.5 AF/yr per square mile of contributing watershed in the region of southern Arizona encompassing the Project. In any case, part of the expected reduction in sediment yield results from the reduced quantity of stormwater runoff emanating from Barrel Canyon, and reducing both runoff and sediment yield together
maintains the existing sediment transport balance. The quality of the stormwater runoff reaching Davidson Canyon will not be materially affected under post-mining conditions because significant portions of the watershed contributing sediment to Barrel Canyon will remain unaffected by the presence of the Project and will continue to produce runoff with essentially unchanged sediment concentrations. While it is true that releases from detention facilities at the Project will yield runoff with lower sediment concentrations than uncontrolled runoff would yield, the small magnitude and the considerable separation in timing of any such releases in comparison with runoff from uncontrolled sources of runoff will not significantly affect the geomorphology of the downstream reaches of Barrel Canyon or Davidson Canyon.

5.5.5 Impacts to Geomorphologic Characteristics

Under post-mining conditions, the hydraulic geometry of Davidson Canyon Wash, which currently has a primary flow channel that typically varies from 40 feet to 60 feet in top width, is predicted to narrow slightly due to the predicted reductions in stormwater runoff and sediment yield. At a location immediately below Davidson Canyon’s confluence with Barrel Canyon, the contributing watershed area is estimated to be about 22.9 square miles under pre-mining conditions and about 15.7 square miles under post-mining conditions. At and near this location, hydraulic capacity calculations estimate that the width of the existing primary flow-conveyance channel could decrease by about 6.3% in response to Project development. Furthermore, the existing channel flow depth could decrease by about 6%, the existing channel flow velocity could decrease by about 3.2%, and the existing bed slope could increase by about 0.01%. However, the predicted sediment concentration at peak discharge would only be reduced by 0.02%. In addition, a very slight change in the sinuosity of the primary channel might also occur in the event that the fluvial system attempts to offset the slight changes in hydraulic parameters along the channel by flattening its energy slope through a very minor increase in channel meandering. None of these small variations in hydraulic geometries is predicted to have a significant impact upon the existing surface water flow characteristics of the Davidson Canyon channel, especially as flows proceed farther downstream and the proportion of the contributing watershed impacted by the Project decreases.

5.6 Summary

The proposed Project will essentially isolate a portion of the watershed that has historically contributed stormwater flow and natural sediment loading to the Barrel Canyon Wash. Because the contributing watershed area tributary to any point in a wash increases with increasing distance downstream, the relative impact of the reduction in watershed area due to the Project decreases with increasing distance downstream. The reduction in stormwater flow due to the proposed Project, as a percentage of the baseline flow condition, is estimated at 7% for the 100-year peak flow rate and 12% for the average total annual flow volume in the OAW reach of Davidson Canyon just before its confluence with Cienega Creek. Very large variations in both the peak flow rate and the total annual flow volume occur
naturally as a result of variations in precipitation. In addition, downstream sediment yield and channel geomorphology will not be significantly affected. In summary, impacts to the watershed downstream from the Project will be minor.

5.7 References


6 GROUNDWATER RESOURCES

Two independent groundwater flow models were designed and calibrated to evaluate impacts to groundwater across the Study Area. The Study Area includes upper and lower reaches of Cienega Creek, Davidson Canyon, and numerous springs. Water-level changes due to dewatering the Open Pit and subsequent formation of the Pit Lake after the cessation of dewatering were modeled. The resulting changes to stream flows and riparian areas from the start of mining through a 1,000-year post-closure period were quantified.

M&A and Tetra Tech developed the separate groundwater models each using MODFLOW-SURFACT (HydroGeoLogic 2006), which is a widely accepted modeling program. Extents of both model domains include essentially all of upper Cienega Creek basin, the southern portion of the lower Cienega Creek basin including Davidson Canyon, and a small eastern portion of the Tucson groundwater basin, as shown on Appendix Figure 2-3. The models simulate groundwater conditions prior to pit excavation (pre-mining conditions), for the 22-year pit dewatering period (active mining period), and for a 1,000-year post-closure groundwater level recovery and Pit Lake development period. The models predict pit dewatering groundwater inflows, post-mining groundwater inflow and Pit Lake development, and resulting drawdown and changes to the groundwater system over time. The post-closure Pit Lake stage is important because it determines whether the Pit Lake will be a terminal or a flow-through lake.

A rigorous modeling process was undertaken to ensure that predicted impacts were representative of future conditions. The model assumptions are based on extensive data and analyses conducted since the 1970’s. Additionally, Rosemont conducted its own characterization studies. Over the period from 2006 through 2010, studies and analyses were conducted to characterize the three-dimensional geology, hydraulic properties of the rocks, riparian vegetation, climate conditions, groundwater recharge, stream flows, spring flows, groundwater levels, groundwater pumping, and trends in the groundwater system. An extensive exploration drilling and hydraulic testing program was conducted to augment existing wells and testing was conducted throughout the Study Area.

The calibrated models were evaluated during a third-party peer review process. The purpose for the review process was to ensure the models appropriately represented the groundwater system, used defensible methods and data, and produced reliable predictions of the Project impacts. Numerous improvements and refinements were made to the flow models during this review process. The review was conducted by SRK Consulting, Inc. on behalf of the USFS.

The refined M&A final model submitted in support of the DEIS was accepted by SRK and was “judged to be sufficient in concept and execution such that resulting predictions of impacts are reasonably supported and defended by the available data” (SRK 2010). The refined Tetra Tech final model submitted in support of the DEIS was accepted by SRK as meeting “industry standards” and that “model predictions for both mining and post-mining conditions are reasonable” (SRK 2011).
groundwater models have been extensively documented in reports and memorandum responses submitted in support of the DEIS. Brief summaries of reported data collection and site investigations, aquifer characterization and testing, and modeling analyses conducted as part of the modeling investigations are summarized at the end of this section.

### 6.1 Groundwater Modeling

M&A and Tetra Tech evaluated the geologically complex study area. Each consulting firm developed independent conceptual models of the groundwater flow system. These conceptual models are different, but equally likely, interpretations of the existing data that describe the occurrence and movement of groundwater. The major differences between the models include: 1) a higher permeability Davidson Canyon fault structure represented only in the M&A model; and 2) a low-permeability intrusive dike transversely oriented across Davidson Canyon represented only in the Tetra Tech model. These are significant differences that alter the predicted drawdown and provide a range of potential impacts that are discussed in subsequent subsections.

#### 6.1.1 Conceptual Flow System and Model Development

Water enters the upper Cienega Creek basin groundwater system as recharge from precipitation, and then moves down-gradient through the fractured bedrock and basin fill flow systems. Water leaves the groundwater system primarily as evapotranspiration from riparian areas along Cienega Creek and Davidson Canyon, and to a lesser degree as discharge to streams or as groundwater outflow from the basin.

Under current conditions the groundwater flow system in the Rosemont Project area and for a majority of the Cienega Creek basin is generally considered to be in a state of equilibrium. Current pumping in the basin is relatively small and dispersed, and water-level changes over time are not common. Observed groundwater levels, gradients, and direction of groundwater movement for the Cienega Creek basin and the model domains are shown on Appendix Figure 2-9. Low permeability bedrock and strongly cemented basin-fill sediments result in the high groundwater levels and steep gradients found in the proposed Project Area. Higher permeability basin fill sediments in the central basin result in flatter groundwater level gradients as the water moves towards the ET and stream discharge areas.

Hydrogeologic bedrock and basin fill units represented in the models are shown on Appendix Figure 2-8. Section A-A’ located west-east through the proposed pit is shown on Appendix Figure 2-10. The Precambrian granodiorite (pb) forms the core of the Santa Rita Mountains with low permeability Bisbee Group (Ksd) present at the surface. Paleozoic carbonate units are exposed in the western part of the pit and then occur at depth to the east. The Bisbee Group generally acts as a confining unit over the Paleozoic units. The Flat Fault has been observed in the northern part of the pit and appears at the contact between the Bisbee Group and the Paleozoic units.
(Appendix Figure 2-10). Wells intersecting the Flat Fault have higher water production, indicating that the fault has some degree of lateral hydraulic connection.

A section (B-B’) east-southeast from the proposed pit, and extending across upper Cienega Creek basin, is shown on Appendix Figure 2-11. Basin fill units outcrop east of Wasp Canyon and overlay the low permeability Bisbee Group. East of Highway 83 and in the lower elevation areas of upper Cienega Creek basin, younger and more permeable basin fill overlays the older basin-fill units. The younger basin fill gets progressively deeper near Cienega Creek, which flows through recent, unconsolidated alluvium (Appendix Figure 2-11). On the eastern side of the upper Cienega Creek basin the basin fill units are terminated and the Bisbee Group bedrock is exposed at surface.

Based on extensive geologic investigations, observed groundwater conditions, and hydraulic testing, bedrock east from the Precambrian core of the Santa Rita Mountains is characterized as a complex system of bedrock with variable fracture densities and generally discrete faults of limited hydraulic connectivity. The bedrock system is modeled as an Equivalent Porous Medium (EPM), which is inherent in the MODFLOW-SURFACT representation, and includes explicit representations of selected fault features determined to be hydraulically significant. The simulated EPM approach incorporates highly variable hydraulic conductivities in the bedrock flow systems that are representative of varying degrees of fracturing and faulting. The overall low-permeability of the bedrock, and the strongly cemented basin fill sediments in the Project Area, will restrict groundwater inflow to the pit and limit groundwater level drawdown distance from the pit.

The models were calibrated to estimate water balance components of precipitation recharge, ET, and streamflow discharge for the Study Area, as well as observed groundwater levels. Contours of simulated pre-mining groundwater levels for the M&A and Tetra Tech models are shown on Appendix Figures 6-1 and 6-2, respectively. The simulated groundwater balances for the M&A and Tetra Tech models are shown on Appendix Figures 6-3 and 6-4, respectively. These water-balance figures illustrate conceptually and quantitatively how the groundwater system changes through pre-mining, end of mining, and into the post-closure period. Over the Study Area the flow-system changes are relatively minor. Brief characterizations of the simulated components of the Cienega Creek basin groundwater system – recharge, evapotranspiration, and streamflow – are as follows.

6.1.1.1 Recharge
Recharge in the Study Area occurs in the higher precipitation areas of the Santa Rita Mountains, as mountain front recharge, in alluvial stormwater drainage channels, and to a lesser extent through distributed infiltration over the relatively flat lying basin-fill units. Quantity and distribution of recharge in the two flow models was determined independently by different methods, but were based on similar data sources.
Fundamental relationships and data used to determine recharge were based on: 1) precipitation altitude relationships; 2) previous study estimates of recharge for upper and lower Cienega Creek basins; 3) recharge models for other southwest basins; 4) recharge capacity of surface geology; 5) topography; 6) calibration of the simulated groundwater recharge to reasonable estimates of groundwater discharge from upper Cienega Creek basin via ET and losses to Cienega Creek; and 7) calibration of simulated groundwater levels to observed data. The majority of simulated recharge is aerially distributed, with some inflow from model boundaries representing precipitation recharge in areas where the model domain does not extend to the hydrographic boundaries of the basins. Recharge in alluvial stormwater drainage channels was not explicitly simulated, but is accounted for in the simulated recharge for the entire basin. Simulated pre-mining recharge is shown on Appendix Figure 6-3 for the M&A model and on Appendix Figure 6-4 for the Tetra Tech model.

Post-mining simulated recharge is altered to account for changes due to the tailings and waste rock facilities. The tailings and waste rock facilities prevent precipitation from infiltrating and becoming recharge (Tetra Tech 2010c), and no recharge from precipitation was simulated under these facilities. However, water within the tailings is anticipated to drain with an estimated initial rate of approximately 13.6 AF/yr (8.4 gpm) that decreases to zero 500 years after the end of mining (AMEC 2009). Recharge from infiltration due to designed stormwater flow-through drains under the tailings and waste rock facilities was simulated (Tetra Tech 2010d). No groundwater recharge occurs in the Open Pit, and estimated recharge from retention basins was assumed negligible due to the low vertical conductivity of the bedrock, limited precipitation events, and high evaporation rate.

6.1.1.2 Evapotranspiration

Evapotranspiration (ET) in the Study Area accounts for the discharge of groundwater to the air from soils and riparian vegetation. Areas of significant ET are along the stream channels where riparian vegetation is present. ET was simulated in the same areas and with the same maximum rates for both flow models. ET was determined for seven (7) different zones with varying rates depending on vegetation type. The M&A model calculated the extinction depth for each zone as a weighted average of the different plant types in each zone, as specified by Leenhouts and others (2006) and by Maddock and Baird (2003). ET discharge can vary in response to future groundwater level changes at the discharging ET model cell. Simulated pre-mining evapotranspiration is shown on Appendix Figure 6-3 for the M&A model and on Appendix Figure 6-4 for the Tetra Tech model.

6.1.2 Groundwater Interaction with Streams

Groundwater discharge to streams and stream discharge to groundwater were simulated for Cienega Creek and Davidson Canyon Wash. Perennial reaches along Cienega Creek were approximately simulated based on the PAG (2000b) stream inventory; perennial reaches are shown on Appendix Figure 6-1. The Davidson
Canyon Wash reach is associated with the Reach 2 Spring discharging to the channel about 11.5 miles north of the proposed Project (Appendix Figure 2-20).

Discharge from the Reach 2 Spring was not simulated explicitly in the models; but simulated groundwater discharge to the stream channel is analogous to spring discharge. Although simulated as perennial in both models, Davidson Canyon stream flow has been observed to be only ephemeral in recent years. Simulated changes in Davidson Canyon stream flow are only applicable to wetter periods when there may be a connection between surface water flows and the regional groundwater table. In reaches of Cienega Creek where groundwater discharges to the stream, simulated stream flow can vary in response to future groundwater level changes. Simulated stream groundwater discharge/recharge is shown on Appendix Figure 6-3 for the M&A model and Appendix Figure 6-4 for the Tetra Tech model.

6.1.3 Groundwater Outflow

Groundwater that doesn’t discharge by ET or streams exits the model Study Area as groundwater outflow, ultimately to the Santa Cruz Aquifer (Appendix Figure 2-9). Simulated pre-mining groundwater outflow from the M&A model domain to the Tucson basin is 2,282 AF/yr, as shown on Appendix Figure 6-3. Simulated pre-mining groundwater outflow from the Tetra Tech model domain to the Tucson basin is 3,238 AF/yr, as shown on Appendix Figure 6-4. Simulated outflow to the Tucson basin includes outflow west of the proposed pit location. Groundwater outflow can vary depending on changes in other components of the groundwater flow system, including increased groundwater withdrawals due to pit dewatering. These changes are discussed in subsequent sub-sections.

6.2 Simulated Pit Dewatering and Lake Development

Excavation of the Open Pit below the water table will result in groundwater inflows to the pit. Groundwater inflow to the pit represents capture of recharged groundwater in the Project area which otherwise would ultimately move down gradient through the groundwater system and discharge as ET, streamflow, or groundwater outflow from the model domain.

During mining, groundwater inflow to the pit, precipitation runoff into the pit, and direct precipitation to the pit will be removed by pumping. After cessation of mining, hydrologic investigations and modeling indicate that the combined water inflow sources to the pit will form a lake. Over several centuries the Pit Lake stage is expected to rise until the evaporation rate from the lake surface equilibrates with the inflowing groundwater, surface runoff, and precipitation. As the lake level rises: 1) the volumetric rate of groundwater inflow to the pit decreases due to the reduced hydraulic gradient between the lake level and groundwater level in the surrounding formation; and 2) the volumetric rate of evaporation from the lake increases due to the expanding surface area of the lake.

Projected groundwater inflows to the pit during the 22-year operations period when dewatering occurs increase rapidly and range between 620 and 530 gpm for
the M&A model (855 AF/yr at end of mining) and between 475 and 350 gpm (565 AF/yr at end of mining) for the Tetra Tech model, as shown on Figure 6-5. Projected groundwater inflows to the Pit Lake over a 1,000-year post-mining period, and corresponding lake levels for both the M&A and Tetra Tech models, are shown on Figure 6-6. For the M&A model, projected groundwater inflows decrease to approximately 104 gpm (167 AF/yr). Projected groundwater inflows based on the Tetra Tech model decrease to approximately 230 gpm (370 AF/yr). These groundwater inflow rates represent the long-term consumptive use of the Pit Lake.

![Figure 6-5. Simulated Groundwater Inflow to the Open Pit During Operations.](image)
The flow models predict the Pit Lake level will reach an approximate equilibrium condition within 500 years post-mining. Equilibrium occurs when pit inflows from direct precipitation, surface runoff, and groundwater inflows equal the evaporative loss from the lake surface (Figure 6-6). Equilibrium lake levels are predicted to remain below the groundwater level in the surrounding bedrock, indicating the pit will remain a terminal, hydraulic sink.

**6.3 Predicted Groundwater System Changes**

Summaries of the maximum projected impacts due to the pit during mining and for the 1,000-year post-mining period are provided below. Impacts predicted by the individual models can be found in the detailed modeling reports (M&A 2010, Tetra Tech 2010b). The groundwater balances (Appendix Figure 6-3 and Appendix Figure 6-4) indicate slight projected decreases compared to pre-mining conditions for ET discharge, groundwater discharge to streams, and groundwater outflow to the Tucson basin, including the outflow boundary west of the pit.

Projected groundwater level changes are provided as follows:

- Contours of projected drawdown at the end of mining, and 150 and 1,000 years post-mining, are shown on Appendix Figures 6-7 through 6-9, respectively. The simulated higher conductivity Davidson Canyon Fault Zone in the M&A model results in drawdown preferentially propagating farther.
down Davidson Canyon. The simulated low permeability intrusive dike structure across Davidson Canyon, located approximately five (5) miles northeast of the pit (Appendix Figure 6-8), mitigates the extent of drawdown to the northeast in the Tetra Tech model. Conversely, drawdown propagation into upper Cienega Creek basin is greater in the Tetra Tech model than in the M&A model. These results illustrate the differences in simulated impacts due to the different conceptual models.

- Projected groundwater levels, gradients, capture zone around the pit, and direction of groundwater movement for the Cienega Creek basin and the model domain at 1,000 years post-mining are shown on Appendix Figure 6-10 and Appendix Figure 6-11. The pit results in a hydraulic sink throughout the mining and post-closure periods for both models. With the exception of the hydraulic sink in the immediate pit area, the overall direction of groundwater movement is similar to pre-mining conditions.

- Sections depicting the simulated pre-mining groundwater level surface, the lowered groundwater level surface at end of mining, and 150 and 1,000 years post-mining, and directions of groundwater movement along transects X-X’, Y-Y’, and Z-Z’ (Appendix Figure 6-1) are provided. These figures illustrate the large drawdown near the Open Pit and the decreasing drawdown away from the pit. Drawdown hydrographs at springs and stream reaches provide detail of the limited drawdown at these distant locations.
  - M&A model results are shown on Appendix Figures 6-12 through 6-14.
  - Tetra Tech model results are shown on Appendix Figures 6-15 through 6-17.

Projected maximum impacts for critical areas across the region are provided as follows:

- Hydrographs of projected drawdown at the Reach 2 Spring in the Davidson Canyon OAW (Appendix Figure 6-12) indicate a maximum drawdown of 1.02 feet after 1,000 years (M&A 2010). Maximum drawdown at the confluence of Davidson Canyon and Cienega Creek was 0.09 feet (Appendix Figure 6-15) (Tetra Tech 2010b).

- Hydrographs at the USGS Cienega Creek Gaging Station (near Sonoita 09484550) indicate a maximum drawdown of 0.52 feet after 1,000 years (Appendix Figure 6-16) (Tetra Tech 2010b)

- Hydrographs of drawdown at Upper Empire Gulch Spring and the confluence of Gardner Canyon and Cienega Creek (Appendix Figure 6-17) indicate a maximum drawdown of 5.95 and 0.45 feet, respectively, after 1,000 years (Tetra Tech 2010b).
• The maximum projected net decrease in ET was 1.5% (45 AF/yr) in upper Cienega Creek and 1.5% (29 AF/yr) in lower Cienega Creek basin (including Davidson Canyon) (Appendix Figure 6-3) (M&A 2010).

• The maximum projected net decrease in groundwater discharge was 2.2% (58 AF/yr) to upper Cienega Creek (Appendix Figure 6-4) (Tetra Tech 2010b).

• The maximum projected net decrease in groundwater outflow to Tucson basin was 2.4% (79 AF/yr), which occurred predominantly along the western model boundary adjacent to the pit (Appendix Figure 6-4) (Tetra Tech 2010b).

• The maximum projected net increase in model boundary inflow to upper Cienega Creek was 1.5% (34 AF/yr) and a projected 1.5% net increase (9 AF/yr) in model boundary inflow to lower Cienega Creek basin (including Davidson Canyon) (Appendix Figure 6-4) (Tetra Tech 2010b).

• Maximum projected decrease in streamflow at 1,000 years post-mining is negligible: 0.08 cfs at USGS Gage 09484550 (Tetra Tech 2010b) and 0.04 cfs at the Reach 2 Spring (Appendix Figure 6-9) (M&A 2010).

Rigorous sensitivity analyses were conducted for both models to evaluate potential variations in projected groundwater impacts for a range of hydraulic parameters. Results of the predictive sensitivity simulations indicate the simulated groundwater system is robust, and worst-case simulated hydraulic parameters resulted in groundwater impacts which were not substantially different from results of the base simulation. The Pit Lake remained a hydraulic sink under all sensitivity simulations.

6.4 Discussion of Results

Model projections indicate substantial groundwater level drawdown will occur in the immediate vicinity of the pit. Drawdown at distance away from the pit will be mitigated due to the low-permeability fractured rocks and cemented sediments in the mine area. Groundwater drawdown is projected to reach riparian and perennial streamflow OAW areas hundreds of years in the future. The quantity of resulting reductions in riparian ET and streamflow in the OAW areas will be slight, reflecting the relatively small long-term groundwater inflows to the pit.

Projected groundwater inflow to the pit during operations is predicted to range between 266 and 620 gpm for the two models. These inflows steadily decrease over the post-closure period and are predicted to be 100 to 230 gpm 1,000 years in the future. This groundwater capture comes from the entire Study Area to offset consumptive groundwater use due to Pit Lake evaporation. This groundwater use is collectively offset by decreases in ET, groundwater discharge to streams, and groundwater outflow from the Study Area. Each of these components adjusts a small degree to the new groundwater system conditions to create a new equilibrium.
Riparian plant root systems will adjust to small changes in depth to water. Long-term equilibrium streamflow conditions will be controlled by the riparian evapotranspiration along the channel. The density of riparian vegetation is self-regulating with changing water-availability conditions. When water is plentiful, the vegetation expands and consumes more water. If the expansion exceeds the available water, there is die-back and the vegetation recedes and consumes less water. In this way, the natural system maintains a balance between stream flow and riparian vegetation.

Springs and seeps in the Study Area are currently undergoing further investigation. Many historical springs and seeps are now dry. Drawdown impacts from the Project may impact discharging springs and seeps if they are in connection with the regional groundwater system. This is discussed in more detail in the following sections.

The projected groundwater drawdown west from the pit through the Santa Rita Mountains results in a small percentage decrease in groundwater outflow across the west boundary. These projected impacts may not extend as far as projected if the rock along the topographic divide is less permeable than represented in the models. The granodiorite may act as a complete barrier to groundwater movement, rather than a very low permeability barrier as simulated in the models. However, predictive sensitivity simulations were conducted with lower granodiorite permeabilities, and resulting changes in projected groundwater impacts distant from the pit were negligible compared to the base simulation. Average hydraulic properties for the granodiorite were simulated and the predicted impacts are considered representative.

As discussed in the Regional Setting section, there is considerable variability in baseline climate conditions. Water-level declines resulting from reduced recharge and increased ET as a result of other environmental factors, including climate variations, will likely result in greater impacts along Cienega Creek than those predicted in the flow models. Historic springs across the Study Area appear to have declining discharge or completely interrupted flow due to the prolonged and ongoing drought conditions. Recent trends in declining stream base flows and spring discharges indicate that the on-going drought is resulting in impacts to the groundwater system and water-dependent ecosystems.

6.5 Conclusions

Based on site investigations and model projections, there is confidence that large drawdown (100 feet) will occur in the vicinity of the pit. More distant from the pit, the predicted groundwater impacts due to drawdown will be small (approximately 1 foot). The ability to accurately project these small groundwater impacts 1,000 years post-mining, and at the farthest edges of the projected drawdown, is limited due to the large and complex hydrogeologic setting. Given the conservative nature of the models used, they likely overstate the amount of impact that will actually occur.
The M&A and Tetra Tech model investigations evaluated a range of variations in aquifer properties and Pit Lake conditions to determine a potential range of projected impacts. Results of the independent models indicate that the expected maximum drawdown impacts after 1,000 years, including changes in ET discharge and discharge to streamflow distant from the pit, are largely insensitive to changes in basic assumptions. Other variables such as long-term changes in precipitation recharge, or temperature or environmental changes that affect ET discharge, will likely have substantially more impact on groundwater levels in the areas distant from the pit than will be caused by pit inflows over the 1,000-year prediction period.

### 6.6 Selected Groundwater Report Summaries

Previous groundwater studies have been conducted for the Project Area and in surrounding areas. Data collection and analysis were conducted as early as 1970-1980 to support an earlier planned development of the Rosemont Project by the Anamax Mining Company. These studies provided the basis and baseline data for the current understanding of the groundwater flow system. Extensive drilling and aquifer testing by Rosemont provided more detailed site-specific geologic information and hydraulic property information that guided the flow model calibration. Analyses were also completed to provide estimates of recharge, riparian vegetation ET, and stream flows. The following brief descriptions of selected reports provide an indication of the breadth and history of previously completed studies.

**Analysis of Groundwater Development Program in the Empire Ranch Area** (July 7, 1975): This report was prepared by Harshbarger & Associates (1975) for Anamax Mining Company and presents the results of drilling and testing in the Empire Ranch area. The aquifer beneath Empire Ranch was the proposed source of water supply for the Rosemont Project when the holdings were owned by Anamax. The report provides extensive data on aquifer parameters, groundwater levels, and groundwater quality data for the basin-fill deposit aquifer in the Empire Ranch area.

**Hydrology and Geology of the Rosemont Area** (October 15, 1976): This report was a preliminary draft prepared by Harshbarger & Hargis (1976) for Anamax Mining Company. It was included in “An Environmental Inventory of the Rosemont Area in southern Arizona”, a compilation of studies prepared by the University of Arizona under contract with Anamax in support of an EIS for mining operations proposed at Rosemont in the 1970s. This report characterized surface water conditions, precipitation, vegetation, soil types and properties, geologic framework, groundwater levels, groundwater quality, and spring conditions.

**Summary of Hydrologic Monitoring Program, Empire Ranch and Rosemont areas, Arizona** (March 18, 1980): This was an annual report of the groundwater and spring monitoring program conducted for Anamax by Harshbarger & Associates (1980) in support of the Rosemont Project. Data presented in this report include water-level data from wells and core holes in the Rosemont and Empire Ranch areas, along with surface water flow monitoring data from Cienega Creek.
Summary of Hydrologic Monitoring Program, Empire Ranch and Rosemont areas, Arizona (February 3, 1981): This was an annual report of the groundwater and spring monitoring program conducted for Anamax by Harshbarger & Associates (1981) in support of the Rosemont Project. Data presented in this report include water level data from wells and core holes in the Rosemont and Empire Ranch areas, along with surface water flow monitoring data from Cienega Creek.

Hydrology and Geology of the Rosemont Addendum Area (July 19, 1981): This report by Hargis & Montgomery (1981) is an update to the Hargis & Montgomery (1976) report on hydrology and geology following the addition of 4 square miles of land to the Rosemont Project. Surface water conditions, precipitation, vegetation analyses, soil types and properties, geologic framework, groundwater levels, groundwater quality, and spring characteristics are included.

Summary of Hydrologic Monitoring Program, Empire Ranch and Rosemont areas, Arizona (May 12, 1982): This was an annual report of the groundwater and spring monitoring program conducted for Anamax by Hargis & Montgomery (1982) in support of the Rosemont Project. Data presented in this report include water level data from wells and core holes in the Rosemont and Empire Ranch areas, along with surface water flow monitoring data from Cienega Creek.

Water Adequacy Report, Stage One Development, Empirita Ranch Area (January 24, 1985): This report by M&A (1985) was prepared to demonstrate the adequacy of the water supply for a proposed residential development in the vicinity of lower Cienega Creek. The development did not occur, and portions of the property were later purchased by Pima County.

Starting in 2006, Rosemont conducted extensive investigations to characterize the groundwater system in support of the current EIS and for development of the M&A and Tetra Tech models. The following brief descriptions of major data collection activities illustrate the data that have been collected. In several cases, collections are on-going.

Results of Drilling, Construction, and Testing of Four Pit Characterization Wells (September 6, 2007): This report by M&A (2007) presents results of the first phase of groundwater characterization of the Rosemont area. In Phase I, four (4) wells in the pit area were drilled, completed, and tested. Lithologic and hydraulic properties were obtained and this information supported development of the Phase II characterization program.

Results of Phase 2 Hydrogeologic Investigations and Monitoring Program, Rosemont Project, Volumes I and II (February 26, 2009): This report by M&A (2009a) presents results of the second phase of groundwater characterization which involved the installation, aquifer testing, and sampling of 30 wells and piezometers in the vicinity of Rosemont Project. It also presents initial results of the Rosemont groundwater monitoring program that includes water level and water quality monitoring for all the Rosemont characterization wells, plus 36 pre-existing wells and core holes, and 18 seeps and springs within a 5-mile radius of the Open Pit.
Analysis of Long-Term, Multi-Well Aquifer Test During the Period November 2008 through January 2009 (May 21, 2009): This report by M&A (2009b) presents the results of a 30-day pumping test that involved the pumping of five (5) wells concurrently while monitoring drawdown and recovery at the five (5) pumped wells and at 46 observation wells and piezometers. The testing also involved the monitoring of flow rates at four springs near the Open Pit. The testing was conducted to assist with the local- and regional-scale three-dimensional characterization of the aquifer system in the Rosemont area to support development of a Rosemont groundwater flow model.

Groundwater Flow Modeling Conducted for Simulation of Proposed Rosemont Pit Dewatering and Post-Closure (October 28, 2009): This report by M&A (2009c) presents results of development, steady-state calibration, and verification of a preliminary version of the M&A groundwater flow model to simulate groundwater conditions prior to pit development, during pit dewatering, and for a 100-year post-closure period. The report presents results of future groundwater conditions, including pit inflow rates and drawdown distribution over time. It demonstrates that the pit will remain a hydraulic sink through and beyond the 100-year post-closure projection period. Model results indicated that drawdown from Rosemont dewatering will not reach Davidson Canyon or Cienega Creek during the 100-year projection period.

Davidson Canyon Hydrogeologic Conceptual Model and Assessment of Spring Impacts (July 2010): This report by Tetra Tech (2010a) evaluated the existing conditions within the Davidson Canyon watershed. The geology, surface water hydrology, groundwater hydrology, surface water and groundwater interactions, water quality, and springs were considered. These data and analyses lead to development of a conceptual model that describe the groundwater flow system and the important features that control potential impacts. The focus of potential impacts was on springs in upper Davidson Canyon and in the OAW reach. This report presented data and analyses that supported the interpretation that the OAW spring was disconnected from the regional groundwater flow system.

Groundwater Flow Modeling Conducted for Simulation of Proposed Rosemont Pit Dewatering and Post-Closure, Volumes 1 and 2, Revised Report (August 30, 2010): This report by M&A (2010) presents results of the final M&A groundwater flow model. The principal revisions incorporated into this revised model report include: 1) the model projection period was increased from 100 to 1,000 years after mine closure; 2) transient calibration of the model to the drawdown and recovery responses observed during the 30-day pumping test; and 3) representation of the fault systems around the pit. The report demonstrates that the pit will remain a hydraulic sink through and beyond the 1,000-year post-closure projection period. It indicates that although drawdown may reach Davidson Canyon and Cienega Creek, reduction in stream flow would be slight.

Regional Groundwater Flow Model, Rosemont Copper Project (November 2010): This report by Tetra Tech (2010b) presents the analyses, construction, and
calibration of the Tetra Tech groundwater flow model. This report summarized and consolidated a series of technical memorandums that were prepared to document the details of the modeling process. The final report and the supporting technical memorandums were peer reviewed by SRK, which resulted in model and documentation improvements. Predicted water level changes and impacts to streams, springs, and riparian areas were presented. An extensive suite of model sensitivity simulations was also completed to provide a range of potential impacts.

During preparation of the DEIS, the Forest Service made several requests for additional information on groundwater flow modeling conducted for the Project. Responses to these requests were provided by M&A and Tetra Tech. Technical memoranda responding to USFS comments dated April 5, 2011 were related to model boundary conditions, justification for use of an equivalent porous media model, selection of model calibration targets, representation of non-Rosemont groundwater pumping in the model, additional sensitivity analyses, and evaluation of the groundwater budget (M&A 2011a, b).

6.7 References


7 AQUATIC RESOURCES

This section focuses on the studies that have been completed in order to understand the potential impacts of the Rosemont Project on aquatic resources in the Study Area. The assessment of impacts to aquatic resources in this discussion is informed by the analyses described in the previous sections of this document. The impacts will vary both spatially and temporally. The Project will have a significant impact on surface water at the Project site and groundwater levels and flow patterns in the immediate Project vicinity. It will fully displace some springs and riparian vegetation that have historically existed or that presently exist at the Project site. These are impacts at the Project site that cannot be avoided if the mineral resource is to be developed. Outside of the Project site, aquatic resources will be indirectly and variably affected. However, the long-term impacts to aquatic resources resulting from the Project will be relatively minor compared to the changes associated with natural regional drought cycles, climate variability, and land and water use in, and immediately adjacent to, significant aquatic resources, such as the OAW reaches of Cienega Creek and lower Davidson Canyon. These other impacts not only include pumping patterns but consumptive use by riparian vegetation.

An evaluation of the effects of groundwater drawdown, stormwater impoundment, and stormwater runoff from the Rosemont Project on sensitive aquatic resources is also provided. The effects of impounding surface water will occur relatively early in the mine life, as Project facilities reduce the watershed tributary to Davidson Canyon and lower Cienega Creek.

Complexities associated with determining the timing and geographic extent of potential effects to aquatic resources is much greater when assessing the consequences of groundwater drawdown, particularly because the majority of the effects of groundwater drawdown are not predicted to occur for centuries. Predicting the responses of aquatic resources to relatively small perturbations so far into the future is problematic and warrants caution. As such, interpreting the results of regional groundwater models with respect to the potential effects of groundwater drawdown on aquatic resources must occur within an appropriate contextual framework. Detailed discussions of the potential impacts to specific aquatic resources, including riparian vegetation, designated OAW reaches, and seeps and springs, are provided within this framework. Potential impacts to sensitive aquatic species or designated critical habitat will be addressed in detail by the USFS and the U.S. Fish and Wildlife Service in the Biological Analysis and associated formal Endangered Species Act Section 7 consultation.
7.1 Application of Model Predictions

The majority of the predicted effects on aquatic resources from Project activities will result from groundwater drawdown. Quantitative predictions of the absolute levels of drawdown have been provided from three different models (M & A 2010, Myers 2010, Tetra Tech 2010b). Two of these were described in detail in Section 6 and the results of the third model, Myers 2010, were provided to the CNF by Pima County for consideration in the DEIS. Although these models include different assumptions, parameter values, and model structure, they all predict similar results. Quantitative predictions (i.e., the absolute level of groundwater drawdown) differ among the models, but the overall geographic extent, relative magnitude, and temporal dynamics of regional groundwater drawdown as a result of the proposed Pit Lake are similar. The fact that the three (3) models have produced similar qualitative results in part addresses the uncertainty associated with equifinality, the principle that environmental systems can be explained equally well by multiple models (see Konikow and Bredehoeft 1992, Beven 2002). The similar results supply confidence in the general conclusions of these models. The overall conclusion is that a dispersed decline in groundwater level will occur gradually over the course of centuries as a result of the Project, and could cause a small magnitude of drawdown (between 0 and 0.52 feet) in sensitive areas such as Cienega Creek. Moreover, sensitivity analyses performed by M&A (2010) and Tetra Tech (2010b) suggest that this general conclusion is consistent even when using large changes in parameter estimates, thus lending further confidence to the qualitative results of these models.

The general findings of the groundwater models provide a robust conclusion suggesting that the drawdown will be small in magnitude in the upper and lower Cienega Creek sections and will occur centuries after the cessation of mining activities. Quantitative predictions of groundwater drawdown and potential reductions in stream flow should not be used to provide an informative analysis of effects on aquatic resources. This notion is particularly relevant for predictions of regional groundwater declines and reductions in stream flow that occur centuries in the future. The ability of any model to predict small quantitative changes in drawdown and stream flow is limited, and reliance on predictions of small magnitude changes over long-time periods has been cautioned against (e.g., Faust et al. 1981, Konikow 1986, Konikow and Bredehoeft 1992, Oreskes et al. 1994, Parker et al. 1995).

Short-term predictions are more reliable. All three models predict groundwater drawdown in the immediate vicinity of the Open Pit with no groundwater drawdown effects in the sensitive aquatic areas of lower Davidson Canyon or Cienega Creek during the next 150 years. As indicated, quantitative estimates of predicted groundwater levels 1,000 years into the future should not be used in analyzing effects to aquatic resources, however, qualitative conclusions of the three groundwater models suggest that drawdown will be small in magnitude along Cienega Creek and lower Davidson Canyon centuries in the future.
Due to the limitations of providing reliable quantitative predictions of groundwater dynamics, there is no attempt herein to quantitatively assess effects to aquatic resources. Instead the focus is on qualitative evidence and the value of an adaptive strategy that includes monitoring efforts. By adopting this approach, it is neither suggested that the groundwater models are uninformative nor that there is no possibility that effects to aquatic resources could occur in the future due to groundwater withdrawal. Rather, this section attempts to provide a scientifically-informed, yet scientifically responsible, discussion of the possible effects of groundwater withdrawal and surface water impoundment at the Project site on down-gradient aquatic resources.

7.2 Riparian Vegetation

7.2.1 Extent of Vegetation

Both WestLand and Pima County provide an estimate of the extent and nature of riparian vegetation in the vicinity of the Project. Pima County provides an estimate concerning riparian vegetation along lower and upper Cienega Creek and Davidson Canyon, and WestLand conducted field surveys and studies along Davidson Canyon and Cienega Creek. Pima County’s mapping has been shown to overestimate the lateral extent of riparian vegetation in the Study Area (WestLand 2010). Pima County mapping is based on satellite analysis only and omits integral parameters in the analysis of riparian vegetation, including the documentation of species composition and the stature of riparian vegetation. Along Davidson Canyon Wash, WestLand (2011a) provides an analysis that integrates riparian species composition, satellite mapping, and vegetation structure to more accurately estimate the nature of the riparian vegetation. This information is integral to understanding the effects of Project activities on riparian vegetation because the effects of groundwater withdrawal and surface water diversion on riparian vegetation will be expressed through alterations in species composition in addition to changes in the extent and structure of vegetation.

Xeroriparian vegetation consists of riparian plant species that do not depend on consistent, shallow groundwater. Instead they rely on ephemeral flows and seasonal changes in soil moisture for water consumption. Mesoriparian vegetation consists of riparian species that rely, at least in part, on relatively shallow groundwater. Hydroriparian vegetation consists of riparian species that require consistent shallow sub-surface water. Thus, as one moves from xeroriparian to hydroriparian vegetation, the importance of consistent shallow groundwater to riparian species increases. Meso- and hydroriparian vegetation types are more vulnerable to variability and reductions in groundwater levels (e.g., Stromberg et al 1996). Impacts from mining activities on groundwater levels and surface water runoff are expected to be greater on this vegetation than on xeroriparian vegetation.

7.2.2 Davidson Canyon

Pima County mapping estimates that approximately 800 acres of hydro- or mesoriparian vegetation exists along Davidson Canyon Wash between its
confluences with Cienega Creek and Barrel Canyon, and along Barrel Canyon between its confluence with Davidson Canyon and where it crosses State Route 83. However, WestLand (2011a) shows that much of this vegetation consists of species that do not rely on consistent, shallow groundwater and that this vegetation is limited in structure and density. These observations suggest that much of the vegetation that occurs in Davidson Canyon and Barrel Canyon downstream of the proposed Project should be considered xeroriparian. Because WestLand (2011a) provides a more detailed analysis of riparian vegetation along Davidson Canyon, these data are relied upon versus those collected by Pima County.

WestLand (2011a) observes that much of Davidson Canyon is xeroriparian habitat, and that in upper Davidson Canyon mesoriparian vegetation occurs only in relatively small pockets. Mesoriparian vegetation is associated with lower Davidson Canyon near the confluence with Cienega Creek and in proximity of the Reach 2 Spring, farther away from the source of groundwater withdrawal and surface water impoundment than those in upper Davidson Canyon.

Groundwater drawdown at the Reach 2 Spring is predicted to be negligible by M&A (2012a) and minimal by Tetra Tech (2010b). At the confluence with Cienega Creek, groundwater drawdown is predicted to be negligible in analyses from both M&A (2012a) and Engineering Analytics (2012). These potential withdrawals are minor, and meso- and hydroriparian vegetation can persist within a range of depth to groundwater (e.g., Stromberg et al. 1996), particularly if they are not associated with substantial intra-annual fluctuations in groundwater level. The xeroriparian vegetation that occurs along Davidson Canyon is not expected to be impacted by groundwater drawdown, as they do not depend on shallow groundwater, but rely largely on seasonal precipitation events and soil moisture.

The impoundment of surface water will occur relatively early in mine life. Annual average runoff through Barrel and Davidson Canyons is predicted to be reduced by 47 percent at the confluence of Barrel and Davidson Canyons and to attenuate as the effect of the reduction of watershed size on runoff diminishes (e.g., with increased distance downstream from the Project) (Tetra Tech 2012). Thus, the xeroriparian and small pockets of more mesoriparian vegetation in upper Davidson and lower Barrel Canyons may be impacted by this reduction in stormwater runoff. Similarly, riparian vegetation within the OAW reach of Davidson Canyon could be affected by a predicted reduction of about 12 percent of average annual runoff (Tetra Tech 2012). The effect of this reduction on riparian vegetation is dependent on the degree to which the reduction in runoff will influence water storage in the channel alluvium, which supplies consistent shallow groundwater for meso- and hydroriparian species. The estimated reduction in average annual runoff in the downstream reach of Davidson Canyon is approximately 350 AF/year, or 12% of current flows. Preliminary calculations by Tetra Tech (M. Zeller 2012, personal communication) estimate that the average annual loss of recharge from stormwater runoff along the reach of Davidson Canyon between Barrel Canyon and Cienega Creek as a result of the Rosemont Project is approximately 84 AF/year, or a reduction of approximately 10%. Rosemont has developed a monitoring plan for this reach of Davidson Canyon.
that will provide additional data regarding surface water and groundwater dynamics. This monitoring plan is described further in the OAW section below.

### 7.2.3 Cienega Creek

Pima County mapping considers all of Cienega Creek, from the confluence with Gardner Canyon to the Pantano Dam, as having hydro- and mesoriparian vegetation. Preliminary observations of the species composition and structure of the riparian vegetation has been conducted by WestLand (2012). Much of the vegetation in upper and lower Cienega Creek is hydro and mesoriparian vegetation. However, particularly in lower Cienega Creek, hydro- and mesoriparian vegetation is interspersed with areas of xeroriparian vegetation (WestLand 2012). Also, between the downstream extent of the LCNCA and the Preserve, Cienega Creek is dominated by xeroriparian vegetation with only small pockets of mesoriparian vegetation. Thus, changes in DTW will affect riparian vegetation in these segments of Cienega Creek considerably less than in areas of upper and lower Cienega Creek.

Upper Cienega Creek may be influenced by potential changes in groundwater as a result of Project development. Changes due to stormwater management will not impact Upper Cienega Creek since there are no Project facilities or stormwater diversions sited upstream. Slight depth to groundwater reductions near the confluence with Gardner Canyon and near “The Narrows” (Appendix Figure 2-3) are predicted by both M&A (2012) and Tetra Tech (2010b) to occur centuries in the future. Riparian vegetation in Empire Gulch could be subject to greater groundwater drawdown, with total groundwater drawdown estimated between one (1) meter (3.28 feet) (M&A 2012a) and two (2) meters (6.56 feet) (Engineering Analytics 2012). While these maximal changes in groundwater depth are not predicted to occur until several hundred years after the end of mining, they could be significant if they result in drawdown past the roots of the hydro- and mesoriparian vegetation associated with Empire Spring. However, surface expression of groundwater in upper Cienega Creek and Empire Gulch suggest that current depth to groundwater in these areas is shallow. Gooding's willow (Salix gooddingii) and cottonwood (Populus fremontii), the two most common riparian trees at Empire Gulch and upper Cienega Creek, can persist within a range of depth to groundwater (Stromberg et al. 1996), suggesting that the estimated drawdown could have limited effect on the persistence of these riparian species.

Lower Cienega Creek has the potential to be affected by both groundwater withdrawal and a reduction in surface water runoff. Groundwater withdrawal is predicted by both M&A (2012a) and Engineering Analytics (2012) to be negligible along lower Cienega Creek. Average annual surface runoff is expected to decrease by approximately 12 percent at the confluence of Davidson Canyon and Cienega Creek (Tetra Tech 2012), and thus something less than 12% at the Pantano Dam. As described above, the reduction in groundwater recharge along the length of Davidson Canyon is estimated to be approximately 10%. In a report prepared by PAG (2003), the estimated portion of groundwater base flow within Cienega Creek downstream of Davidson Canyon that could be attributed to flows or groundwater in Davidson Canyon was 8 to 23%. This fractional contribution would be expected...
to be reduced by 10% (representing the reduction in groundwater recharge) as a result of the Rosemont Project, thereby reducing base flow in Cienega Creek by between 0.8 and 2.3%.

7.3 Outstanding Arizona Waters

The OAW reach of lower Davidson Canyon Wash extends from the Reach 2 spring downstream for approximately 3.0 miles to the confluence of Cienega Creek. The Reach 2 spring (i.e. the upstream start of the OAW) is located approximately 14.3 river miles downstream of the Rosemont Project compliance point dam.

Cienega Creek from the confluence with Gardner Canyon to the Pantano Dam is also considered an OAW. These OAW reaches are subject to both numerical and narrative surface water quality standards, prohibiting degradation of the quality of these waters.

7.3.1 Surface Water Quality Standards

Arizona surface water quality standards apply to Davidson Canyon and Cienega Creek (ADEQ 2009). These water quality standards are in place and enforced through Arizona law, and typically include criteria designed to protect aquatic life and wildlife as well as human health. The use designations for segments of each water body determine the applicable numeric standards. In general, for the waters in question, the strictest standards are chronic aquatic and wildlife, warm water standards for perennial waters, which are designed to protect aquatic organisms from adverse impacts caused by long-term exposure to selected contaminants. For several metals, the numeric aquatic and wildlife standards vary as a function of the hardness of the source water.

The headwater areas of Davidson Canyon are designated for the following uses: aquatic and wildlife ephemeral, partial (human) body contact, and agricultural livestock watering. The OAW reach at the downstream end of Davidson Canyon is divided into three segments. The upstream and downstream segments extend downstream from spring locations and are designated for the following uses: aquatic and wildlife warm water, full (human) body contact, fish consumption, and agricultural livestock watering. The intermediate segment, extending downstream from a confluence with a tributary wash, is designated for aquatic and wildlife ephemeral, partial (human) body contact, and agricultural livestock watering uses. The headwaters and OAW portions of Cienega Creek are designated for aquatic and wildlife warm water, full (human) body contact, fish consumption, and agricultural livestock watering uses.

7.3.2 Potential for Water Quality Effects to OAW

In addition to numeric surface water quality standards, the OAW designation of portions of Cienega Creek and Davidson Canyon provides further protection of those waters, prohibiting degradation of water quality in those waters. However, limited baseline monitoring for surface water quality in Davidson Canyon exists since Davidson Canyon no longer supports perennial reaches (Tetra Tech 2010a,
WestLand 2011a). A baseline stormwater quality monitoring program is ongoing to characterize existing on-site stormwater quality. Water samples are taken at monitoring locations in Barrel Canyon and in several tributaries of Barrel Canyon for each storm event that causes runoff. This sampling is designed to better establish the existing stormwater water quality in the area of the planned facility.

As a result of comments by ADEQ, Rosemont voluntarily developed a water monitoring plan for Davidson Canyon to complement and expand upon the current on-site stormwater monitoring. The Davidson Canyon monitoring plan has been designed to continue current measurement of flow and water quality at springs throughout Davidson Canyon and to implement surface water monitoring throughout Davidson Canyon and in Cienega Creek near its confluence with Davidson Canyon. The plan locates surface water monitoring and groundwater monitoring stations on State, Pima County, and private lands, so full implementation of the plan is dependent upon cooperation of the landowners.

Planned monitoring stations are located to characterize water quality for runoff generated from watershed areas upstream and downstream of the Project, and to provide quantification of longitudinal variations in flow and water quality throughout Davidson Canyon and into its confluence with Cienega Creek. The monitoring network is designed to measure watershed conditions prior to constructing the Project, during the period of active mining, and continuing past closure. Several monitoring stations in Davidson Canyon and Cienega Creek will combine surface and alluvial groundwater quantity and quality measurements to quantify potential surface and groundwater interactions. Water quality analyses will be performed on samples obtained from each runoff event in the watershed.

The data collected by the Davidson Canyon water monitoring plan will be used to augment existing information in the following ways:

- To increase the existing data available and to quantify flow and water quality in Davidson Canyon.
- To measure water quality in Barrel Canyon just downstream of the Project area, between Barrel Canyon and the OAW segment in Davidson Canyon just upstream of the OAW segment and in the Davidson Canyon and Cienega Creek OAW segments.

7.4 Seeps and Springs

M&A (2010) and Tetra Tech (2010b) provide information on regional hydrogeology of the Study Area, including a brief discussion on seeps and springs (hereafter referred to as springs). Springs in the Project area are considered to be potentially supplied by shallow, local, or perched aquifers (i.e., primarily supplied via local precipitation events and subsequent runoff) or from deeper, regional aquifers. In general, springs with a more local source are expected to have variable discharges (i.e., ranging from ephemeral to intermittent and potentially perennial) and variable temperatures (i.e., more subject to ambient air temperature effects), whereas those
springs supported by regional aquifers tend to have more stable and consistent discharges and temperatures at the point of issuance. The potential does exist that an individual spring’s hydrologic source may be some combination of these two source types (i.e., springs with more local sources that are temporarily or seasonally connected to the regional groundwater) (M&A 2010, Tetra Tech 2010b). In most cases, it is difficult to determine with certainty the hydrological source of a particular spring, although its source may be inferred based on a combination of physical, chemical, and potentially biological characteristics (M&A 2010).

Determining or estimating the hydrological source, based on the best scientific information to reduce the uncertainty associated with a spring's hydrological source to the fullest practical extent, is important in determining potential impacts to spring environments, because Project impacts to a particular spring will be determined primarily by its hydrological source and its location relative to Project activities (i.e., distance from the Open Pit) (M&A 2010).

Based on groundwater model outputs (M&A 2010, Tetra Tech 2010b), it was determined that springs supported by regional groundwater would be subject to impacts from the Open Pit and subsequent dewatering, with the degree of impact being greatest near the pit and diminishing with distance from the pit (M&A 2010). For those springs with a local source, it was estimated that impacts would occur only to springs located within the proposed mine footprint or in close proximity to the Open Pit (Tetra Tech 2010a). As described above, however, determining the hydrological source of a given spring is challenging.

An initial survey of data sources indicated that 94 springs, plus eleven (11) other man-made aquatic features (dams, adits, etc.) have or might discharge, for a total of 105, potentially occur within the Study Area. Information sources utilized for identifying these springs included USGS topographical maps, the USGS Geographical Name Information System (GNIS) database, the ADWR - Statement of Claimant database (as compiled by Pearce (2007) and USDA (2011)), and published reports (M&A 2009, 2010, Tetra Tech 2010a, WestLand 2007). Initially it was assumed that as many as 65% of the 105 spring features (USDA 2011) could be indirectly impacted by the Project based on their unknown hydrological sources or their existence and/or persistence on the landscape. It is recognized that springs that existed and were mapped decades ago may have ceased to discharge during present times (USDA 2011) and surveys have been performed by WestLand to verify the presence of currently recognized springs (WestLand 2012- in preparation). It was determined that ADWR records are unreliable for identifying spring locations due to the inaccuracies and imprecision associated with using the cadastral mapping system rather than discrete geographic points in space (USDA 2011).

Twenty-three (23) of these springs have been monitored monthly for discharge and water chemistry beginning between 2008 and 2010, and continuing to the present (M&A 2011). These monitored springs can serve as a baseline from which to characterize other springs. These springs range from those with a relatively constant discharge (e.g., Sycamore, Helvetia, and Rosemont springs) to those that have never flowed or only flowed ephemerally during the monitoring period (e.g.,
SW, SC-2, and Barrel springs). Ephemeral springs flow only for a short time in response to precipitation or stream flow events. Intermittent springs are sourced from local precipitation or stream flow events but can flow more continuously or longer after storm events due to an additional shallow alluvial or perched “aquifer” source.

As described above, 105 potential spring “features” were identified for evaluation, including springs in a somewhat natural state, those that have been modified (primarily for watering livestock), and several entirely man-made sites (e.g., dams, adits) that collect surface or groundwater. Four of these potential spring features were ultimately determined to be duplicates, leaving the overall total number of features at 101. Rosemont surveyed 69 (68%) of these features, which included 16 of the 23 previously monitored springs (M&A 2010b). The remaining 32 spring features were not surveyed due to access constraints, including extremely remote locations and lack of access to private property. Of the 69 surveyed spring features, 45 springs were located with some degree of confidence (65%) while the remaining 24 springs (35%) could not be located despite thorough searches in the vicinity of the mapped spring.

The significant percentage of springs that could not be located with confidence may be explained by several possibilities:

1. The spring was initially mapped incorrectly or the coordinates were recorded incorrectly. This is a possibility when data are initially entered or are subsequently transcribed from previous data sources.

2. The coordinates for the spring were too imprecise (in particular the cadastral locations from ADWR) and surveys simply failed to intersect the true location of the spring.

3. The spring no longer exists. In many cases these springs were mapped or claimed by individuals 30 to 60+ years ago, and a variety of changes could lead to the failure of small, localized springs. Impacts to upland areas (e.g., fire, cattle grazing) can lead to increased sedimentation of the stream channel thus burying a spring that once issued at the surface. In addition, prolonged drought conditions and changes in local water usage could lead to the cessation of surface flow at a particular spring.

4. The spring never existed and an illegitimate claim on its occurrence was submitted.

Thirty-six (36) of the 45 located spring features (80%) contained some sign of observable water during surveys, ranging from flowing water to pooled water (including above-ground spring boxes), and/or moist (seepy) soils. Of the seven (7) monitored spring features (M&A 2010b) that WestLand did not observe, six (6) are recorded to have observable surface water, at least during certain times of year. It should be noted that some of WestLand’s surveys occurred following the onset of
the summer rains and the presence of water may not represent the spring conditions during the greater part of the year (i.e., it may be dry).

Eighteen (18) of the 45 located spring features have been modified, (spring are considered modified if a majority of the spring feature is modified) primarily to accommodate livestock watering, and it appears that five (5) of these are currently non-functional. Modified spring features range from plumbed, above-ground cattle "drinkers" (e.g., Mueller Spring) to those that have been modified to contain the spring source and still support some more mesic-adapted vegetation through seepage (e.g., Ojo Blanco Spring).

Twelve (12) of the 45 located sites had spring features that indicated consistent enough surface expression to support wetland-type species (e.g., giant sedge, horsetail) and/or riparian species (sycamore, cottonwood, willow, ash). These range from small springs/seeps (e.g., Mudhole Spring) supporting a relatively small patch of vegetation (approximately 1.5 - 4m²) to those springs that support a riparian gallery forest ≥ 100 meters long (e.g., Sycamore, Zachendorph Springs).

Seven (7) springs are currently identified as occurring within the footprint of the Barrel Alternative and thus will be directly impacted by the Project. Based on survey results, one of these springs, Mueller Spring, is no longer functioning as there was no observable surface water at the above-ground cistern, and Peligro Adit (not a spring) and Bee Spring are highly modified and no longer function as natural spring sites. Of the remaining four (4) spring features within the proposed Project footprint, only one (1) supports a relatively constant discharge (Rosemont Spring), and it does not support notable wetland or riparian vegetation.

As mentioned, those springs that occur outside of the direct mine footprint have the potential to be indirectly impacted depending on their hydrologic source (local or regional groundwater) and distance from the mine. Forty-eight (48) springs, excluding those that will be directly impacted, occur within the combined 5-foot drawdown contour of the Tetra Tech and M&A models at the end of mining. Of these 48 spring features, eight (8) were not surveyed as part of this effort, 16 were surveyed but could not be located, and 24 springs were located with some degree of confidence. Eighteen (18) of the 24 located spring features (75%) within these drawdown contours had observable surface water, at least during surveys, and six (6) of the 24 (25%) located spring features had supported wetland-type and/or riparian vegetation. In short, of the 48 springs within the combined 5-ft drawdown contour at the end of mine life, 1/3 could not be found and of those that could be found, only a quarter of them supported wetland-type and/or riparian vegetation.

Seventy-eight (78) spring features, excluding those that will be directly impacted by the Project, occur within the combined 5-foot drawdown contour of the Tetra Tech and M&A models 150 years following the end of mining. Of these 78 spring features, 19 springs were not surveyed, 23 were surveyed but could not be located, and 36 springs were located with some degree of confidence. Twenty-eight (28) of the 36 located spring features (78%) within these drawdown contours had observable
surface water, at least during surveys, and ten (10) of the 36 (28%) located spring features supported wetland-type and/or riparian vegetation. Again, in short, of the 78 springs within the combined 5-ft drawdown contour 150 years after the end of mine life, nearly 1/3 could not be located, and of those that were located, only 10 (or just over one quarter) supported wetland-type and/or riparian vegetation.

7.5 Summary

- The effects of stormwater management will start relatively early in the mine life, as Project facilities, including Project site stormwater retention, reduce the watershed tributary to Davidson Canyon and lower Cienega Creek. However, the significance of reduced ephemeral stream flows on aquatic resources is limited due to the short duration and relative infrequency of stream flows.

- A qualitative evaluation of the effects of groundwater withdrawal on aquatic resources suggests that resources far from the proposed mine, such as Cienega Creek and lower Davidson Canyon, will experience relatively small magnitudes of groundwater drawdown that will not occur for centuries.

Much of the riparian vegetation in Davidson Canyon can be characterized as xeroriparian, and will be influenced by reductions in ephemeral flows, but minimally affected by groundwater withdrawal. Meso- and hydoriparian vegetation in lower Davidson Canyon and Cienega Creek could be affected by minimal predicted groundwater drawdown, but these effects will not occur for centuries. Vegetation along lower Davidson Canyon Wash and lower Cienega Creek will experience a small reduction in ephemeral flows from reduced surface water runoff. Efforts are underway to expand an ongoing program of on-site stormwater to include monitoring in the Davidson Canyon watershed.

The potential impacts of mining activities to seeps and springs will be largely determined by their hydrologic source and distance from the Open Pit. Although the hydrologic source of many of the located springs is currently unknown, many of the springs purported to exist in the vicinity of the proposed Project could not be located, indicating that the number of springs and seeps that could potentially be affected is much less than the DEIS assumed. In addition, a significant number of the spring features within the Study Area have been modified for livestock watering purposes, or otherwise do not support significant wetland or riparian vegetation.

7.6 References


8 CONCLUSIONS

This Integrated Watershed Summary report has summarized and described the results of, and relationships between, the investigations that were used to assess, quantify (to the extent possible), and minimize (to the extent practicable) the impacts from the Rosemont Project on water and aquatic resources at the Project site and in the Davidson Canyon/Cienega Creek watershed. These investigations were undertaken specifically to assess potential Project impacts, to enhance the design of Project facilities, and to provide information for the NEPA process.

Rosemont has conducted extensive site evaluation, field work, well construction and testing, mine rock characterization, water quality sampling and monitoring, hydrologic modeling, design, and documentation for more than five (5) years. This information has been presented in numerous (over 400) reports, memoranda, and other documents that are a part of the overall record for the Project and that are available for review. The information presented in this report is only a subset of the totality of modeling, monitoring and analyses conducted for this Project.

Mining is an activity that is vital to human well-being and our modern lifestyle. The Rosemont Project has been designed to avoid impacts through engineering and project design, and to minimize impacts to the natural environment while developing a significant copper resource. Rosemont is committed to ensuring that it complies with the multitude of Federal and State environmental and operational permits and approvals that are required for the Project. Rosemont has developed a robust monitoring program to detect changes in environmental conditions that could warrant operational changes to better protect the environment.

The magnitude of natural variations in the region has become apparent as improved data collection and analysis methods have been developed. These variations can limit the conclusions that may be drawn about Project impacts since these impacts are generally dwarfed by natural variations, especially for impacts occurring distant from the Project. However, these natural variations do provide the context and the perspective for interpreting the estimated Project impacts.

Major elements of the Project’s design relevant to protecting water resources include the following:

- The natural geochemistry of the vast majority of the rock to be excavated at the Project site is alkaline (over 90%). This natural characteristic of the site provides a primary level of protection for the Rosemont Project. The small percentage of potentially acid-generating material that is present at the site will be managed within the facilities by blending with acid-neutralizing materials.

- As a second level of protection for water quality, the mine facilities have been designed to limit seepage to extremely low rates (orders of magnitude lower than in older copper mines in Arizona) by using dry stack tailings technology, co-locating waste disposal sites, and utilizing stormwater diversions and concurrent reclamation techniques.
• The Open Pit will create a permanent hydraulic sink directing groundwater flow towards the pit within its capture zone; no outflow from the Pit Lake will occur due to terminal Pit Lake conditions. Any seepage from the waste rock and tailings storage area that is discharged within the extent of this capture zone will report to the Pit Lake.

• Groundwater levels surrounding the pit will decline within two (2) to three (3) miles of the pit, with the area affected by groundwater decline gradually spreading as the drawdown attenuates over a larger area for many years after the mine closes. However, these water level declines are very small in the critical environmental areas along Cienega Creek and the Outstanding Arizona Water (OAW) section of Davidson Creek. Declines are estimated at less than one (1) foot, even after 1,000 years after the cessation of mine dewatering.

• Reductions in storm-induced surface water flows will be substantial in the small ephemeral drainages immediately downstream of the Project. However, for the larger Davidson Canyon watershed and the much larger Cienega Creek watershed, the flow reductions will represent a small incremental change, particularly given the wide natural variability in precipitation and surface water flow. The range of post-mining flows will remain within the pre-mining range of flows based on these natural variations.

• Reductions in sediment load will be substantial for the small drainages in which the Project facilities are located. However, for the larger Davidson Canyon and Cienega Creek watersheds, these reductions in sediment load will be quite small.

• Effects on aquatic resources in the immediate Project Area will be substantial, resulting in almost complete relocation, reconstruction, or displacement of existing stream channels and springs within the area covered by Project facilities. Outside the Project site, however, effects on aquatic resources will be minimal and within the range of natural variations caused by drought cycles and resulting vegetative changes.

• The Project-induced changes in surface water, water quality, sedimentation, and groundwater will be small outside the immediate Project Area. Impacts will be further reduced through implementation of the mitigation elements described by the USFS in the DEIS and of a mitigation plan which will be required by the USACE.

The design of the Project facilities has been guided by Rosemont's desire to plan, build, operate, and reclaim an exemplary hard rock mine and mineral processing facility. The results of the analyses described in this report have been used to improve the Project so that it will have limited and manageable impacts on water and other resources within the Cienega Creek/Davidson Canyon watersheds. Agencies with regulatory authority over the Project, with extensive input from
neighboring landowners and other interested parties, have been able to influence the means and methods that have been, and will continue to be, used to incorporate environmental considerations into the Project.

The analyses that have been conducted, in conjunction with the monitoring and maintenance requirements established through the Aquifer Protection Program and through applicable stormwater regulations will ensure that the Rosemont Project remains in compliance with groundwater, surface water, and downstream outstanding resource water standards through construction, operation, reclamation, closure, and post closure. The monitoring activities and infrastructure developed during the Project planning and permitting process will not only assure Project compliance with all legal and regulatory requirements, but will also be invaluable in providing data that will be shared with all of the regional public entities tasked with managing and protecting natural resource values in the years to come.

In summary, the studies of geochemistry, seepage, groundwater, surface water, water quality, sedimentation, and aquatic resources have been extensive, and were conducted by qualified engineers, hydrologists, geologists, and other environmental scientists under Rosemont’s direction. These studies have been thoroughly peer-reviewed by additional qualified consultants working for the USFS CNF. Results of the studies, and refinements resulting from USFS input and from the NEPA cooperating agencies, have been incorporated into the design of the Project to ensure that important natural resources in the regional environment will be monitored and protected.
FIGURE APPENDIX
EXPLANATION

- Study Area
- Extent of Ultimate Pit
- Mining Claims

REGIONAL SETTING

FIGURE 2-1
EXPLANATION

- Proposed Rosemont Open Pit
- Tailings and Waste Rock Facilities
- Subwatersheds
- Active Groundwater Flow Model Boundary
- Riparian Vegetation (Westland, 2012*)
- Sonora Plain

Land Ownership

- Bureau of Land Management
- Coronado National Forest
- Private Land
- State Trust Land
- Pima County
- Rosemont Patent and Private

*NOTE: Riparian areas were only mapped for the Project Area, Davidson Canyon, Cienega Creek, and Gardner Canyon

GISProjects\1332.34\Landuse.mxd15June2012 UTM NAD 83 Zone 12 N

FIGURE 2-2

LAND USE
The diagram illustrates various geographical features and hydrological aspects of the Cienega Creek area. Key elements include:

- **Hydrogeologic Section Line**
- **Perennial Spring or Seep**
- **Hydrography**
- **Proposed Rosemont Open Pit**
- **Waste Rock Facilities**
- **Tailings Facilities**
- **Extent of Model Domain**
- **Cienega Creek Natural Preserve**
- **Las Cienagas National Conservation Area (NCA)**

The map highlights the Cienega Creek Natural Preserve and Las Cienagas National Conservation Area (NCA) within the broader context of the Cienega Creek Watershed and the Tucson Basin. Various geographic features such as the Upper and Lower Cienega Creek Basins, the Santa Rita Mountains, and the Empire Mountains are also indicated. The map provides a comprehensive view of the area's hydrological and geological features, including perennial and ephemeral drainage channels, springs, and seeps.
EXPLANATION

- Weather Stations
- Study Area
- Proposed Rosemont Open Pit

Precipitation (inches/year)

- < 15
- 15.1 - 20
- 20.1 - 25
- > 25

* Note: Nogales Weather Station includes location for Nogales 6N.
Patagonia Weather Station includes location for Patagonia 2.

Regional Precipitation and Weather Stations

Source: PRISM (Parameter-elevation Regressions on Independent Slopes Model) climate mapping system (PRISM Climate Group, Oregon State University, http://prism.oregonstate.edu, created 31 Oct 2008)
EXPLANATION

- Location of Observed Groundwater Level
- 4,200 Contour of Water Table Groundwater Level Altitude, in feet above mean sea level
- Large Hydraulic Gradient Area
- Direction of Groundwater Flow
- Perennial Stream Reach
- Ephemeral Drainage Channel

Cienega Creek Watershed
Proposed Rosemont Open Pit
Waste Rock Facilities
Tailings Facilities
Extent of Model Domain

MEASURED GROUNDWATER LEVEL ALTITUDES FOR THE MODEL STUDY AREA

FIGURE 2-9
A
GAINING STREAM

B
LOSEING STREAM

C
LOSEING STREAM THAT IS DISCONNECTED FROM THE WATER TABLE

(Modified from Winter and Others, 1998)
EXPLANATION

- PAG Well Location
- Perennial Stream Reach (Pima, 2000)
- Ephemeral Stream Reach (Pima, 2000)
- Cienega Creek Natural Preserve

FIGURE 2-16

LOWER CIENEGA CREEK FLOWING REACHES AND MONITORING LOCATIONS
NOTES:


The period of record ranged from June 1984 through June 2011.

**) Land surface elevation was obtained from a ground surface elevation survey conducted by the Arizona Department of Environmental Quality (ADEQ, 2003), a handheld global positioning system elevation survey conducted by Engineering Analytics, Inc. in April 2012, and/or a 10-meter digital elevation model (DEM) obtained from the United States Geological Survey’s Seamless Data Warehouse.

File: P:\110195\2.0\2.6\SectionAlongLowerCienegaCreek.grf

FIGURE 2-17. GENERALIZED CROSS SECTION ALONG LOWER CIENEGA CREEK
EXPLANATION

△ Hydrograph Location

~ Perennial Spring or Seep

4,800 Simulated Contour of Groundwater Level Altitude, in feet above mean sea level

← Direction of Groundwater Movement

Groundwater Surface Section Line

Hypothetical Stream Reach (Pima, 2000)

Ephemeral Drainage Channel (Pima, 2000)

Approximate Boundary between Upper and Lower Cienega Creek Basins

Cienega Creek Watershed

Proposal Rosemont Open Pit

Tailings Facilities

Extent of Model Domain

SIMULATED PRE-MINING STEADY-STATE CONTOURS OF GROUNDWATER LEVEL ALTITUDE FOR THE MODEL STUDY AREA TETRA TECH MODEL

FIGURE 6-2
**EXPLANATION**

- **Perennial Spring or Seep**
- **Perennial Stream Reach (Pima, 2000)**
- **Ephemeral Drainage Channel (Pima, 2000)**
- **Approximates Boundary between Upper and Lower Cienega Creek Basins**
- **Cienega Creek Watershed**
- **Proposed Rosemont Open Pit**
- **Waste Rock Facilities**
- **Tailings Facilities**
- **Extent of Model Domain**

**GROUNDWATER BALANCE RATES**

<table>
<thead>
<tr>
<th>TIME</th>
<th>INFLOW (acre-feet per year)</th>
<th>OUTFLOW (acre-feet per year)</th>
<th>DECREASE IN GROUNDWATER STORAGE (acre-feet per year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-Mining</td>
<td>9,907</td>
<td>9,907</td>
<td>0</td>
</tr>
<tr>
<td>End of Mining</td>
<td>9,907</td>
<td>10,175</td>
<td>243</td>
</tr>
<tr>
<td>150 Years Post-Mining</td>
<td>10,110</td>
<td>10,146</td>
<td>27</td>
</tr>
<tr>
<td>1,000 Years Post-Mining</td>
<td>10,098</td>
<td>10,097</td>
<td>0</td>
</tr>
</tbody>
</table>

**SIMULATED GROUNDWATER BALANCE FOR PRE-MINING, END-OF-MINING, AND POST-MINING AT 150 AND 1,000 YEARS TETRA TECH MODEL**

**FIGURE 6-4**

**FILE NAME**: GIS\1232.34\Premining_SimGW_Balance_TETRA TECH\11June2012
Projected Decrease in Stream Base Flow at Reach #2 Spring in Davidson Canyon:
M&A = 0 cfs
Tetra Tech = 0 cfs

Projected Decrease in Stream Base Flow at USGS Gage #09484550:
M&A = 0 cfs
Tetra Tech = 0 cfs

EXPLANATION
- Perennial Spring or Seep
- Contour of Projected Drawdown, in feet (Montgomery & Associates, 2010)
- Contour of Projected Drawdown, in feet (Tetra Tech, 2010b)
- Perennial Stream Reach (Pima, 2000)
- Ephemeral Drainage Channel (Pima, 2000)
- Approximate Boundary between Upper and Lower Cienega Creek Basins
- Cienega Creek Watershed
- Proposed Rosemont Open Pit
- Waste Rock Facilities
- Tailings Facilities
- Extent of Model Domain

PROJECTED GROUNDWATER LEVEL DRAWDOWN AT END OF 22-YEAR MINING OPERATIONS
M&A AND TETRA TECH MODELS

FIGURE 6-7
Projected Decrease in Stream Base Flow at USGS Gage #09484550:
M&A = 0 cfs
Tetra Tech = 0.03 cfs

Projected Decrease in Stream Base Flow at Reach #2 Spring in Davidson Canyon:
M&A = 0.02 cfs
Tetra Tech = 0 cfs

EXPLANATION
- Perennial Spring or Seep
- Contour of Projected Drawdown, in feet (Montgomery & Associates, 2010)
- Contour of Projected Drawdown, in feet (Tetra Tech, 2010b)
- Perennial Stream Reach (Pima, 2000)
- Ephemeral Drainage Channel (Pima, 2000)
- Approximate Boundary between Upper and Lower Cienega Creek Basins
- Cienega Creek Watershed
- Proposed Rosemont Open Pit
- Waste Rock Facilities
- Tailings Facilities
- Extent of Model Domain

PROJECTED GROUNDWATER LEVEL DRAWDOWN
150 YEARS AFTER THE END OF MINING OPERATIONS
M&A AND TETRA TECH MODELS
FIGURE 6-8
Projected Decrease in Stream Base Flow at USGS Gage #09484550:

- Montgomery & Associates (M&A) = 0.02 cfs
- Tetra Tech = 0.08 cfs

Projected Decrease in Stream Base Flow at Reach #2 Spring in Davidson Canyon:

- M&A = 0.04 cfs
- Tetra Tech = 0.01 cfs

EXPLANATION

- Perennial Spring or Seep
- Contour of Projected Drawdown, in feet (Montgomery & Associates, 2010)
- Contour of Projected Drawdown, in feet (Tetra Tech, 2010b)
- Perennial Stream Reach (Pima, 2000)
- Ephemeral Drainage Channel (Pima, 2000)
- Approximate Boundary between Upper and Lower Cienega Creek Basins
- Cienega Creek Watershed
- Proposed Rosemont Open Pit
- Waste Rock Facilities
- Tailings Facilities
- Extent of Model Domain

PROJECTED GROUNDWATER LEVEL DRAWDOWN
1,000 YEARS AFTER THE END OF MINING OPERATIONS
M&A AND TETRA TECH MODELS

FIGURE 6-9
EXPLANATION

- Direction of Groundwater Movement
- Contour of Projected Groundwater Level Altitude, in feet above mean sea level
- Groundwater Surface Section Line
- Perennial Stream Reach (Pima, 2000)
- Ephemeral Drainage Channel (Pima, 2000)
- Approximate Boundary between Upper and Lower Cienega Creek Basins
- Cienega Creek Watershed
- Proposed Rosemont Open Pit
- Waste Rock Facilities
- Tailings Facilities
- Extent of Model Domain
EXPLANATION

- Land Surface
- Planned Pit
- Simulated Pre-Mining Groundwater Level Surface
- Projected Groundwater Level Surface at End of Mining
- Projected Groundwater Level Surface 150 Years After End of Mining
- Projected Groundwater Level Surface 1,000 Years After End of Mining
- Direction of Groundwater Movement
- Approximate Location of Hydrograph (dashed where projected)

| Gal: Recent Alluvium | QTg: Basin Fill | Bedrock |

Confluence of Davidson Canyon and Lower Cienega Creek

Approximate groundwater flow divide, 150 to 1,000 years post-mining

Vertical exaggeration = 5:1

SECTION OF SIMULATED GROUNDWATER LEVEL SURFACE PRE- AND POST-MINING FOR TRANSECT X-X’ FOR M&A MODEL

FIGURE 6-12
**EXPLANATION**

- Land Surface
- Planned Pit
- Simulated Pre-Mining Groundwater Level Surface
- Projected Groundwater Level Surface at End of Mining
- Projected Groundwater Level Surface 150 Years After End of Mining
- Projected Groundwater Level Surface 1,000 Years After End of Mining
- Direction of Groundwater Movement
- Approximate Location of Hydrograph
- Qal: Recent Alluvium
- QTg: Basin Fill
- Bedrock

**SECTION OF SIMULATED GROUNDWATER LEVEL SURFACE PRE- AND POST-MINING FOR TRANSECT Y-Y’ FOR M&A MODEL**

**FIGURE 6-13**
**EXPLANATION**

- Land Surface
- Planned Pit
- Simulated Pre-Mining Groundwater Level Surface
- Projected Groundwater Level Surface at End of Mining
- Projected Groundwater Level Surface 150 Years After End of Mining
- Projected Groundwater Level Surface 1,000 Years After End of Mining
- Direction of Groundwater Movement
- Approximate Location of Hydrograph (dashed where projected)

Legend:
- Qal: Recent Alluvium
- QTg: Basin Fill
- Bedrock

**Date:** 23 May 2012    **File path:** S:\1232.34\Rev2\SectionX_TT.grf

**SECTION OF SIMULATED GROUNDWATER LEVEL SURFACE PRE- AND POST-MINING FOR TRANSECT X-X’ FOR TETRA TECH MODEL**

**FIGURE 6-15**

*Vertical exaggeration = 5:1*
**EXPLANATION**

- Land Surface
- Planned Pit
- Simulated Pre-Mining Groundwater Level Surface
- Projected Groundwater Level Surface at End of Mining
- Projected Groundwater Level Surface 150 Years After End of Mining
- Projected Groundwater Level Surface 1,000 Years After End of Mining
- Direction of Groundwater Movement
- Approximate Location of Hydrograph
- Qal: Recent Alluvium
- QTg: Basin Fill
- Bedrock

**HYDROGRAPH OF PROJECTED DRAWDOWN AT CENEGA CREEK GAGING STATION REHABILITEC (Tetra Tech, 2016)**

**SECTION OF SIMULATED GROUNDWATER LEVEL SURFACE PRE- AND POST-MINING FOR TRANSECT Y-Y’ FOR TETRA TECH MODEL**

**FIGURE 6-16**

**Cienega Creek Gaging Station 2**

**Qal: Recent Alluvium**

**QTg: Basin Fill**

**Bedrock**

**Direction of Groundwater Movement**

**Approximate groundwater flow divide, 150 to 1,000 years post-mining**

**Vertical exaggeration = 5:1**

**DISTANCE FROM CENTER OF PIT, in miles**

**ELEVATION, in feet above mean sea level (msl)**

**Date: 23May2012  01/1210 349Rev3SectionY_TT.pf**
EXPLANATION

- Land Surface
- Planned Pit
- Simulated Pre-Mining Groundwater Level Surface
- Projected Groundwater Level Surface at End of Mining
- Projected Groundwater Level Surface 150 Years After End of Mining
- Projected Groundwater Level Surface 1,000 Years After End of Mining
- Direction of Groundwater Movement
- Approximate Location of Hydrograph (dashed where projected)

| Qal: Recent Alluvium | QTg1: Basin Fill | QTg: Basin Fill | QTg2: Cemented Basin Fill | Bedrock |

Vertical exaggeration = 5:1

SECTION OF SIMULATED GROUNDWATER LEVEL SURFACE PRE- AND POST-MINING FOR TRANSECT Z-Z' FOR TETRA TECH MODEL

FIGURE 6-17

Date: 23May2012   File path: S:\Projects\1232.34\GWL_sectionZ.grf   Data from UTM NAD 83, Zone 12, feet