Overview

Natural water features are scarce and important to tribes, wildlife, residents, and recreationists. The Resolution Copper Project could affect both water availability and quality in several ways.

In order to construct mine infrastructure, dewatering of the deep groundwater system below Oak Flat began in 2009, and would continue through mining. As the block-caving and subsidence progress, eventually the effects of dewatering would extend to overlying aquifers as well. Changes in these aquifers, as well as capture of runoff by mine facilities and the subsidence area, could in turn affect springs, flowing streams, and riparian areas.

In addition to loss of water, water quality changes could result from stormwater runoff, tailings seepage, or exposure of rock in the block-cave zone.

3.7 Water Resources

3.7.1 Groundwater Quantity and Groundwater-Dependent Ecosystems

3.7.1.1 Introduction

This section describes the analysis and predicted effects on the groundwater dependent ecosystems (GDEs), public and private water supply wells, and subsidence from dewatering.

Resolution Copper has monitored the quantity and quality of water in streams, springs, and riparian areas as far back as 2003, and dozens of wells have been installed for the sole purpose of understanding the local and regional hydrogeology, not just below Oak Flat but throughout the region. To assess impacts on groundwater resources, the long history of baseline data collection was considered holistically alongside

- the large geographic area involved;
- the complex geology and multiple aquifers, including the incorporation of the block-caving itself, which would fundamentally alter the geological structure of these aquifers over time;
- the long time frames involved for mining (decades) as well as the time for the hydrology to adjust to these changes (hundreds of years); and
- the fact that even relatively small changes in water levels can have large effects on natural systems.

A numerical groundwater flow model is the best available tool to assess groundwater impacts.

Like all modeling, the Resolution Copper Mine groundwater model requires great care to construct, calibrate, and properly interpret. The Forest Service collaborated with a broad spectrum of agencies and professionals over several years to assess the groundwater modeling. This diverse group (see section 3.7.1.2) vetted the construction, calibration, and use of the groundwater model, and focused on understanding any sensitive areas with the potential to be negatively affected, including Devil's Canyon, Oak Flat, Mineral Creek, Queen Creek, Telegraph Canyon, Arnett Creek, and springs located across the landscape. The Forest Service refers to such areas as GDEs, which are "communities of plants, animals, and other organisms whose extent and life processes are dependent on access to or discharge of groundwater" (U.S. Forest Service 2012b).

Just as much care was taken to understand the limitations of the groundwater model. Specific model limitations are described in section 3.7.1.2 and reflect a careful assessment of how the results of a groundwater model can reasonably be used, given the uncertainties involved. This reflects a careful assessment of how the results of a groundwater model can reasonably be used, given the uncertainties involved.

The Forest Service undertook a two-part strategy to manage this uncertainty. First, any GDEs were assumed to be connected with the regional aquifers (and therefore potentially affected by the mine) unless direct evidence existed to indicate otherwise. Second, regardless of what the model might predict, a monitoring plan would be implemented to ensure that actual real-world impacts are fully observed and understood.

This section analyzes impacts on GDEs and local water supplies from dewatering and block-caving, the amount of water that would be used by each alternative, the impacts from pumping of the mine water supply from the Desert Wellfield, and the potential for ground subsidence to occur because of groundwater pumping. Some aspects of the analysis are briefly summarized in this section. Additional details not included here are in the project record (Newell and Garrett 2018d).

3.7.1.2 Analysis Methodology, Assumptions, and Uncertain and Unknown Information

Analysis Area

The analysis area for assessing impacts on groundwater quantity and GDEs comprises the groundwater model boundary for the mine site (figure 3.7.1-1) as well as the groundwater model boundary for the East Salt River valley model (figure 3.7.1-2). Models were run up to 1,000 years in the future, but as described below quantitative results were reasonably applied up to 200 years in the future.

Modeling Process

In September 2017, the Tonto National Forest convened a multidisciplinary team of professionals, referred to as the Groundwater Modeling Workgroup. The Groundwater Modeling Workgroup included Tonto National Forest and Washington-level Forest Service hydrologists, the groundwater modeling experts on the project NEPA team, representatives from ADWR, AGFD, the EPA, the San Carlos Apache Tribe, and Resolution Copper and its contractors. This group included not only hydrologists working on the groundwater model itself, but also the biologists and hydrologists who have conducted monitoring in the field and are knowledgeable about the springs, streams, and riparian systems in the project vicinity. The Groundwater Modeling Workgroup tackled three major tasks: defining sensitive areas, evaluating the model and assisting the Tonto National Forest in making key decisions on model construction and methodology, and assisting the Tonto National Forest in making key decisions on how to use and present model results.

SELECTED MODEL APPROACH

The groundwater model selected for the project is the MODFLOW-SURFACT program, selected in part because of the ability to change aquifer properties over time because of the effects of the block-caving. The assessment of the model by the Groundwater Modeling Workgroup, as well as the assessment of the conceptual hydrologic model upon which the numerical model is based, can be found in the technical memorandum summarizing the workgroup process and conclusions (BGC Engineering USA Inc. 2018a). A description of the model construction can be found in WSP USA (2019). Predictive and sensitivity results can be found in Meza-Cuadra et al. (2018b) and Meza-Cuadra et al. (2018c).

IDENTIFYING AND DEFINING GROUNDWATER-DEPENDENT ECOSYSTEMS

The Groundwater Modeling Workgroup developed the list of GDEs based on multiple sources of information; it ultimately evaluated in detail 67 different locations (Garrett 2018d). Any riparian vegetation or aquatic habitat around the GDEs is considered an integral part of the GDE.

The source of water for each GDE is important. Most of the 67 GDE locations the Groundwater Modeling Workgroup assessed were identified because of the persistent presence of water, year-to-year and season-to-season. In most cases this persistent water suggests a groundwater connection; however, the specific type of groundwater is important for predicting impacts on GDEs. There are generally two regional aquifers in the area: the Apache Leap Tuff, and the deep groundwater system. Any GDEs tied to these two aquifers have the potential to be impacted by mining. The deep groundwater system is being and would continue to be actively dewatered, and once

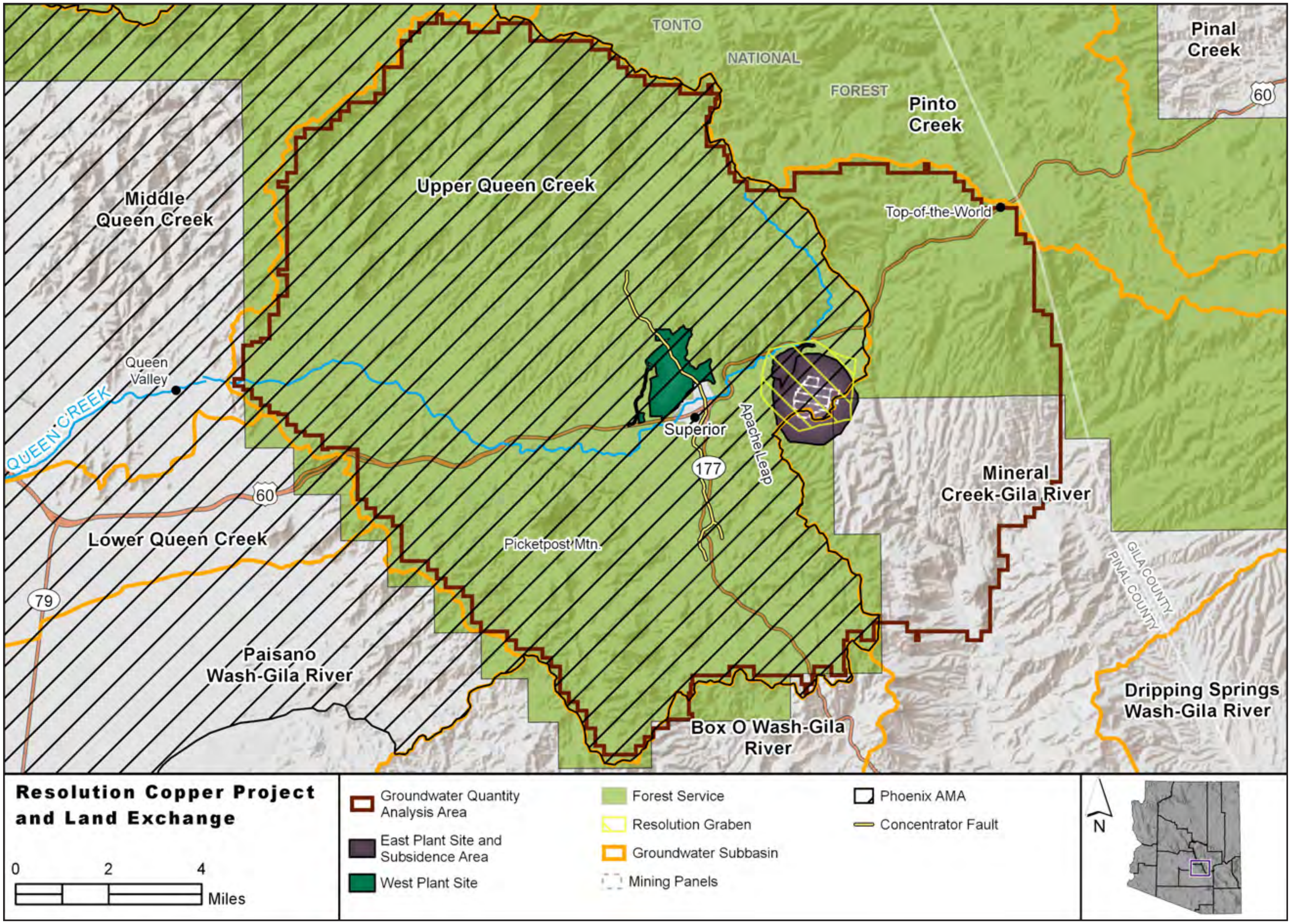


Figure 3.7.1-1. Overview of groundwater modeling analysis area

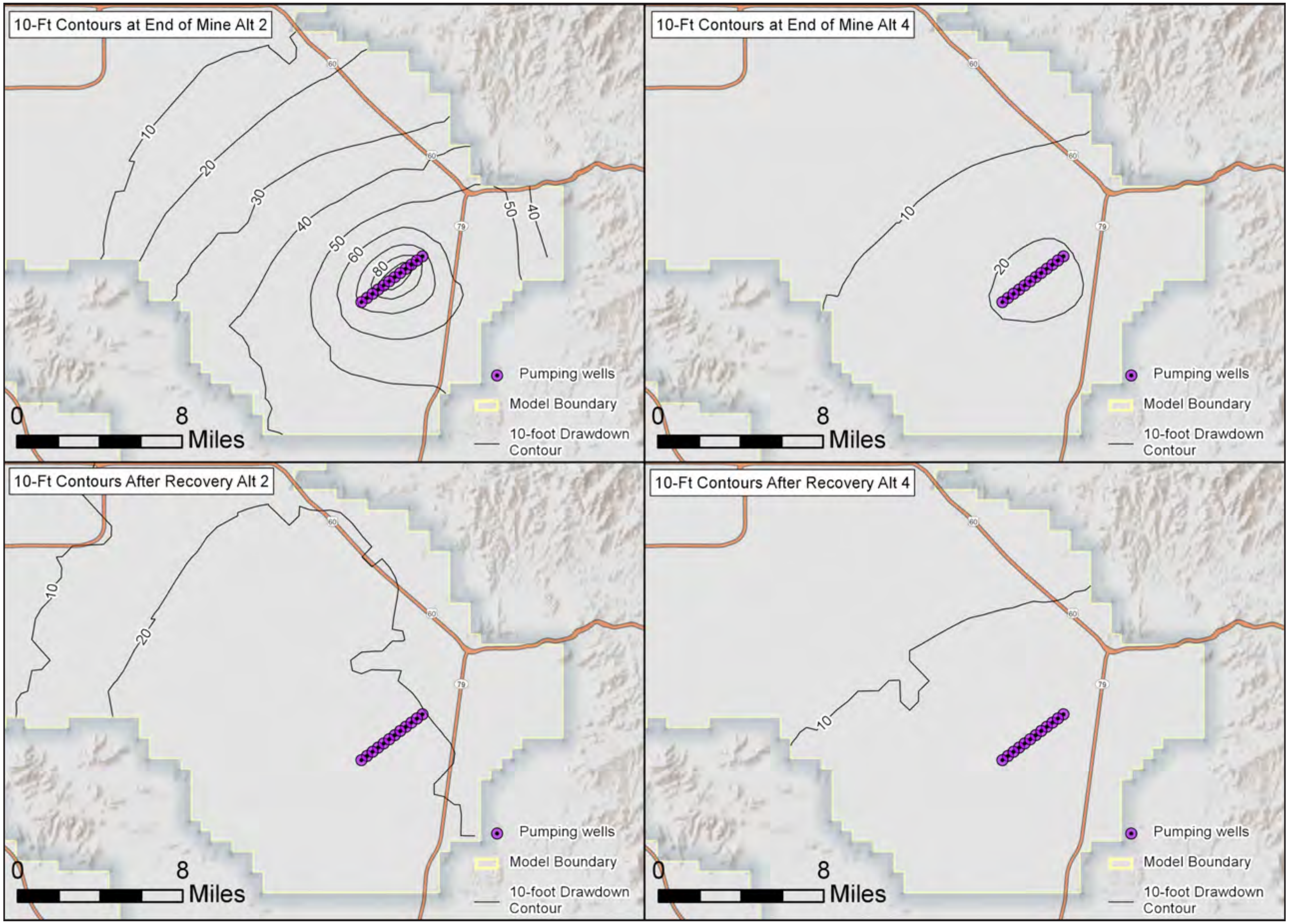


Figure 3.7.1-2. Desert Wellfield modeling analysis area and maximum (Alternative 2, left) and minimum (Alternative 4, right) modeled pumping impacts

block-caving begins the Apache Leap Tuff would begin to dewater as well.

In addition to the regional groundwater systems, another type of groundwater results from precipitation that is temporarily stored in near-surface fractures or alluvial sediments. While temporary, this water still may persist over many months or even years as it slowly percolates back to springs or streams or is lost to evapotranspiration. These near-surface features are perched well above and are hydraulically disconnected from both the Apache Leap Tuff aquifer and the deep groundwater system; therefore, this groundwater source does not have the potential to be impacted by mine dewatering. However, changes in the surface watershed could still affect these shallow, perched groundwater sources. Predictions of reductions in runoff caused by changes in the watershed are discussed in section 3.7.3; these changes are also incorporated into this section (3.7.1) in order to clearly identify all the combined effects that could reduce water available for a GDE.

Identifying whether a GDE derives flow from the deep groundwater system, the Apache Leap Tuff, or shallow, perched aquifers was a key part of the Groundwater Modeling Workgroup's efforts. A number of lines of evidence helped determine the most likely groundwater source for a number of GDEs: hydrologic and geological framework, inorganic water quality, isotopes, riparian vegetation, and the flow rate or presence of water. However, many more GDEs had little or no evidence to consider, or the evidence was contradictory. In these cases the Forest Service policy is to assume that a GDE has the potential to be impacted (Garrett 2018d; Newell and Garrett 2018a). In addition to identifying GDEs, the Groundwater Modeling Workgroup identified three key public water supply areas to assess for potential impacts from the mine.

EVALUATING THE MODEL AND MODELING APPROACH

The Groundwater Modeling Workgroup reviewed the work done by WSP (a contractor of Resolution Copper) and assisted the Tonto National Forest in determining the appropriate methodologies and approaches that should be used. In practice, this consisted of an open, iterative process by which the Groundwater Modeling Workgroup requested data, the data were prepared and presented, and the results and meaning were discussed in Groundwater Modeling Workgroup meetings. All fundamental parts of developing a numerical groundwater flow model were discussed: developing a conceptual model, numerical model construction, model calibration, model sensitivity, model predictive runs, and model documentation. The results and conclusions of the Groundwater Modeling Workgroup's effort are documented in a final Groundwater Modeling Workgroup report (BGC Engineering USA Inc. 2018d).

The conceptual understanding of the hydrogeology and the geological framework of the area is fundamental to developing a valid groundwater flow model. A separate but related workgroup focused specifically on the geological data collection and interpretation, and the subsidence modeling. The results of this workgroup are discussed in Section 3.2, Geology, Minerals, and Subsidence, and documented in a final workgroup report (BGC Engineering USA Inc. 2018a). Several team members collaborated in both workgroups and facilitated sharing of information.

After receiving input from the Groundwater Modeling Workgroup, the Forest Service and its contractors ultimately determined that WSP's groundwater model, as amended and clarified over the course of the workgroup meetings, is a reasonable and appropriate tool for assessing hydrologic changes.

KEY DECISION ON USE OF MODEL RESULTS – BASELINE CONDITIONS

The Groundwater Modeling Workgroup made four specific key decisions about how the groundwater modeling results would be used:

1. Define appropriate baseline conditions,
2. Select an appropriate time frame for model output,
3. Select an appropriate precision for model output, and
4. Develop a strategy to deal with uncertainties.

The first key decision is how potential impacts from the mine operations are to be defined. With many resources, this is a simple task: predicted conditions during or after mine operations are compared with the affected environment, and the difference is considered the “impact” caused by the mine. In this case, renewed dewatering of the deep groundwater system has taken place since 2009 to allow construction and maintenance of mine infrastructure; this is described further in “Current and Ongoing Pumping and Water Level Trends” later in this section. This dewatering pumping is legal and has been properly permitted by the ADWR (see the “Current and Ongoing Pumping and Water Level Trends” section). Resolution Copper is continuing this dewatering and would continue dewatering throughout the mine life. Further, even if the mine is not operated, Resolution Copper would continue legally dewatering to preserve its infrastructure investment.

The Tonto National Forest made the decision to handle this situation in two ways. First, continued dewatering of the mine would be included as part of the no action alternative. Second, the Tonto National Forest is ensuring that any effects of the past dewatering are disclosed as ongoing trends as part of the affected environment (Garrett 2018c).

As such, two separate models were prepared: a No Action model (with continued dewatering, but no block-caving), and a Proposed Action model (with continued dewatering and block-caving as proposed).

- For the no action alternative, the potential impact from the mine is defined as the drawdown as predicted in the no action groundwater flow model, up to 200 years after the start of mining (see next section for discussion on time frames).
- For the action alternatives, the potential impact from the mine is defined as the drawdown predicted in the proposed action groundwater flow model, up to 200 years after the start of mining (see next section for discussion on time frames). However, some of the GDEs impacted by proposed action drawdown would have been impacted by the no action alternative as well. The GDEs anticipated to be impacted by both models are disclosed for comparison, to clearly identify which impacts result from ongoing dewatering alone and which impacts result from the block-caving.

KEY DECISION ON USE OF MODEL RESULTS – TIME FRAME

Groundwater models are generally run until they reach a point where the aquifer has sufficient time to react to an induced stress (in this case, the effects of block-caving) and reach a new point of equilibrium. In some systems this can take hundreds or even thousands of years. The groundwater flow model for the Resolution Copper project was run for 1,000 years, or roughly 950 years after closure of the mine, to approach equilibrium conditions. The Groundwater Modeling Workgroup recognized that a fundamental limitation of the model—of any model—is the unreliability of predictions far in the future, and the workgroup was tasked with determining a time frame that would be reasonable to assess. Based on combined professional judgment, the Groundwater Modeling Workgroup determined that results could be reasonably assessed up to 200 years into the future. All quantitative results disclosed in the EIS are restricted to this time frame.

The Groundwater Modeling Workgroup also recognized that while quantitative predictions over long time frames were not reliable, looking at the general trends of groundwater levels beyond the 200-year time frame still provides valuable context for the analysis. In most cases, the point of maximum groundwater drawdown or impact for any given GDE does not occur at the end of mining. Rather, it takes time for the full impacts to be seen—decades or even centuries. Even if quantitative results are unreliable at long time frames, the general trends in modeled groundwater levels can indicate whether the drawdown or impact reported at 200 years represents a maximum impact, or whether conditions might still worsen at that location. These trends are qualitatively explored, regardless of time frame.

KEY DECISION ON USE OF MODEL RESULTS – LEVEL OF PRECISION

Numerical groundwater models produce highly precise results (i.e., many decimal points). Even in a well-calibrated model, professional hydrologists and modelers recognize that there is a realistic limit to this precision, beyond which results are meaningless. The Groundwater Modeling Workgroup was tasked with determining the appropriate level of precision to use for groundwater modeling results.

Based on combined professional judgment, the Groundwater Modeling Workgroup determined that to properly reflect the level of uncertainty inherent in the modeling effort, results less than 10 feet should not be disclosed or relied upon, as these results are beyond the ability of the model to predict. For values greater than 10 feet, the Groundwater Modeling Workgroup decided to use a series of ranges to further reflect the uncertainty: 10 to 30 feet, 30 to 50 feet, and greater than 50 feet. Regardless of these ranges, the quantitative modeled results for each GDE are still provided in the form of hydrographs (see appendix L). Several strategies were developed to help address the uncertainties associated with the groundwater modeling results, as described in the remainder of this section.

The precision of the results (10 feet) also reflects the inability of a regional groundwater model to fully model the interaction of groundwater with perennial or intermittent streams (see BGC Engineering USA Inc. (2018d) for a full discussion). This limitation means that impacts on surface waters are based on predicted groundwater drawdown, rather than modeled changes in streamflow.

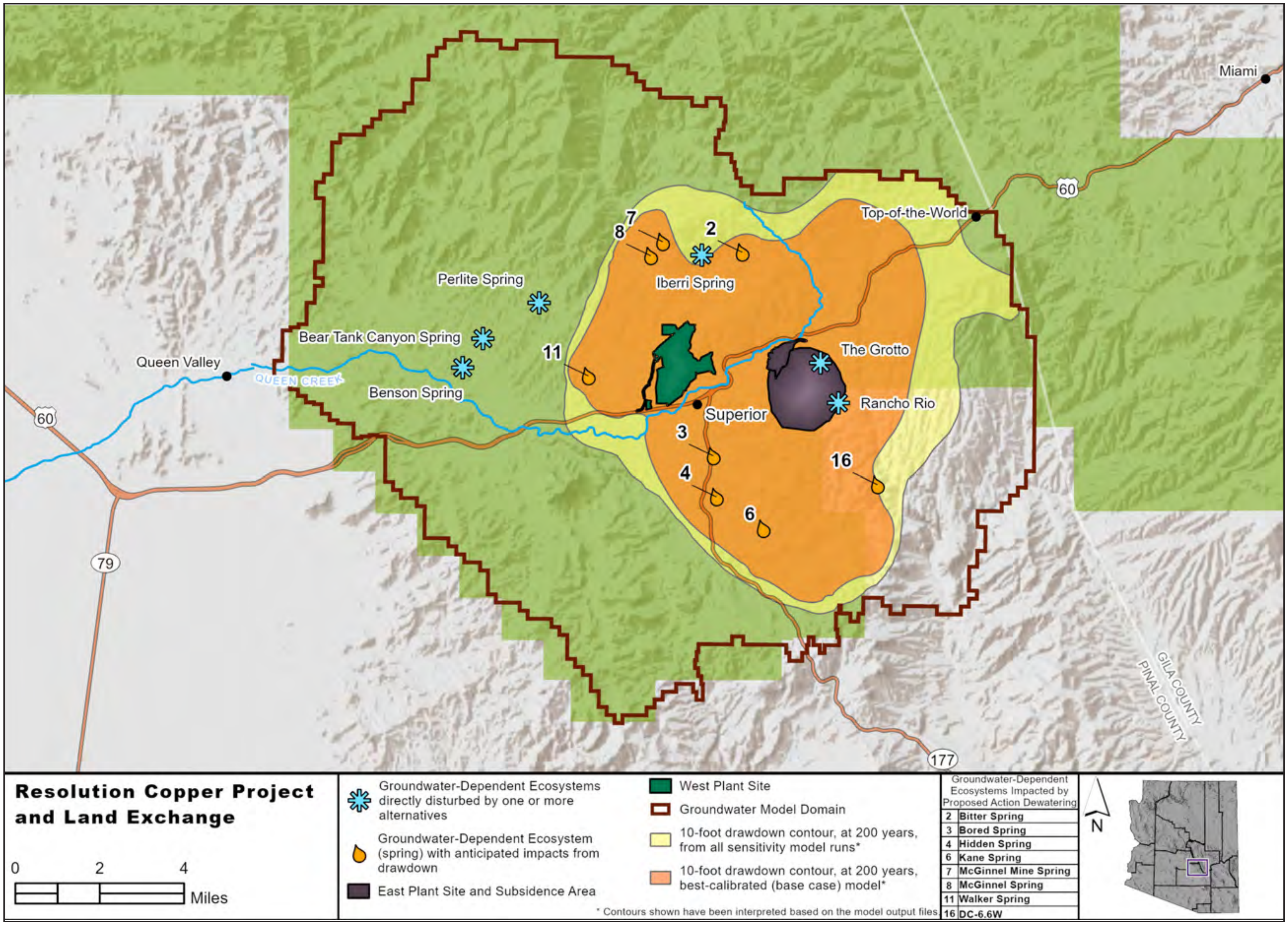
KEY DECISION ON USE OF MODEL RESULTS – STRATEGIES TO ADDRESS UNCERTAINTY

Two key strategies were selected to deal with the uncertainty inherent in the groundwater model: the use of sensitivity model runs and the use of monitoring. The model runs used to predict impacts are based on the best-calibrated version of the model; however, there are many other variations of the model and model parameters that may also be reasonable. Sensitivity model runs are used to understand how other ways of constructing the model change the results. In these sensitivity runs, various model parameters are increased or decreased within reasonable ranges to see how the model outcomes change. In total, 87 model sensitivity runs were conducted, in addition to the best-calibrated version of the model.

Because of the uncertainty and limitations of the model, the Groundwater Modeling Workgroup decided that it would be most appropriate to disclose not only impacts greater than 10 feet based on the best-calibrated model, but also impacts greater than 10 feet based on any of the sensitivity runs. The predicted model results disclosed in this section represent a range of results from the best-calibrated model as well as the full suite of sensitivity runs. These are considered to encompass a reasonable range of impacts that could occur as a result of the project.

As can be seen in figure 3.7.1-3, which shows the 10-foot drawdown contour that encompasses all sensitivity runs (yellow area), some of the sensitivity runs show drawdown abutting the eastern edges of the model domain, which is an undesirable situation for a groundwater model. This result is driven by a single sensitivity run that looked at an increased hydraulic conductivity in the Apache Leap Tuff aquifer. This has been taken into consideration when interpreting the model results. For some GDEs, this particular sensitivity run represents the sole outcome where impact is anticipated; for these, impacts are considered possible but unlikely, given that the base case and all other model sensitivity runs show consistent results.

The Groundwater Modeling Workgroup recognized that while the model may not be reliable for results less than 10 feet in magnitude, changes in aquifer water level much less than 10 feet still could have meaningful effects on GDEs, even leading to complete drying. The Groundwater Modeling Workgroup explored a number of other modeling techniques, including explicitly modeling the interaction between groundwater and surface water to predict small changes in streamflow, but found that these techniques had similar limitations. To address this problem, monitoring of GDEs would be implemented



Groundwater-Dependent Ecosystems Impacted by Proposed Action Dewatering	
2	**Bitter Spring**
3	**Bored Spring**
4	**Hidden Spring**
6	**Kane Spring**
7	**McGinnel Mine Spring**
8	**McGinnel Spring**
11	**Walker Spring**
16	**DC-6.6W**

Figure 3.7.1-3. Modeled groundwater drawdown—proposed action, 200 years after start of mine

during mine operations, closure, and potentially beyond. For many of these GDEs, this monitoring effort simply continues monitoring that has been in place from as early as 2003. Details of monitoring conducted to date are available in the project record for springs and surface waters (Montgomery and Associates Inc. 2017d), water quality sampling (Montgomery and Associates Inc. 2016), and well construction and groundwater levels (Montgomery and Associates Inc. and Resolution Copper 2016). If monitoring identifies real-world impacts that were not predicted by the modeling, mitigation would be implemented. Mitigation is not restricted to unanticipated impacts; mitigation may also be undertaken for those GDEs where impacts are expected to occur.

Summary of Models Used for Mine Site Dewatering/Block-Caving Effects

The following groundwater flow models provide the necessary impact predictions. Each of the models included best-calibrated, base-case modeling runs as well as sensitivity runs:

- **No Action model, Life of Mine.** This model assumes that no mining occurs and that therefore no block-caving occurs that connects the Apache Leap Tuff aquifer to the deep groundwater system. While dewatering of the deep groundwater system is assumed to continue, for the most part those dewatering effects are confined to the deep groundwater system, and the Apache Leap Tuff aquifer does not dewater. This model was run for 51 years, until closure of the mine.
- **No Action model, Post-closure.** This model continues after 51 years, with dewatering being curtailed at the end of the Life of Mine model. This model was run to 1,000 years, but quantitative results are only used out to 200 years after start of the model, which is 149 years after closure of the mine. Model results beyond 200 years are still used but are discussed qualitatively.
- **Proposed Action model, Life of Mine.** This model assumes that mining and block-caving occur as proposed, along with the dewatering necessary to maintain project infrastructure. Under these conditions, the Apache Leap Tuff aquifer becomes hydraulically connected to and partially drains downward into the deep groundwater system. This model was run for 51 years, until closure of the mine. The proposed action model is applicable to all action alternatives.
- **Proposed Action model, Post-closure.** This model continues after 51 years, with dewatering being curtailed at the end of the Life of Mine model. This model was run to 1,000 years, but quantitative results are only used out to 200 years after start of the model, which is 149 years after closure of the mine. Model results beyond 200 years are still used but are discussed qualitatively. The proposed action model is applicable to all action alternatives.

Model Used for Mine Water Supply Pumping Effects

One additional model was part of the analysis process. Resolution Copper also ran a model to predict pumping impacts from the water supply wellfield located along the MARRCO corridor in the East Salt River valley. This groundwater flow model was built from an existing, calibrated, regulatory model prepared by ADWR. In some form, this model has been used widely for basin-wide planning purposes since the 1990s, as well as to estimate project-specific water supply impacts, and therefore did not require as extensive a review as the models prepared specifically for the mine. Since the water balance differs greatly between alternatives, due to operations of the tailings facilities, this model was run separately to reflect each of the action alternatives.

3.7.1.3 Affected Environment

Relevant Laws, Regulation, Policies, and Plans

The State of Arizona has jurisdiction over groundwater use; however, the Forest Service also has pertinent guidance on analyzing groundwater impacts, disclosing these impacts appropriately during NEPA analysis, and managing GDEs on NFS land.

Primary Legal Authorities Relevant to the Groundwater Analysis

- Arizona Groundwater Management Act of 1980, along with implementing regulations that govern groundwater use within Active Management Areas
- Forest Service Manual 2520 (management of riparian areas, wetlands, and floodplains), 2530 (collecting water resource data), and 2880 (inventory and analysis of GDEs)

Existing Conditions and Ongoing Trends

REGIONAL HYDROLOGIC FRAMEWORK

The project is located within a geological region known as the Basin and Range province, near the boundary with another geological region known as the Arizona Transition Zone. The Basin and Range aquifers generally consist of unconsolidated gravel, sand, silt, and clay, or partly consolidated sedimentary or volcanic materials. These materials have filled deep fault-block valleys formed by large vertical displacement across faults. Mountain ranges that generally consist of impermeable rocks separate adjacent valleys (Robson and Banta 1995), leading to compartmentalized groundwater systems. Stream alluvium is present along most of the larger stream channels. These deposits are about 100 feet thick and 1 to 2 miles wide along the Gila, Salt, and Santa Cruz Rivers in Arizona aquifers (Robson and Banta 1995). The hydrology of the Arizona Transition Zone is generally more complex, characterized largely by fractured rock aquifers with some small alluvial basins.

The semiarid climate in the region limits the amount of surface water available for infiltration, resulting in slow recharge of the groundwater with an average annual infiltration of 0.2 to 0.4 inch per year (Woodhouse 1997). Much of this recharge occurs as mountain-front recharge, where runoff concentrates along ephemeral channels.

GROUNDWATER IN THE ANALYSIS AREA

The analysis area contains several distinct groundwater systems, as shown on the conceptual cross section in figure 3.7.1-4:

- Groundwater east of the Concentrator Fault:
    - a shallow, perched groundwater system
    - the Apache Leap Tuff aquifer
    - a deep groundwater system
- Groundwater west of the Concentrator Fault in the Queen Creek watershed:
    - alluvial groundwater, primarily in floodplain alluvium along Queen Creek
    - deep groundwater system in poorly permeable basin-fill sediments

The groundwater underlying most of the analysis area is within the Phoenix AMA, as defined by the Arizona Groundwater Management Act, and is in the East Salt River valley groundwater subbasin of the AMA, as shown in figure 3.7.1-1. Groundwater use within the AMA is administered by the ADWR (Newell and Garrett 2018d).

Summaries of the geology of the area are found in Section 3.2, Geology, Minerals, and Subsidence; the following discussion focuses on the hydrology and groundwater of the area.

East Plant Site

The East Plant Site is located on Oak Flat, east of the Concentrator Fault. The Concentrator Fault is a barrier to flow in the deep groundwater

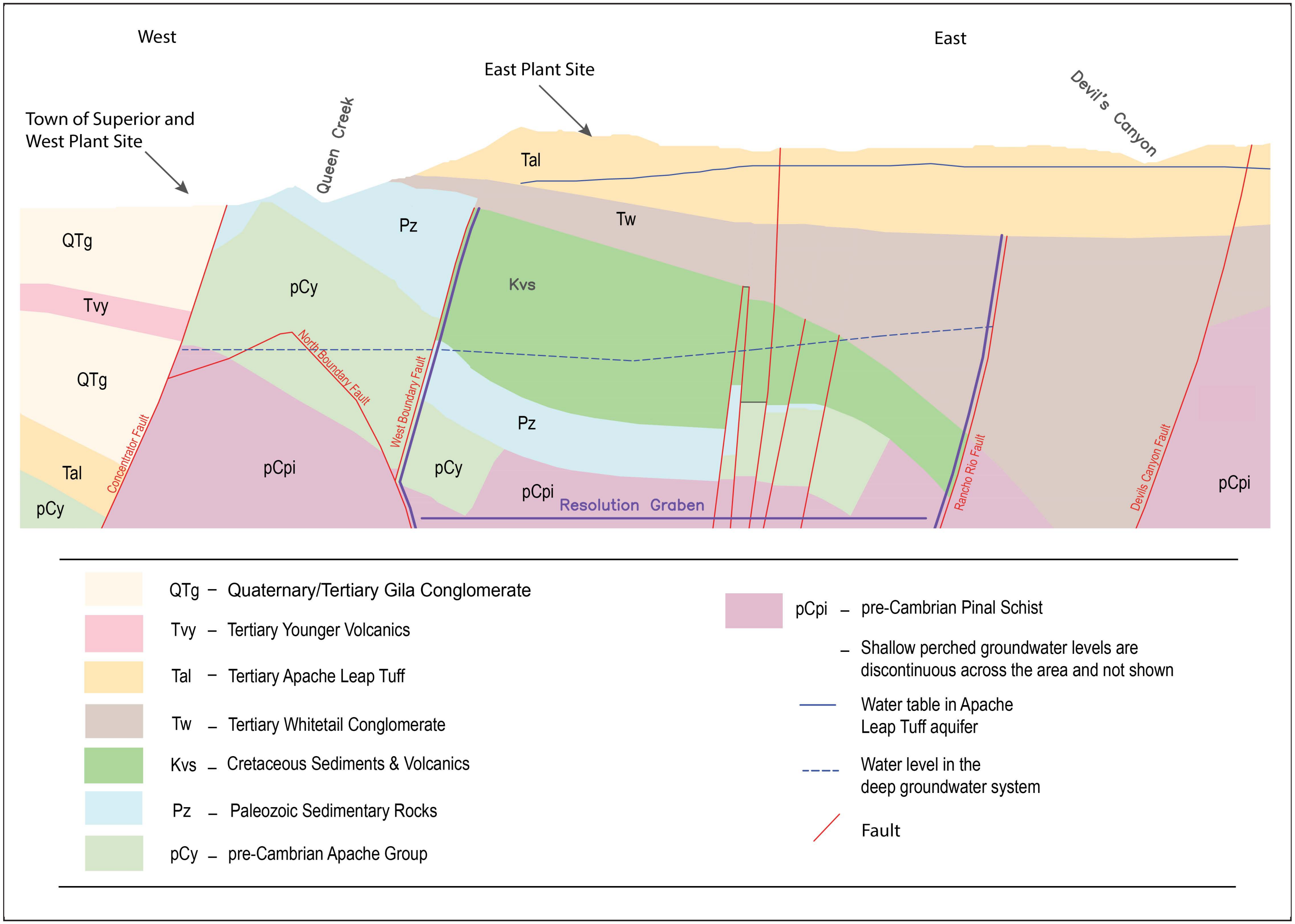


Figure 3.7.1-4. Conceptual cross section of the groundwater systems

systems on either side of the fault. Groundwater characterization wells for the shallow, perched groundwater, the Apache Leap Tuff aquifer, and the deep groundwater system are shown in figure 3.7.1-5.

The shallow groundwater system consists of several shallow, perched aquifers of limited areal extent hosted in alluvial deposits and the uppermost weathered part of the Apache Leap Tuff. The primary shallow aquifers in this area are located near Top-of-the-World and JI Ranch, and to a lesser degree along some of the major drainages such as Hackberry Canyon and Rancho Rio Canyon.

The Apache Leap Tuff aquifer is a fractured-rock aquifer that extends throughout much of the Upper Queen Creek and Devil's Canyon watersheds, and the western part of the Upper Mineral Creek watershed. The Apache Leap Tuff aquifer is separated from the deep groundwater system by a thick sequence of poorly permeable Tertiary basin-fill sediments (the Whitetail Conglomerate). In general, the direction of groundwater movement in the Apache Leap Tuff follows surface drainage patterns, with groundwater moving from areas of recharge at higher elevations to natural discharge areas in Devil's Canyon and in Mineral Creek. Regional water levels in the Apache Leap Tuff aquifer, and general flow directions, are shown in figure 3.7.1-6.

The deep groundwater system east of the Concentrator Fault is compartmentalized, and faults separate individual sections of the groundwater system from each other. Depending on their character, faults can either inhibit or enhance groundwater flow. Based on available evidence, the faults in the project area tend to restrict groundwater flow between individual sections. The ore body and future block-cave zone lie within a geological structure called the Resolution Graben, which is bounded by a series of regional faults. The deep groundwater system in the Resolution Graben is hydraulically connected to existing mine workings, and a clear decrease in water levels in response to ongoing dewatering of the mine workings has been observed (Resolution Copper 2016d).

Three wells monitor the deep groundwater system inside the Resolution Graben (table 3.7.1-1). As noted earlier in this section, groundwater levels in the deep groundwater system below Oak Flat (close to the pumping, within the Resolution Graben) have declined more than 2,000 feet since 2009 (Montgomery and Associates Inc. and Resolution Copper 2016). The deep groundwater system east of the Concentrator Fault, but outside the Resolution Graben, appears to have a limited hydraulic connection with the deep groundwater system inside the graben. Resolution Copper monitors groundwater levels at eight locations in the deep groundwater system outside the Resolution Graben (see table 3.7.1-1). Outside the graben, groundwater level decreases have been smaller, with a maximum decline of about 400 feet since 2009, while near Superior, water levels associated with similar connected units have declined up to 50 feet since 2009 (Montgomery and Associates Inc. and Resolution Copper 2016).

West Plant Site

At the West Plant Site, shallow and intermediate groundwater occurs in the Gila Conglomerate. In addition, groundwater occurs in shallow alluvium to the south of the West Plant Site and in fractured bedrock (Apache Leap Tuff) on the eastern boundary of the West Plant Site.

Groundwater in the shallow, unconfined Gila Conglomerate discharges locally, as evidenced by the presence of seeps and evaporite deposits. The groundwater deeper in the Gila Conglomerate, below a separating mudstone formation, likely flows to the south or southwest toward regional discharge areas (Resolution Copper 2016d). Several wells monitor the Gila Conglomerate near the West Plant Site. Most of these wells have shown steady long-term declines in water level since 1996. These declines are consistent with water level declines occurring regionally in response to drought conditions (Montgomery and Associates Inc. 2017b).

The deep groundwater west of the Concentrator Fault is hosted in low permeability Quaternary and Tertiary basin-fill deposits, fractured Tertiary volcanic rocks, and underlying Apache Leap Tuff. Four wells monitor the deep groundwater system west of the Concentrator Fault. These wells have shown varying rises and declines (Montgomery and Associates Inc. 2017b).

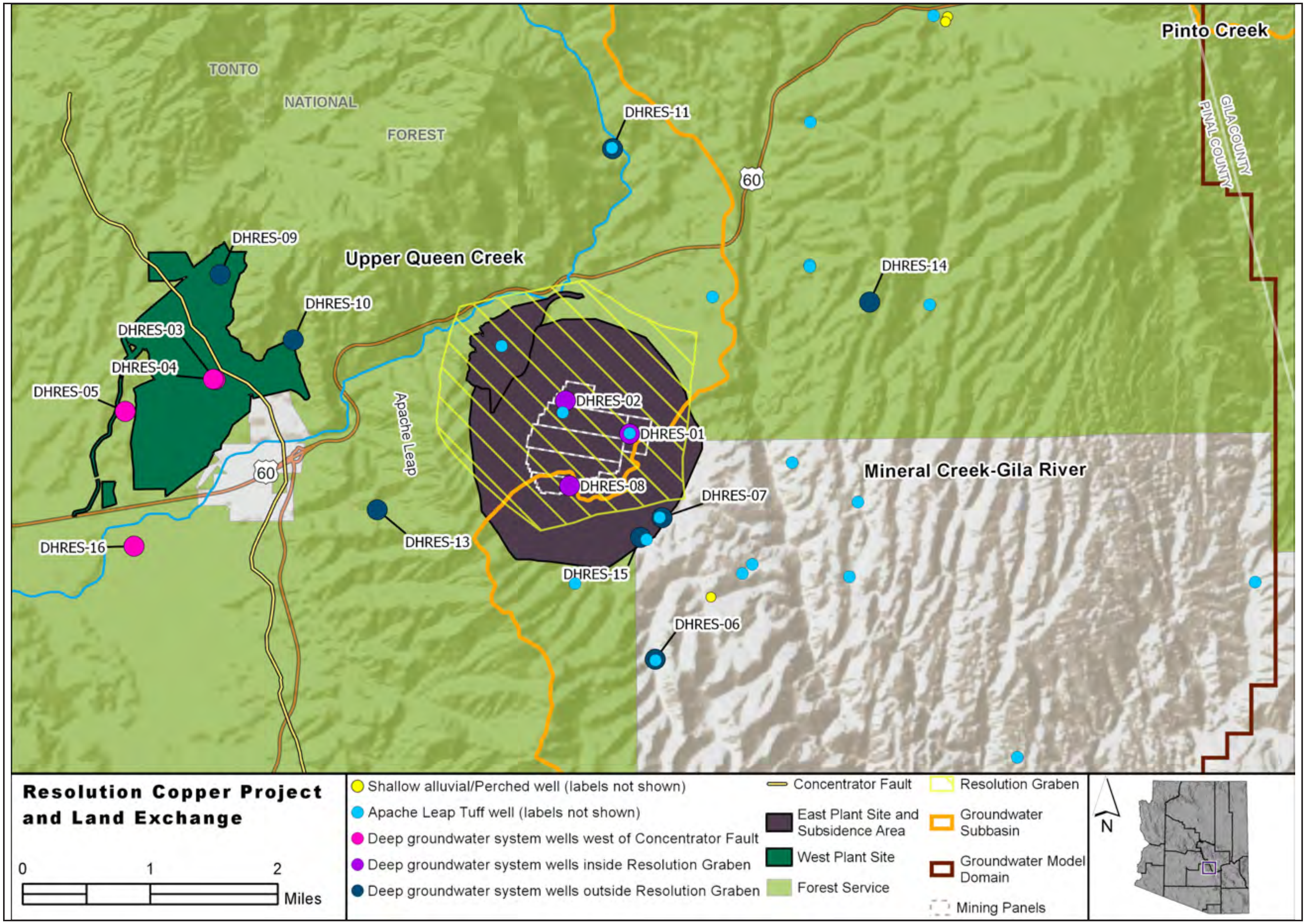


Figure 3.7.1-5. Characterization wells for the shallow, perched groundwater, the Apache Leap Tuff aquifer, and the deep groundwater system

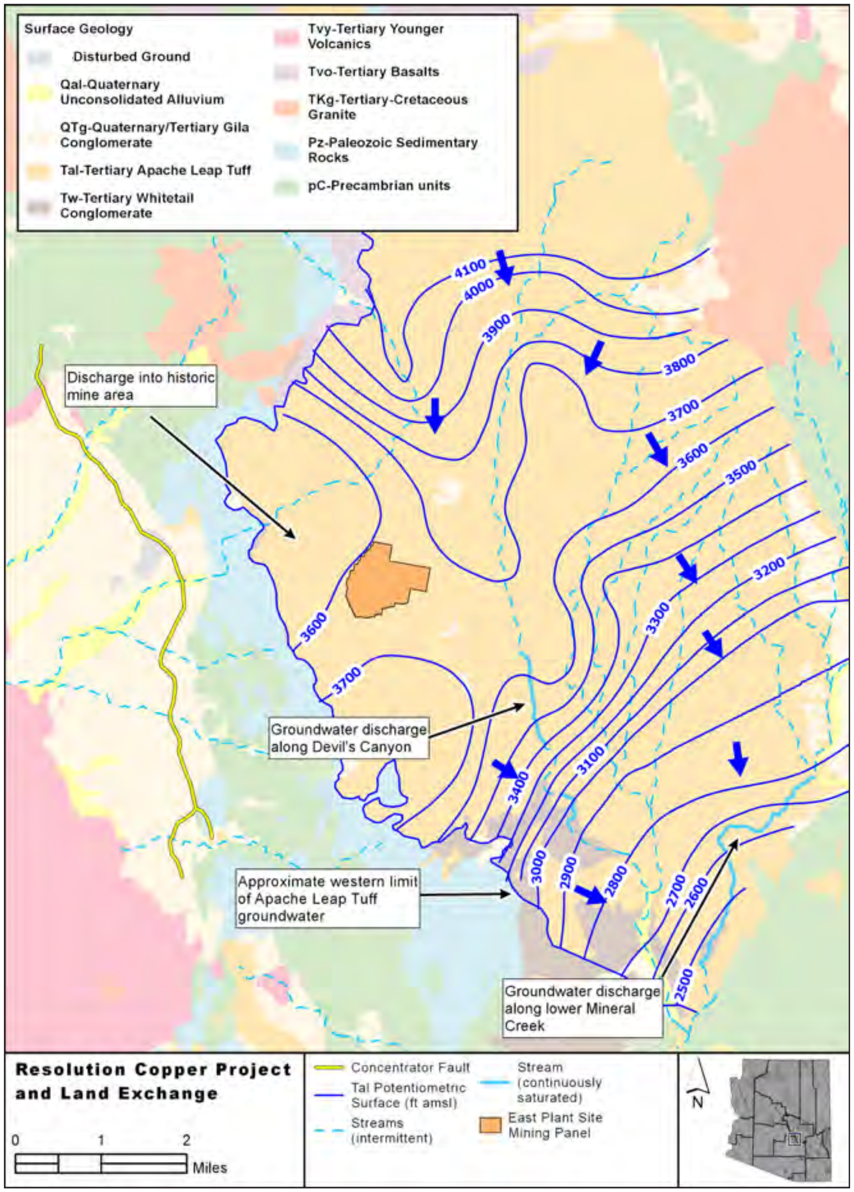


Figure 3.7.1-6. Apache Leap Tuff aquifer water-level elevations and general flow directions

Table 3.7.1-1. Changes in groundwater head in the deep groundwater system due to dewatering

Deep Groundwater System Wells*	Earliest Groundwater Head Elevation, in feet amsl (date shown in parentheses)	Groundwater Head Elevation in 2016 (in feet amsl)	Overall Change (feet)
Deep groundwater system wells: east of the Concentrator Fault within the Resolution Graben			
DHRES-01 (water level in Kvs)	2,090 (2009)	−50	−2,140
DHRES-02 (water level in Kvs)	2,100 (2008)	−380	−2,480
DHRES-08 (DHRES-08_-231 in Kvs)	1,920 (2010)	280	−1,640
Deep groundwater system wells: east of the Concentrator Fault outside of the Resolution Graben			
DHRES-06 (water level in Pz [Pnaco, Me, Dm, Cb, pCdiab])	3,254 (2010)	3,242	−12
DHRES-07 (DHRES-07_-108 in Pz [Cb])	3,000 (2010)	2,890	−110
DHRES-09 (water level in pCdsq and pCdiab)	2,990 (2011)	2,944	−46
DHRES-10	N/A	N/A	N/A
DHRES-11 (water level in Pz and pCy)	3,300 (2011)	2,940	−360
DHRES-13 (water level in pCy and pCpi)	2,790 (2011)	2,704	−86
DHRES-14 (water level in Tw and pCpi)	3,508 (2012)	3,484	−24
DHRES-15 (water level in Dm and Cb)	3,210 (2015)	3,240	+30
Deep groundwater system wells: west of the Concentrator Fault			
DHRES-03 (DHRES-03_335 in Tvs)	2,526 (2009)	2,496	−30
DHRES-04 (water level in Tvs)	2,570 (2009)	2,600	+30
DHRES-05B (water level in Tal)	2,620 (2010)	2,578	−42
DHRES-16 (DHRES-16_-387 in Tal)	2,316 (2014)	2,268	−48

Source: All data taken from Montgomery and Associates Inc. and Resolution Copper (2016)

Notes: Some elevations approximated to nearest 10 feet for clarity. N/A = Data not available; amsl = above mean sea level

Tal = Apache Leap Tuff; Tw = Whitetail conglomerate; Tvs = Tertiary sedimentary and volcanic rocks; Kvs = Cretaceous sedimentary and volcanic rocks; Pz = Paleozoic sedimentary rocks (Pnaco = Naco formation; Me = Escabrosa limestone; Dm = Martin formation; Cb = Bolsa quartzite);
pCy = Precambrian Apache Group; pCdiab = Precambrian diabase; pCdsq = Precambrian Dripping Springs quartzite; pCpi = Precambrian Pinal schist

* For wells with multiple monitoring depths, specific monitoring location is shown in parentheses

MARRCO Corridor, Filter Plant and Loadout Facility, and Desert Wellfield

Along much of the MARRCO corridor, groundwater is present in a shallow aquifer within the alluvium along Queen Creek. The groundwater flow direction in this part of the corridor generally follows the Queen Creek drainage to the west.

In the portion of the corridor between Florence Junction and Magma, where the filter plant and loadout facility would be located, the groundwater is present in deep alluvial units. The regional groundwater flow direction in this area is generally toward the northwest (Resolution Copper 2016d).

The makeup water supply[36] for the mine would come from a series of wells installed within the MARRCO corridor, drawing water from these deep alluvial units of the East Salt River valley. These wells are known as the "Desert Wellfield." Although groundwater development in the vicinity of the Desert Wellfield has heretofore been limited, historically areas of the East Salt River valley to the west and south have been heavily used for agriculture. Until the late 1980s to early 1990s, groundwater levels were declining in much of the basin. Passage of the 1980 Groundwater Management Act which imposed limits on pumping, the availability of a renewable source of water, and the development of a regulatory framework allowing for recharge of the aquifer, all of which in combination with reduced agricultural pumping, have contributed to rising water levels. In the New Magma Irrigation and Drainage District (NMIDD) to the southwest, groundwater levels have recovered on the order of 170 feet over the past three decades, with somewhat lesser water level increases occurring in the area of the Desert Wellfield (Bates et al. 2018). Current depths to groundwater in the vicinity of the Desert Wellfield range from 400 to 600 feet below ground surface.

Tailings Storage Facility – Alternatives 2 and 3 – Near West

Thin alluvial deposits on the floors of canyons and washes at the location of the proposed tailings storage facility contain small amounts of shallow, perched groundwater. The majority of the tailings storage facility site is underlain by rocks with little permeability, with no indication of a water within the upper 150 to 300 feet of ground surface (Montgomery and Associates Inc. 2017c). Where those rocks are fractured, they have the potential to store groundwater and allow for groundwater flow. Three springs are in the footprint of the proposed tailings storage facility: the Perlite, Benson, and Bear Tank Canyon Springs (see figure 3.7.1-3). Groundwater flow generally follows the topography toward Queen Creek. Several wells were installed in the tailings storage facility area to provide information on groundwater levels (Montgomery and Associates Inc. 2017c).

Tailings Storage Facility – Alternative 4 – Silver King

Similar to the Near West site, thin alluvial deposits on the floors of canyons and washes, especially in Silver King Wash, contain small amounts of shallow, perched groundwater (Cross and Blainer-Fleming 2012; Klohn Crippen Berger Ltd. 2018c). The majority of the tailings storage facility site is underlain by rocks with little permeability. Groundwater moves generally southwest (Cross and Blainer-Fleming 2012). A number of perennial springs are located near Alternative 4. McGinnel Spring and Iberri Spring are located within the footprint of Alternative 4, and several other perennial springs (McGinnel Mine Spring, Rock Horizontal Spring, and Bitter Spring) are located within 1 mile (see figure 3.7.1-3).

Tailings Storage Facility – Alternative 5 – Peg Leg

A broad alluvial groundwater basin underlies the Peg Leg location (Ludington et al. 2007). Limited site water level data suggest

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[36] The mine process incorporates numerous means of recycling water back into the process wherever possible. However, for all alternatives, there remains the need for substantial additional fresh water for the processing. The fresh water fed into the processing stream is termed "makeup" water.

that groundwater depths below the facility footprint are relatively shallow, with depths less than 50 feet (Golder Associates Inc. 2018a). Groundwater flow is to the northwest, generally following the ground surface topography. The site is located in the Donnelly Wash groundwater basin, outside of any AMA.

Tailings Storage Facility – Alternative 6 – Skunk Camp

Deposits of sand and gravel less than 150 feet thick underlie the Skunk Camp location and contain shallow groundwater (Klohn Crippen Berger Ltd. 2018d). Regional groundwater is assumed to flow from northwest to southeast within the proposed tailings storage facility area toward the Gila River. Shallow groundwater flow is expected to be primarily through the surface alluvial channels and upper weathered zone of the Gila Conglomerate (Klohn Crippen Berger Ltd. 2018d). The site is located in the Dripping Spring Wash groundwater basin, outside of any AMA.

GROUNDWATER BALANCE WITHIN MODELING ANALYSIS AREA

Groundwater systems are considered to be at steady state when outflow equals inflow. In the modeling analysis area, outflows due to mine dewatering exceed inflows, with the result that the groundwater system is not at steady state and water is removed from storage.

Inflow components of the groundwater balance include recharge from precipitation, groundwater inflows from adjacent groundwater basins, and deep percolation from irrigation and from the Town of Superior Wastewater Treatment Plant. Recharge from precipitation is the largest component of inflow into the groundwater of the analysis area.

Groundwater outflows include mine dewatering, groundwater pumping, subsurface and surface flow at Whitlow Ranch Dam (a flood control structure located on Queen Creek, just upstream of the community of Queen Valley), and groundwater evapotranspiration.

The largest component of groundwater outflow for both the shallow perched groundwater and the Apache Leap Tuff aquifer is groundwater evapotranspiration, primarily from where vegetation has access to near-surface groundwater. The largest component of groundwater outflow for deep groundwater is mine dewatering, primarily from Resolution Copper but also from an open-pit perlite mining operation near Queen Creek. In 2017, mine dewatering removed approximately 1,360 acre-feet of water from the deep groundwater system (Montgomery and Associates Inc. 2018).

ONGOING CLIMATIC TRENDS AFFECTING WATER BALANCE

The annual mean and minimum temperatures in the lower Colorado River Basin have increased 1.8 degrees Fahrenheit (°F) to 3.6°F for the time period 1900–2002, and data suggest that spring minimum temperatures for the same time period have increased 3.6°F to 7.2°F (Dugan 2018). Winter temperatures have increased up to 7.2°F, and summer temperatures 1.6°F. Increasing temperature has been correlated with decreasing snowpack and earlier runoff in the lower Colorado River Basin, with runoff increasing between November and February and decreasing between April and July (April to July is traditionally recognized as the peak runoff season in the basin).

Future projected temperature increases are anticipated to change the amount of precipitation only by a small amount but would change the timing of runoff and increase the overall evaporative demand. Groundwater recharge is most effective during low-intensity, long-duration precipitation events, and when precipitation falls as snow. With ongoing trends for the southwestern United States toward higher temperatures with less snow and more high-intensity rainstorms, more runoff occurs, but groundwater recharge may decline, leading to a decrease in groundwater levels. Increased demand for groundwater, due to higher water demand under higher temperatures, may also lead to greater stresses on groundwater supplies.

CURRENT AND ONGOING PUMPING AND WATER LEVEL TRENDS

Mining near Superior started about 1875, and dewatering of the Magma Mine began in earnest in 1910 as production depths increased. Dewatering continued with little interruption until 1998, after active mining ceased at the Magma Mine. In 2009, Resolution Copper resumed dewatering as construction began on Shaft 10 (WSP USA 2019). Since 2009, Resolution Copper has reported pumping about 13,000 acre-feet of groundwater under their dewatering permit.[37] Almost all of this water is treated and delivered to the NMIDD. Most historical dewatering pumping took place east of the Concentrator Fault, primarily at the Magma Mine, but also at the Silver King, Lake Superior and Arizona, and Belmont mines (Keay 2018).

Resolution Copper removes groundwater from sumps in Shafts 9 and 10, effectively dewatering the deep groundwater system that lies below the Whitetail Conglomerate unit (the bottom of Shaft 10 is about 7,000 feet below ground level). Groundwater levels in the deep groundwater system below Oak Flat (close to the pumping) have dropped over 2,000 feet since 2009. These same hydrogeological units extend west, below Apache Leap, and into the Superior Basin. Near Superior, water levels associated with these units have declined roughly 20 to 90 feet since 2009 (Montgomery and Associates Inc. and Resolution Copper 2016).

In the Oak Flat area, the Apache Leap Tuff aquifer overlies the deep groundwater system, and the Whitetail Conglomerate unit separates the two groundwater systems. The Whitetail Conglomerate unit acts as an aquitard—limiting the downward flow of groundwater from the Apache Leap Tuff. Groundwater level changes in the Apache Leap Tuff that have been observed have generally been 10 feet or less since 2009.

Groundwater levels in the Apache Leap Tuff are important because they provide water to GDEs, such as the middle and lower reaches of Devil's Canyon (Garrett 2018d). Resolution Copper has extensively monitored Devil's Canyon since as early as 2003. Most hydrologic indicators show no significant change over time in Devil's Canyon (Garrett 2019d). A number of other water sources have been monitored on Oak Flat and show seasonal drying, but these locations have been demonstrated to be disconnected from the Apache Leap Tuff aquifer, relying instead on localized precipitation (Garrett 2018d; Montgomery and Associates Inc. 2017a). Other pumping also occurs within the Superior Basin, but is substantially less than the Resolution Copper dewatering, roughly accounting for less than 10 percent of groundwater pumped within the model area (Montgomery and Associates Inc. 2018).

GROUNDWATER-DEPENDENT ECOSYSTEMS

The Tonto National Forest evaluated 67 different spring or stream locations in the project area as potential GDEs. These include the following:

- **Queen Creek watershed.** Areas evaluated include Queen Creek itself from its headwaters to Whitlow Ranch Dam, four tributaries (Number Nine Wash, Oak Flat Wash, Arnett Creek, and Telegraph Canyon), and 29 spring locations.
- **Devil's Canyon watershed.** Areas evaluated include Devil's Canyon from its headwaters to the confluence with Mineral Creek at the upper end of Big Box Reservoir, three tributaries (Hackberry Canyon, Rancho Rio Canyon, and Iron Canyon), and seven spring locations. Four of these springs are located along the main stem of Devil's Canyon and contribute to the general streamflow.
- **Mineral Creek watershed.** Areas evaluated include Mineral Creek from its headwaters to the confluence with Devil's Canyon at the upper end of Big Box Reservoir, and five spring locations. Three of these springs are located along the main stem of Mineral Creek and contribute to the general streamflow.

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[37] The current mine infrastructure lies almost entirely within the Phoenix AMA. In this area, pumping groundwater requires a groundwater right from the ADWR. Resolution Copper's dewatering right (59-524492) is permitted through 2029 (Rietz 2016b).

After evaluating available lines of evidence for portions of Queen Creek, Devil's Canyon, Mineral Creek, Telegraph Canyon, and Arnett Creek, the Groundwater Modeling Workgroup thought it likely that some stream segments within these watersheds could have at least a partial connection to regional aquifers, and each is described in more detail in the following text of this section. In addition, the Groundwater Modeling Workgroup identified 17 springs that they believe have at least a partial connection to regional aquifers. The remainder of the potential GDEs were eliminated from analysis for various reasons (Garrett 2018d).[38] GDEs with a likely or possible regional groundwater source, and therefore analyzed in this section, are listed in table 3.7.1-2 and shown in figure 3.7.1-7.

Devil's Canyon

The upper reach of Devil's Canyon (from above the U.S. 60 bridge to approximately km 9.3) includes a reach of perennial flow from approximately DC-11.0 to DC-10.6. The geohydrology suggests that this section of Devil's Canyon lies above the water table in the Apache Leap Tuff aquifer and is most likely supported by snowmelt or precipitation stored in near-surface fractures, and/or floodwaters that have been stored in shallow alluvium along the stream, before slowly draining into the main channel. Further evaluation of hydrochemistry and flow data support this conclusion (Garrett 2018d). Streamflow in Upper Devil's Canyon is not considered to be connected with the regional Apache Leap Tuff aquifer and would not be expected to be impacted by groundwater drawdown caused by the block-cave mining and dewatering. This portion of Devil's Canyon is also upstream of the subsidence area and unlikely to be impacted by changes in surface runoff.

Moving downstream in Devil's Canyon, persistent streamflow arises again about km 9.3. From this point downstream, Devil's Canyon contains stretches of perennial flow, aquatic habitat, and riparian galleries. Flow arises both from discrete springs along the walls of the canyon (four total), as well as groundwater inflow along the channel bottom. These reaches of Devil's Canyon also are supported in part by near-surface storage of seasonal precipitation; however, the available evidence indicates that these waters arise primarily from the regional Apache Leap Tuff aquifer. Streamflow in middle and lower Devil's Canyon is considered to be connected with the regional aquifer, which could potentially be impacted by groundwater drawdown caused by the block-cave mining and dewatering. These reaches of Devil's Canyon also receive runoff from the area where the subsidence area would occur and therefore may also lose flow during runoff events.

Queen Creek

The available evidence suggests that Queen Creek from headwaters to Whitlow Ranch Dam is ephemeral in nature, although in some areas above Superior it may be considered intermittent, as winter base flow does occur and likely derives from seasonal storage of water in streambank alluvium, which slowly seeps back in to the main channel (Garrett 2018d). This includes three springs located along the main stem of Queen Creek above Superior.

An exception for Queen Creek is a perennially flowing reach between km 17.39 and 15.55, which is located downstream of Superior and upstream of Boyce Thompson Arboretum. Originally this flowing reach had been discounted because it receives effluent discharge from the Superior Wastewater Treatment Plant. However, discussions within the Groundwater Modeling Workgroup suggested that a component of baseflow supported by regional aquifer discharge may exist in this reach as well. Regardless of whether baseflow directly enters the channel from the regional aquifer, substantial flow in this reach also derives from dewatering discharges from a small open-pit perlite mining operation, where the mine pit presumably intersects the regional aquifer

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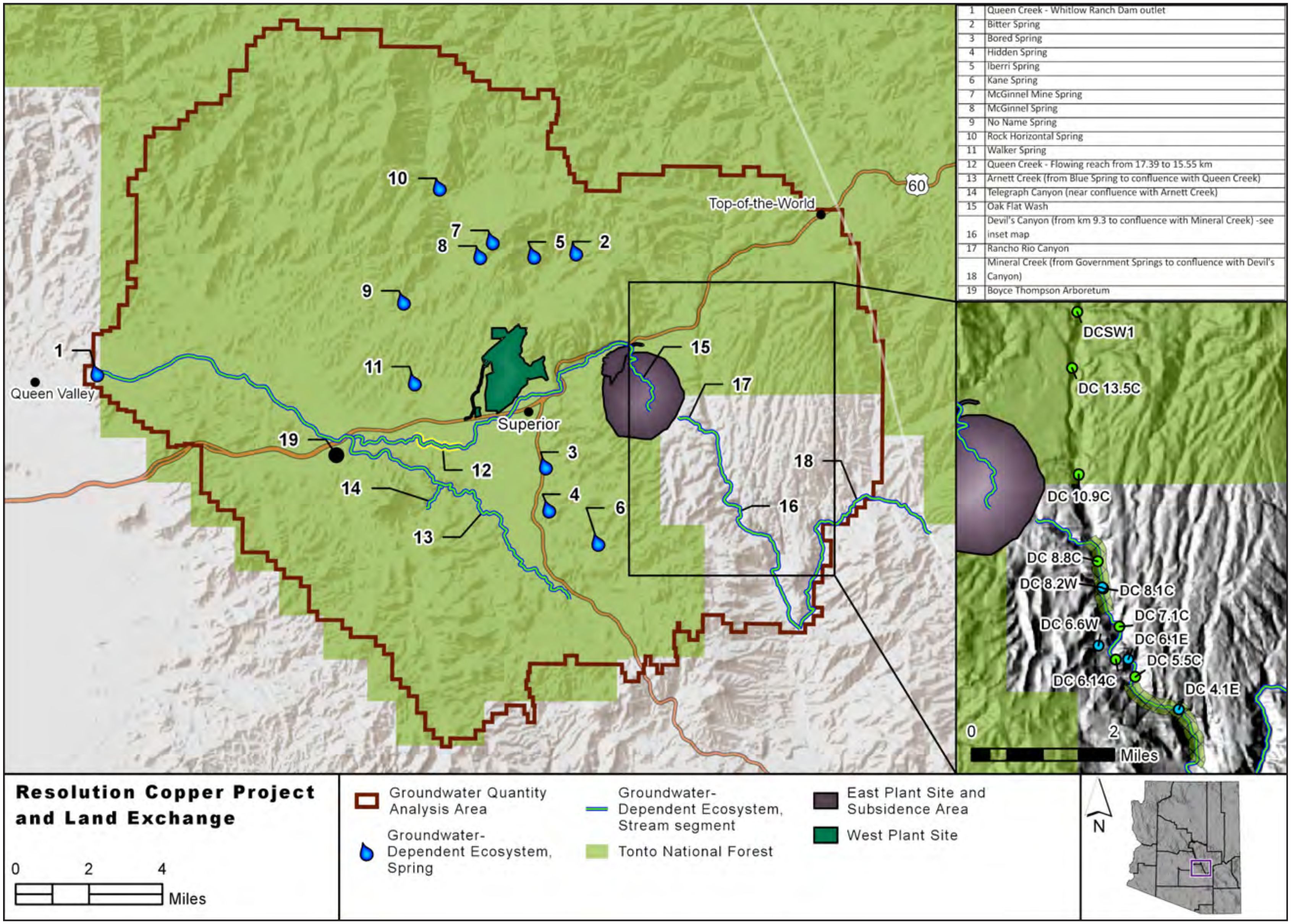
[38] To summarize, potential GDEs were eliminated from analysis using the groundwater flow model because they did not appear to exist within the analysis area (five springs); or had sufficient evidence to indicate a shallow groundwater source instead of a connection to the regional aquifers (19 springs; most of Queen Creek; upper Devil's Canyon; two tributaries to Queen Creek; and three tributaries to Devil's Canyon). Some of these GDEs may still be affected by changes in surface runoff, and these changes are still analyzed in this section.

Table 3.7.1-2. GDEs identified as having at least a partial connection to regional groundwater

Type of Feature	Name/Description*	Type of Impact Analysis Used in EIS
Queen Creek Watershed		
Stream segments	Queen Creek, between km 17.39 and 15.55 (downstream of Superior and upstream of Boyce Thompson Arboretum); approximately 1.2 miles long Queen Creek at Whitlow Ranch Dam Arnett Creek, near the confluence with Telegraph Canyon (km 4.5) and upstream at Blue Spring (km 12.5) Telegraph Canyon, near the confluence with Arnett Creek	Groundwater flow model (all stream segments); Surface water flow model (Queen Creek only)
Springs (10 total)	Bitter, Bored, Hidden, Iberri, Kane, McGinnel, McGinnel Mine, No Name, Rock Horizontal, and Walker	Groundwater flow model
Devil's Canyon Watershed		
Stream segments	Devil's Canyon, from km 9.14 to confluence with Mineral Creek/Big Box Reservoir; approximately 5.7 miles long	Groundwater flow model; Surface flow water model
Springs (4 total)	DC-8.2W, DC-6.6W, DC-6.1E, DC-4.1E	Groundwater flow model
Mineral Creek Watershed		
Stream segments	Mineral Creek from km 8.7 to confluence with Devil's Canyon/Big Box Reservoir, approximately 5.4 miles long	Groundwater flow model
Springs (3 total)	Government Springs, MC-8.4C, MC-3.4W (Wet Leg Spring)	Groundwater flow model

* Many of the stream descriptions reference the distance upstream of the confluence, measured in kilometers. This reference system is also incorporated into many stream/spring monitoring locations. For instance, spring "DC-8.4W" is located 8.4 km upstream of the mouth of Devil's Canyon, on the west side of the drainage.



1	Queen Creek - Whitlow Ranch Dam outlet
2	Bitter Spring
3	Bored Spring
4	Hidden Spring
5	Iberri Spring
6	Kane Spring
7	McGinnel Mine Spring
8	McGinnel Spring
9	No Name Spring
10	Rock Horizontal Spring
11	Walker Spring
12	Queen Creek - Flowing reach from 17.39 to 15.55 km
13	Arnett Creek (from Blue Spring to confluence with Queen Creek)
14	Telegraph Canyon (near confluence with Arnett Creek)
15	Oak Flat Wash
16	Devil's Canyon (from km 9.3 to confluence with Mineral Creek) -see inset map
17	Rancho Rio Canyon
18	Mineral Creek (from Government Springs to confluence with Devil's Canyon)
19	Boyce Thompson Arboretum

Figure 3.7.1-7. Groundwater-dependent ecosystems of concern

(Garrett 2018d). Therefore, for several reasons, this reach was included as a potential GDE, with the potential to be impacted by regional groundwater drawdown. The AGFD conducted surveys on this reach in 2017 and found that while flow fluctuated throughout the survey reach, aquatic wildlife and numerous other avian and terrestrial species use this habitat, and that aquatic species appeared to be thriving and reproducing (Warnecke et al. 2018).

Queen Creek also has perennial flow that occurs at Whitlow Ranch Dam and supports a 45-acre riparian area (primarily cottonwood, willow, and saltcedar). This location is generally considered to be where most subsurface flow in the alluvium along Queen Creek and other hydrologic units exits the Superior Basin. Queen Creek above and below Superior receives runoff from the area where the subsidence area would occur and therefore may also lose flow during runoff events. Runoff from over 20 percent of the Queen Creek watershed above Magma Avenue Bridge would be lost to the subsidence area (described in more detail in Section 3.7.3, Surface Water Quantity).

Mineral Creek

Mineral Creek is similar in nature to lower Devil’s Canyon. While flows are supported in part by near-surface storage of seasonal precipitation, the available evidence indicates that these waters arise partially from the Apache Leap Tuff aquifer and other regional sources. For the purposes of analysis, Mineral Creek is considered to be connected with regional aquifers, which could potentially be impacted by groundwater drawdown caused by the block-cave mining and dewatering; whether this impact is predicted to occur or not is determined using the results of the groundwater modeling.

Approximately the lower 4 miles of Mineral Creek exhibits perennial flow that supports riparian galleries and aquatic habitat. Three perennial springs also contribute to Mineral Creek (Government Springs, MC-8.4C, and MC-3.4W or Wet Leg Spring). Government Springs is the farthest upstream, roughly 5.4 miles above the confluence with Devil’s Canyon (Garrett 2018d).

Mineral Creek is designated as critical habitat for Gila chub. The AGFD has conducted fish surveys on Mineral Creek periodically since 2000 and has not identified Gila chub in Mineral Creek since 2000. While the presence of amphibians suggested acceptable water quality in this reach, until 2006 no fish populations were observed despite acceptable habitat. AGFD stocked native longfin dace in Mineral Creek downstream of Government Springs in 2006, and as of 2017, these fish were still present in the stream, though Gila chub have not been seen (Crowder et al. 2014; WestLand Resources Inc. 2018a).

Arnett Creek

Fairly strong and consistent evidence indicates that several reaches of Arnett Creek likely receive some contribution from groundwater that looks similar to the Apache Leap Tuff aquifer, though these units are not present in this area. This includes Blue Spring (located in the channel of Arnett Creek above Telegraph Canyon) and in the downstream portions of Arnett Creek immediately downstream of Telegraph Canyon. Arnett Creek is considered to be connected with regional aquifers, which could potentially be impacted by groundwater drawdown caused by the block-cave mining and dewatering; whether this impact is predicted to occur or not is determined using the results of the groundwater modeling.

Telegraph Canyon

Telegraph Canyon is a tributary to Arnett Creek. Unlike Arnett Creek, there was insufficient evidence to determine whether or not these waters were tied to the regional aquifers. In such cases, the Forest Service policy is to assume that a connection exists; therefore, Telegraph Canyon is also considered to be connected with the regional aquifers, which could potentially be impacted by groundwater drawdown caused by the block-cave mining and dewatering; whether this impact is predicted to occur or not is determined using the results of the groundwater modeling.

Tributaries to Queen Creek and Devil’s Canyon

A number of tributaries were evaluated originating in the Oak Flat area and feeding either Queen Creek or Devil’s Canyon. These include Number 9 Wash and Oak Flat Wash (Queen Creek watershed) and Iron Canyon, Hackberry Canyon, and Rancho Rio Canyon (Devil’s Canyon watershed). Sufficient evidence existed for all of these tributaries to demonstrate that they most likely have local water sources that are not connected to the regional Apache Leap Tuff aquifer (Garrett 2018d).

WATER SUPPLY WELLS

GDEs represent natural systems that could be impacted by the project, but human communities also rely on groundwater sources in the area. In lieu of analyzing individual wells, typical wells in key communities were analyzed using the groundwater flow model (Newell and Garrett 2018d). These areas include the following:

- **Top-of-the-World.** Many wells in this location are relatively shallow and rely on near-surface fracture systems and shallow perched alluvial deposits (see Garrett (2018d), Attachment 7); these wells would not be impacted by changes in the regional aquifers. However, other wells in this area could be completed deeper into the Apache Leap Tuff aquifer. Impacts on well HRES-06 is used as a proxy for potential impacts on water supplies and individual wells in this area.
- **Superior.** The Arizona Water Company serves the Town of Superior; the water comes from the East Salt River valley. Even so, there are assumed to still be individual wells within the town that use local groundwater (stock wells, domestic wells, commercial wells). As with Top-of-the-World, some of these wells may rely on near-surface groundwater and would not be impacted by changes in the regional aquifers. Other wells could be completed in geological units in hydraulic connection to the deep groundwater system. Well DHRES-16_743 is used as a proxy for potential impacts on water supplies and individual wells in this area.
- **Boyce Thompson Arboretum.** The Gallery Well is used as a proxy for impacts on water supplies associated with Boyce Thompson Arboretum. This well likely uses groundwater from local sources, but for the purposes of analysis it is assumed to be connected to regional aquifers.

3.7.1.4 Environmental Consequences of Implementation of the Proposed Mine Plan and Alternatives

Alternative 1 – No Action

ANTICIPATED IMPACTS ON GDES (UP TO 200 YEARS)

Under the no action alternative, which includes continued dewatering pumping of the deep groundwater system, no perennial streams are anticipated to be impacted, but six perennial springs experience drawdown greater than 10 feet. These springs are Bitter, Bored, Hidden, McGinnel, McGinnel Mine, and Walker Springs, as shown in figures 3.7.1-8 and 3.7.1-9, and summarized in table 3.7.1-3. Hydrographs showing drawdown under the no action alternative for all GDEs with connections to regional aquifers are included in appendix L.

The 10-foot drawdown contour shown on figure 3.7.1-8 represents the limit of where the groundwater model can reasonably predict impacts with the best-calibrated model (orange area). GDEs falling within this contour are anticipated to be impacted. GDEs outside this contour may still be impacted, but it is beyond the ability of the model to predict.

It is not possible to precisely predict what impact a given drawdown in groundwater level would have on an individual spring; however, given the precision of the model (10 feet), it is reasonable to assume any spring with anticipated impact of this magnitude could experience complete drying.

Bored Spring has the highest riparian value, supporting a standing pool and a 500-foot riparian string of cottonwood, willow, mesquite,

Table 3.7.1-3. Summary of potential impacts on groundwater-dependent ecosystems from groundwater drawdown

Reference Number on Figure 3.7.1-7	Specific GDE	Drawdown (feet) from Dewatering under No Action Alternative (end of mining)	Drawdown (feet) from Dewatering and Block-Cave under Proposed Action (end of mining)	Drawdown (feet) from Dewatering under No Action Alternative (200 years after start of mine)	Drawdown (feet) from Dewatering and Block-Cave under Proposed Action (200 years after start of mine)	Number of Sensitivity Runs with Drawdown greater than 10 Feet (based on Proposed Action, 200 yearsafter start of mine)	Summary of Expected Impacts on GDEs
	Queen Creek and Tributaries						
12	Queen Creek – Flowing reach from km 17.39 to 15.55	<10	<10	<10	<10	4 of 87 sensitivity runs show impacts greater than 10 feet; impacts are possible but unlikely	No Action – Drawdown is not anticipated.* Proposed Action – Additional drawdown due to block-caving is not anticipated with the base case model. Drawdown is possible but unlikely under the sensitivity modeling runs.* Reach has two other documented and substantial water sources.
1	Queen Creek – Whitlow Ranch Dam Outlet‡	<10	<10	<10	<10	Not available	No Action – Drawdown is not anticipated.* Proposed Action – Additional drawdown due to block-caving is not anticipated.†
13	Arnett Creek (from Blue Spring to confluence with Queen Creek)	<10	<10	<10	<10	0 of 87 sensitivity runs show impacts greater than 10 feet	No Action – Drawdown is not anticipated.* Proposed Action – Additional drawdown due to block-caving is not anticipated.*
14	Telegraph Canyon (near confluence with Arnett Creek)	<10	<10	<10	<10	0 of 87 sensitivity runs show impacts greater than 10 feet	No Action – Drawdown is not anticipated.* Proposed Action – Additional drawdown due to block-caving is not anticipated.*
	Devil's Canyon and Springs along Channel						

continued

Table 3.7.1-3. Summary of potential impacts on groundwater-dependent ecosystems from groundwater drawdown *(cont’d)*

Reference Number on Figure 3.7.1-7	Specific GDE	Drawdown (feet) from Dewatering under No Action Alternative (end of mining)	Drawdown (feet) from Dewatering and Block-Cave under Proposed Action (end of mining)	Drawdown (feet) from Dewatering under No Action Alternative (200 years after start of mine)	Drawdown (feet) from Dewatering and Block-Cave under Proposed Action (200 years after start of mine)	Number of Sensitivity Runs with Drawdown greater than 10 Feet (based on Proposed Action, 200 yearsafter start of mine)	Summary of Expected Impacts on GDEs
16	Middle Devil’s Canyon (from km 9.3 to km 6.1, including springs DC8.2W, DC6.6W, and DC6.1E)	<10	<10	<10	10–30 (Spring DC-6.6W)	For spring DC6.6W, 76 of 87 sensitivity runs show impacts greater than 10 feet; confirms base case impacts For the main channel (DC8.8C, DC 8.1C) and spring DC8.2W, 1 of 87 sensitivity runs shows impacts greater than 10 feet; impacts are possible but unlikely For spring DC6.1E, 0 of 87 sensitivity runs show impacts greater than 10 feet	No Action – Drawdown is not anticipated.* Proposed Action – Addition drawdown due to block-caving is anticipated in spring DC-6.6W with the base case model and most sensitivity modeling runs (see description of impacts).*† Drawdown is possible but unlikely under the sensitivity modeling runs for main channel groundwater inflow and spring DC6.1E.2
16	Lower Devil’s Canyon (from km 6.1 to confluence with Mineral Creek, including spring DC4.1E)	<10	<10	<10	<10	0 of 87 sensitivity runs show impacts greater than 10 feet	No Action – Drawdown is not anticipated.* Proposed Action – Additional drawdown due to block-caving is not anticipated.*
	Mineral Creek and Springs along Channel						

continued

Table 3.7.1-3. Summary of potential impacts on groundwater-dependent ecosystems from groundwater drawdown *(cont'd)*

Reference Number on Figure 3.7.1-7	Specific GDE	Drawdown (feet) from Dewatering under No Action Alternative (end of mining)	Drawdown (feet) from Dewatering and Block-Cave under Proposed Action (end of mining)	Drawdown (feet) from Dewatering under No Action Alternative (200 years after start of mine)	Drawdown (feet) from Dewatering and Block-Cave under Proposed Action (200 years after start of mine)	Number of Sensitivity Runs with Drawdown greater than 10 Feet (based on Proposed Action, 200 yearsafter start of mine)	Summary of Expected Impacts on GDEs
18	Mineral Creek (from Government Springs [km 8.7] to confluence with Devil's Canyon, including springs MC8.4C and MC3.4W [Wet Leg Spring])	<10	<10	<10	<10	0 of 87 sensitivity runs show impacts greater than 10 feet	No Action – Drawdown is not anticipated.* Proposed Action – Additional drawdown due to block-caving is not anticipated.*
	Queen Creek Basin Springs						
2	Bitter Spring	10–30	10–30	<10	10–30	87 of 87 sensitivity runs show impacts greater than 10 feet; confirms base case impacts	No Action – Drawdown is anticipated (see description of impacts).*† Proposed Action – Additional drawdown due to block-caving is anticipated (see description of impacts).*†
3	Bored Spring	30–50	30–50	>50	>50	87 of 87 sensitivity runs show impacts greater than 10 feet; confirms base case impacts	No Action – Drawdown is anticipated (see description of impacts).*† Proposed Action – Additional drawdown due to block-caving is anticipated (see description of impacts).*†

continued

Table 3.7.1-3. Summary of potential impacts on groundwater-dependent ecosystems from groundwater drawdown *(cont'd)*

Reference Number on Figure 3.7.1-7	Specific GDE	Drawdown (feet) from Dewatering under No Action Alternative (end of mining)	Drawdown (feet) from Dewatering and Block-Cave under Proposed Action (end of mining)	Drawdown (feet) from Dewatering under No Action Alternative (200 years after start of mine)	Drawdown (feet) from Dewatering and Block-Cave under Proposed Action (200 years after start of mine)	Number of Sensitivity Runs with Drawdown greater than 10 Feet (based on Proposed Action, 200 yearsafter start of mine)	Summary of Expected Impacts on GDEs
4	Hidden Spring	10–30	10–30	30–50	>50	87 of 87 sensitivity runs show impacts greater than 10 feet; confirms base case impacts	No Action – Drawdown is anticipated (see description of impacts).*† Proposed Action – Additional drawdown due to block-caving is anticipated (see description of impacts).*†
5	Iberri Spring	<10	<10	<10	<10	1 of 87 sensitivity runs show impacts greater than 10 feet; impacts are possible but unlikely	No Action – Drawdown is not anticipated.* Proposed Action – Addition drawdown due to block-caving is not anticipated with the base case model. Drawdown is possible but unlikely under the sensitivity modeling runs.*
6	Kane Spring	<10	<10	<10	>50	84 of 87 sensitivity runs show impacts greater than 10 feet; confirms base case impacts	No Action – Drawdown is not anticipated.* Proposed Action – Additional drawdown due to block-caving is anticipated (see description of impacts).*†
7	McGinnel Mine Spring	<10	<10	10–30	10–30	86 of 87 sensitivity runs show impacts greater than 10 feet; confirms base case impacts	No Action – Drawdown is anticipated (see description of impacts).*† Proposed Action – Addition drawdown due to block-caving is anticipated (see description of impacts).*†

continued

Table 3.7.1-3. Summary of potential impacts on groundwater-dependent ecosystems from groundwater drawdown *(cont'd)*

Reference Number on Figure 3.7.1-7	Specific GDE	Drawdown (feet) from Dewatering under No Action Alternative (end of mining)	Drawdown (feet) from Dewatering and Block-Cave under Proposed Action (end of mining)	Drawdown (feet) from Dewatering under No Action Alternative (200 years after start of mine)	Drawdown (feet) from Dewatering and Block-Cave under Proposed Action (200 years after start of mine)	Number of Sensitivity Runs with Drawdown greater than 10 Feet (based on Proposed Action, 200 yearsafter start of mine)	Summary of Expected Impacts on GDEs
8	McGinnel Spring	<10	<10	10–30	10–30	85 of 87 sensitivity runs show impacts greater than 10 feet; confirms base case impacts	No Action – Drawdown is anticipated (see description of impacts).*† Proposed Action – Addition drawdown due to block-caving is anticipated (see description of impacts).*†
9	No Name Spring	<10	<10	<10	<10	0 of 87 sensitivity runs show impacts greater than 10 feet	No Action – Drawdown is not anticipated.* Proposed Action – Additional drawdown due to block-caving is not anticipated.*
10	Rock Horizontal Spring	<10	<10	<10	<10	0 of 87 sensitivity runs show impacts greater than 10 feet	No Action – Drawdown is not anticipated.* Proposed Action – Additional drawdown due to block-caving is not anticipated.*
11	Walker Spring	10–30	10–30	10–30	30–50	87 of 87 sensitivity runs show impacts greater than 10 feet; confirms base case impacts	No Action – Drawdown is anticipated (see description of impacts).*† Proposed Action – Additional drawdown due to block-caving is anticipated (see description of impacts).*†

* Regardless of anticipated impacts, monitoring would occur during operations for verification. Predictions of drawdown are approximations of a complex physical system, inherently limited by the quality of input data and structural constraints imposed by the model grid and modeling approach. The groundwater model does not predict changes to flow magnitude and timing at a given GDE. By extension, drawdown contours may not represent the aerial extent of anticipated impacts on GDEs. These contours will be used to inform more site-specific impact monitoring and mitigation.

† For all springs, streams, and associated riparian areas potentially impacted, impacts could include a reduction or loss of spring/stream flow, increased mortality or reduction in extent or health of riparian vegetation, and reduction in the quality or quantity of aquatic habitat from loss of flowing water, adjacent vegetation, or standing pools.

‡ Whitlow Ranch Dam outlet is not modeled specifically, as this cell is defined by a constant head in the model. Output described is based on estimated head levels at this location.

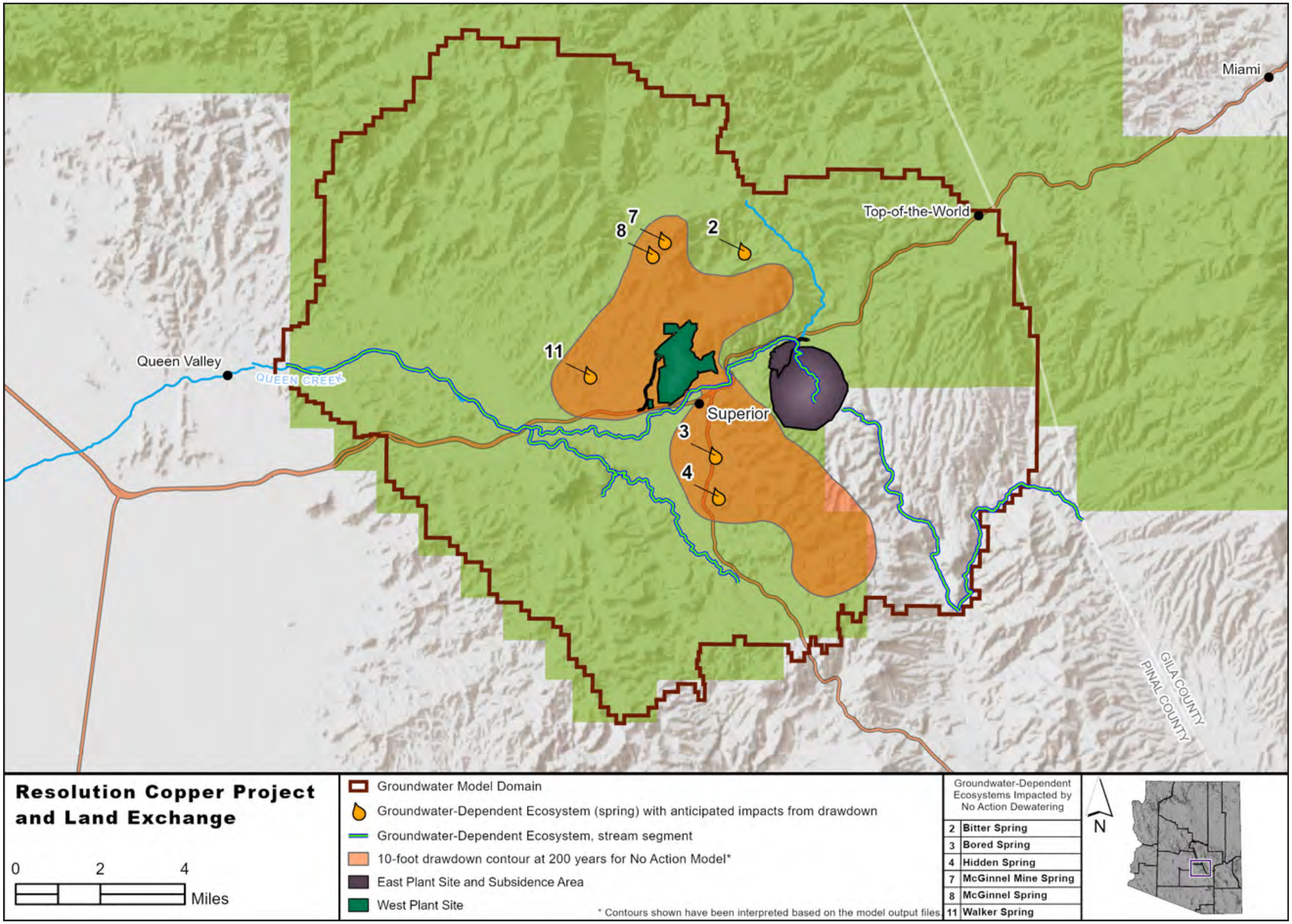


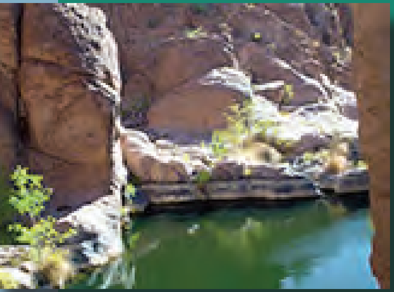
Figure 3.7.1-8. Modeled groundwater drawdown—no action

IMPACTS TO GDEs

NO ACTION

Continued Dewatering

- Bitter Spring
- Bored Spring
- Hidden Spring
- McGinnel Mine Spring
- McGinnel Spring
- Walker Spring



ALL ACTION ALTERNATIVES

Best-calibrated Model (Impacts are anticipated)	DC-6.6W Spring Kane Spring
All Sensitivity Model Runs (Impacts are possible)	No Additional GDEs
All Sensitivity Runs (Impacts are possible but unlikely)*	Middle Devil's Canyon (DC-8.8C, DC-8.82W, DC-8.1C) Queen Creek (17.4-15.6) Iberri Spring

* Totals shown do not include GDEs with "possible but unlikely" impacts; while at least one model sensitivity run indicates impacts could happen to these GDEs, the great majority of model runs indicate otherwise.

ALTERNATIVES

	Subsidence Crater Alone	Alt 2/3 (Near West)	Alt 4 (Silver King)	Alt 5 (Peg Leg)	Alt 6 (Skunk Camp)
Direct Disturbance	Grotto Rancho Rio	Benson Bear Canyon Perlite	Iberri McGinnel	None	None
Surface Water Reductions	Queen Creek (17.4-15.6) Queen Creek (Whitlow Ranch Dam) Devil's Canyon	Queen Creek (Whitlow Ranch Dam)	Queen Creek (Whitlow Ranch Dam)	Gila River	Gila River
Total GDEs Impacted†		**16**	**14**	**14**	**14**

† Totals shown include both GDEs impacted by the subsidence crater and GDEs impacted by specific alternatives.

Figure 3.7.1-9. Summary of impacts on GDEs by alternative saltcedar, and sumac. The loss of water to this spring would likely lead to complete loss of this riparian area.

Bitter, Hidden, McGinnel, McGinnel Mine, and Walker Springs all have infrastructure improvements to some degree and host relatively little riparian vegetation, although standing water and herbaceous and wetland vegetation may be present. The loss of flowing water would likely lead to complete loss of these pools and fringe vegetation.

ANTICIPATED IMPACTS ON WATER SUPPLY WELLS

Many domestic and stock water supply wells in the area are shallow and likely make use of water stored in shallow alluvium or shallow fracture networks. These wells are unlikely to be impacted by groundwater drawdown from mine dewatering under the no action alternative. However, groundwater drawdown caused by the mine could affect groundwater supplies for wells that may draw from either the regional Apache Leap Tuff aquifer or the deep groundwater system. Drawdown from 10 to 30 feet is anticipated in wells in the Superior area, as shown in table 3.7.1-4.

Unlike the action alternative, the applicant-committed environmental protection measures that would remedy any impacts on water supply wells caused by drawdown from the project (discussed later in this section) would not occur under the no action alternative.

LONGER TERM MODELED IMPACTS

The only GDEs impacted under the no action alternative are the six distant springs identified earlier in this section, which are modeled as having connections to the regional deep groundwater system. Based on long-term modeled hydrographs, these springs generally see maximum drawdown resulting from the continued mine pumping within 150 to 200 years after the end of mining; the impacts shown in table 3.7.1-3 likely represent the maximum impacts that would be experienced under the no action scenario.

SUBSIDENCE IMPACTS

Under the no action alternative, small amounts of land surface displacement could continue to occur due to ongoing pumping (Newell and Garrett 2018d). These amounts are observable using satellite monitoring techniques but are unlikely to be observable on the ground.

Impacts Common to All Action Alternatives

EFFECTS OF THE LAND EXCHANGE

The land exchange would have effects on groundwater quantity and GDEs.

The Oak Flat Federal Parcel would leave Forest Service jurisdiction. Several GDEs were identified on the Oak Flat Federal Parcel, including Rancho Rio Canyon, Oak Flat Wash, Number 9 Wash, the Grotto (spring), and Rancho Rio spring. The role of the Tonto National Forest under its primary authorities in the Organic Administration Act, Locatable Regulations (36 CFR 228 Subpart A), and Multiple-Use Mining Act is to ensure that mining activities minimize adverse environmental effects on NFS surface resources; this includes these GDEs. The removal of the Oak Flat Federal Parcel from Forest Service jurisdiction negates the ability of the Tonto National Forest to regulate effects on these resources.

The offered lands parcels would enter either Forest Service or BLM jurisdiction. A number of perennial water features are located on these lands, including the following:

- Tangle Creek. Features of the Tangle Creek Parcel include Tangle Creek and one spring (LX Spring). Tangle Creek is an intermittent or perennial tributary to the Verde River and bisects the parcel. It includes associated riparian habitat with mature hackberry, mesquite, ash, and sycamore trees.
- Turkey Creek. Features of the Turkey Creek Parcel include Turkey Creek, which is an intermittent or perennial tributary to Tonto Creek and eventually to the Salt River at Roosevelt

Table 3.7.1-4. Summary of potential impacts on groundwater supplies from groundwater drawdown

Water Supply Area	Drawdown (feet) from Dewatering under No Action Alternative (end of mining)	Drawdown (feet) from Dewatering and Block-Cave under Proposed Action (end of mining)	Drawdown (feet) from Dewatering under No Action Alternative (200 years after start of mine)	Drawdown (feet) from Dewatering and Block-Cave under Proposed Action (200 years after start of mine)	Potential for Greater Drawdown Based on Sensitivity Runs?	Summary of Expected Impacts on Groundwater Supplies
DHRES-16_743 (Superior)	<10	10–30	<10	10–30	86 of 87 sensitivity runs show impacts greater than 10 feet; confirms base case impacts	No Action – Drawdown is not anticipated. Proposed Action – Additional drawdown due to block-caving is anticipated for water supply wells in this area, except for those completed solely in alluvium or shallow fracture systems. Impacts could include loss of well capacity, the need to deepen wells, the need to modify pump equipment, or increased pumping costs. Applicant-committed remedy if impacts occur.
Gallery Well (Boyce Thompson Arboretum)	<10	<10	<10	<10	0 of 87 sensitivity runs show impacts greater than 10 feet	No Action – Drawdown is not anticipated. Proposed Action – Additional drawdown due to block-caving is not anticipated.
HRES-06 (Top-of-the-World)	<10	<10	<10	<10	17 of 87 sensitivity runs show impacts greater than 10 feet; impacts are possible beyond base case impacts	No Action – Drawdown is not anticipated. Proposed Action – Additional drawdown due to block-caving is anticipated for water supply wells in this area, except for those completed solely in alluvium or shallow fracture systems. Impacts could include loss of well capacity, the need to deepen wells, the need to modify pump equipment, or increased pumping costs. Applicant-committed remedy if impacts occur.

Lake. Riparian vegetation occurs along Turkey Creek with cottonwood, locus, sycamore, and oak trees.

- Cave Creek. Features of the Cave Creek Parcel include Cave Creek, an ephemeral to intermittent tributary to the Agua Fria River, with some perennial reaches in the vicinity of the parcel.
- East Clear Creek. Features of the East Clear Creek Parcel include East Clear Creek, a substantial perennial tributary to the Little Colorado River. Riparian vegetation occurs along East Clear Creek, including boxelder, cottonwood, willow, and alder trees.
- Lower San Pedro River. Features of the Lower San Pedro River Parcel include the San Pedro River and several large, ephemeral tributaries (Cooper, Mammoth, and Turtle Washes). The San Pedro River itself is ephemeral to intermittent along the 10-mile reach that runs through the parcel; some perennial surface water is supported by an uncapped artesian well. The San Pedro is one of the few remaining free-flowing rivers in the Southwest and it is recognized as one of the more important riparian habitats in the Sonoran and Chihuahuan Deserts. The riparian corridor in the parcel includes more than 800 acres of mesquite woodlands that also features a spring-fed wetland.
- Appleton Ranch. The Appleton Ranch Parcels are located along ephemeral tributaries to the Babocomari River (Post, Vaughn, and O’Donnel Canyons). Woody vegetation is present along watercourses as mesquite bosques, with very limited stands of cottonwood and desert willow.
- No specific water sources have been identified on the Apache Leap South Parcel or the Dripping Springs Parcel.

Specific management of water resources on the offered lands would be determined by the agencies, but in general when the offered lands enter Federal jurisdiction, these water sources would be afforded a level of protection they currently do not have under private ownership.

EFFECTS OF FOREST PLAN AMENDMENT

The Tonto National Forest Land and Resource Management Plan (1985b) provides guidance for management of lands and activities within the Tonto National Forest. It accomplishes this by establishing a mission, goals, objectives, and standards and guidelines. Missions, goals, and objectives are applicable on a forest-wide basis. Standards and guidelines are either applicable on a forest-wide basis or by specific management area.

A review of all components of the 1985 Forest Plan was conducted to identify the need for amendment due to the effects of the project, including both the land exchange and the proposed mining plan of operations (Shin 2019). A number of standards and guidelines (16) were identified applicable to management of groundwater resources. None of these standards and guidelines were found to require amendment to the proposed project, either on a forest-wide or management area-specific basis. For additional details on specific rationale, see Shin (2019).

SUMMARY OF APPLICANT-COMMITTED ENVIRONMENTAL PROTECTION MEASURES

A number of environmental protection measures are incorporated into the design of the project that would act to reduce potential impacts on groundwater quantity and GDEs. These are non-discretionary measures and their effects are accounted for in the analysis of environmental consequences.

From the GPO (2016d), Resolution Copper has committed to various measures to reduce impacts on groundwater quantity and GDEs:

- Groundwater levels will be monitored at designated compliance monitoring wells located downstream of the tailings storage facility seepage recovery embankments in accordance with the requirements of the APP program;
- All potentially impacted water will be contained on-site during operations and will be put to beneficial use, thereby reducing the need to import makeup water;

- Approximately one-half of Resolution Copper's water needs will be sourced from long-term storage credits (surface stored underground);
- As much water as possible will be recycled for reuse; and
- The water supply will also include the beneficial reuse of existing low-quality water sources such as impacted underground mine dewatering water.

HYDROLOGIC CHANGES ANTICIPATED FROM MINING ACTIVITIES

The block-caving conducted to remove the ore body would unavoidably result in fracturing and subsidence of overlying rocks. These effects would propagate upward until reaching the ground surface approximately 6 years after block-caving begins (Garza-Cruz and Pierce 2017). It is estimated that the subsidence area that would develop at the surface would be approximately 800 to 1,100 feet deep (see Section 3.2, Geology, Minerals, and Subsidence).

Fracturing and subsidence of rock units would extend from the ore body to the surface. This includes fracturing of the Whitetail Conglomerate that forms a barrier between the deep groundwater system and the Apache Leap Tuff aquifer. When the Whitetail Conglomerate fractures and subsides, a hydraulic connection is created between all aquifers. Effects of dewatering from the deep groundwater system would extend to the Apache Leap Tuff aquifer at this time.

CHANGES IN BASIN WATER BALANCE – MINE DEWATERING

Mine dewatering is estimated to remove approximately 87,000 acre-feet of water from the combined deep groundwater system and Apache Leap Tuff aquifer over the life of the mine, or about 1,700 acre-feet per year (Meza-Cuadra et al. 2018a).

ANTICIPATED IMPACTS FOR GDES (UP TO 200 YEARS AFTER START OF MINING)

As assessed in this EIS, GDEs can be impacted in a number of ways:

- Ongoing dewatering (described in the no action alternative section)
- Expansion of dewatering impacts caused by the block-caving (described in this section)
- Direct physical disturbance by either the subsidence area or tailings storage facilities (described in following sections for each individual alternative)
- Reduction in surface flow from loss of watershed due to subsidence area or tailings facility (described in section 3.7.3 and also summarized in this section)

Six springs experienced drawdown greater than 10 feet under the no action alternative, and these springs are also impacted under the proposed action (Bitter, Bored, Hidden, McGinnel, McGinnel Mine, and Walker Springs). Under the proposed action, the hydrologic changes caused by the block-caving would allow the dewatering impacts to expand, impacting two additional springs: Kane Spring and DC6.6W. Impacts on springs under the proposed action are summarized in table 3.7.1-3 and figure 3.7.1-9 and are shown along with the model results (10-foot drawdown contour) in figure 3.7.1-3. Hydrographs of drawdown under the proposed action for all GDEs are also included in appendix L.

As one strategy to address the uncertainty inherent in the groundwater model, sensitivity modeling runs were also considered in addition to the base case model. The sensitivity modeling runs strongly confirm the impacts on the eight springs listed earlier in this section. Sensitivity runs show additional impact could be possible in Middle Devil's Canyon (locations DC8.8C, DC8.2CW, and DC8.1C), in Queen Creek below Superior, and at Iberri Spring. In each case, however, the large majority of sensitivity runs are consistent with the base case modeling and show drawdown less than 10 feet. Based on the sensitivity runs, impacts at these locations may be possible but are considered unlikely.

The 10-foot drawdown contour shown on figure 3.7.1-3 represents the limit of where the groundwater model can reasonably predict impacts, either with the best-calibrated model (orange area) or the model sensitivity runs (yellow area). GDEs falling within this contour are anticipated to be impacted. GDEs outside this contour may still be impacted, but it is beyond the ability of the model to predict.

ANTICIPATED IMPACTS ON DEVIL'S CANYON

Groundwater inflow along the main stem of Devil's Canyon is not anticipated to be impacted using the best-calibrated groundwater model; however, tributary flow from spring DC-6.6W along the western edge of Devil's Canyon is anticipated to be impacted. Based on field measurements, flow from this spring contributes up to 5 percent of flow in the main channel downstream at location DC-5.5C (Newell and Garrett 2018d). There is little indication that any other springs along Devil's Canyon or groundwater contribution to the main stem of the stream would be impacted; out of 87 modeling runs, only a single modeling run indicates impact on GDE locations in Devil's Canyon besides spring DC-6-6W.

Potential runoff reductions in Devil's Canyon are summarized in table 3.7.1-5. Percent reductions in average annual flow due to the subsidence area range from 5.6 percent in middle Devil's Canyon to 3.5 percent at the confluence with Mineral Creek; percent reductions during the critical low-flow months of May and June are approximately the same. Combined with loss from spring DC-6.6W due to groundwater drawdown, total estimated flow reductions along the main stem of lower Devil's Canyon caused by the proposed project could range from 5 to 10 percent.

The habitat in Devil's Canyon downstream of spring DC-6.6W and the subsidence area that would potentially lose flow includes a roughly 2.1-mile-long, 50-acre riparian gallery, and a 0.5-mile-long continuously saturated reach that includes several large perennial pools. Riparian vegetation in this portion of the canyon ranges from 40 to 300 feet wide. Dominant riparian species are sycamore, cottonwood, ash, alder, and willow, as well as wetland species at spring locations.

The anticipated 5 to 10 percent loss in flow during the dry season could contribute to a reduction in the extent and health of riparian vegetation and aquatic habitat. Complete drying of the downstream habitat, loss of dominant riparian vegetation, or loss of standing pools would be unlikely.

ANTICIPATED IMPACTS ON SPRINGS

It is not possible to precisely predict what impact a given drawdown in groundwater level would have on an individual spring; however, given the precision of the model (10 feet), it is reasonable to assume any spring with anticipated impact of this magnitude could experience complete drying.

Bored Spring has the highest riparian value, supporting a standing pool and a 500-foot riparian string of cottonwood, willow, mesquite, saltcedar, and sumac. The loss of water to this spring would likely lead to complete loss of this riparian area.

Hidden, McGinnel, McGinnel Mine, Walker, Bitter, and Kane Springs all have infrastructure improvements to some degree and host relatively little riparian vegetation, although standing water and herbaceous and wetland vegetation may be present. The loss of flowing water would likely lead to complete loss of these pools and fringe vegetation.

ANTICIPATED IMPACTS ON QUEEN CREEK

Impact on the flowing reach of Queen Creek between Superior and Boyce Thompson Arboretum is not anticipated under the best-calibrated model run, and impact is anticipated under less than 5 percent of the sensitivity model runs (4 of 87 sensitivity runs suggest an impact). Impacts on groundwater inflow in this reach are considered possible, but unlikely.

Table 3.7.1-5. Summary of potential impacts on groundwater-dependent ecosystems from surface flow losses

Reference Number on Figure 3.7.1-7	GDE	Summary of Expected Impacts on GDEs
	Queen Creek and Tributaries	
Not numbered on figure	Queen Creek above Superior (from confluence with Oak Flat Wash [~km 26] to Magma Avenue Bridge [km 21.7], including springs QC23.6C [Boulder Hole], Queen Seeps, and QC22.6E [Karst Spring])	No Action – No reduction in runoff would occur from subsidence. Proposed Action – Reduction in surface runoff volume due to subsidence is estimated to be 18.6% at Magma Avenue Bridge (see Section 3.7.3, Surface Water Quantity). Reduction in runoff volume could reduce amount of water temporarily stored in shallow alluvium or fracture networks. Impacts above Superior could include a reduction or loss of spring/stream flow, increased mortality or reduction in extent or health of riparian vegetation, and reduction in the quality or quantity of aquatic habitat from loss of flowing water, adjacent vegetation, or standing pools.
Not numbered on figure	Queen Creek below Superior (from Magma Avenue Bridge [km 21.7] to Whitlow Ranch Dam [km 0])	No Action – No reduction in runoff would occur from subsidence or tailings alternatives. Proposed Action/Subsidence – Reduction in surface runoff volume due to subsidence is estimated to range from 13.4% reduction at Boyce Thompson Arboretum to 3.5% reduction at Whitlow Ranch Dam. Channel largely ephemeral and habitat is generally xeroriparian in nature, accustomed to ephemeral, periodic flows. Impacts on this type of vegetation would be unlikely due to surface flow reductions of this magnitude. Alternative 2 and 3 – The combined reduction in runoff volume from subsidence with a reduction in runoff volume due to a tailings storage facility at the Near West location (Alternative 2 or 3) is estimated as 6.5% at Whitlow Ranch Dam. Channel largely ephemeral and habitat is generally xeroriparian in nature, accustomed to ephemeral, periodic flows. Impacts on this type of vegetation would be unlikely due to surface flow reductions of this magnitude. Alternative 4 – The combined reduction in runoff volume from subsidence with a reduction in runoff volume due to a tailings storage facility at the Silver King location (Alternative 4) is estimated to range from a 19.9% reduction at Boyce Thompson Arboretum to an 8.9% reduction at Whitlow Ranch Dam. Reduction in runoff volume could reduce the amount of water temporarily stored in shallow alluvium or fracture networks. Impacts at Boyce Thompson Arboretum could include a reduction or loss of spring/stream flow, increased mortality or reduction in extent or health of riparian vegetation, and reduction in the quality or quantity of aquatic habitat from loss of flowing water, adjacent vegetation, or standing pools.
1	Whitlow Ranch Dam Outlet	No Action – Drawdown is not anticipated. Proposed Action – Additional drawdown due to block-caving is not anticipated, and reduction in surface runoff is anticipated 3.5%, but impacts on riparian vegetation are unlikely due to geological controls on groundwater levels. Location would be monitored during operations for verification of potential impacts.

continued

Table 3.7.1-5. Summary of potential impacts on groundwater-dependent ecosystems from surface flow losses *(cont'd)*

Reference Number on Figure 3.7.1-7	GDE	Summary of Expected Impacts on GDEs
15	Oak Flat Wash	No Action – No reduction in runoff would occur from subsidence. Proposed Action – A portion of the Oak Flat Wash watershed is within the subsidence area, and a reduction in surface water volume is anticipated. These impacts are already incorporated into the quantitative modeling for Queen Creek.
	Devil's Canyon and Tributaries	
16	Devil's Canyon (from km 9.3 to confluence with Mineral Creek [km 0]).	No Action – No reduction in runoff would occur from subsidence. Proposed Action – Reduction in surface runoff volume due to subsidence ranges from 5.6% reduction at DC8.1C to 3.5% reduction at confluence with Mineral Creek (see Section 3.7.3, Surface Water Quantity). During critical dry season (May/June), percent reductions are approximately the same. Flow reductions could contribute to a reduction in the extent and health of riparian vegetation and aquatic habitat. Complete drying of the downstream habitat, loss of dominant riparian vegetation, or loss of standing pools would be unlikely.
17	Rancho Rio Canyon (RR1.5C)	No Action – No reduction in runoff would occur from subsidence. Proposed Action – A portion of the Rancho Rio Canyon watershed is within the subsidence area, and a reduction in surface water volume is anticipated. These impacts are already incorporated into the quantitative modeling for Devil's Canyon.

This reach is believed to potentially have three sources of flow (Garrett 2018d):

- groundwater inflow into this reach is possible and assumed, but not certain;
- effluent from the Town of Superior Wastewater Treatment Plant occurs and is estimated at 170 acre-feet per year; and
- discharge of groundwater from a perlite mine pit southwest of Superior is estimated at 170 acre-feet per year.

Aside from groundwater drawdown, this reach of Queen Creek also would see reductions in runoff due to the subsidence area, ranging from about 19 percent in Superior to 13 percent at Boyce Thompson Arboretum (see table 3.7.1-5). The anticipated 13 to 19 percent loss in flow during the dry season could contribute to a reduction in the extent and health of riparian vegetation and aquatic habitat. The complete drying of the downstream habitat, loss of dominant riparian vegetation, or loss of standing pools would be unlikely.

Between Boyce Thompson and Whitlow Ranch Dam, Queen Creek is largely ephemeral, and habitat is generally xeroriparian in nature, accustomed to ephemeral, periodic flows. Impacts on this type of vegetation would be unlikely due to surface flow reductions. The riparian area along Queen Creek at Whitlow Ranch Dam would be impacted by reductions in surface flow of roughly 3.5 percent. The groundwater levels in this area are primarily controlled by the fact that this area represents the discharge point for the Superior basin and the influence of Whitlow Ranch Dam impounding flow. Given this control, a 3.5 percent change in surface flow would be unlikely to greatly affect groundwater levels at this location, nor does the groundwater flow model predict any drawdown at this distance from the mine. Impacts on the riparian area at Whitlow Ranch Dam would not be expected to be substantial.

The location on Queen Creek most at risk is likely above Superior, with possible surface flow losses of more than 19 percent. Reduction in runoff volume could reduce the amount of water temporarily stored in shallow alluvium or fracture networks. Impacts above Superior could include a reduction or loss of spring/stream flow, increased mortality or reduction in extent or health of riparian vegetation, and reduction in the quality or quantity of aquatic habitat from loss of flowing water, adjacent vegetation, or standing pools.

POTENTIAL IMPACT ON SURFACE WATER RIGHTS FROM GROUNDWATER DRAWDOWN

Arizona law allows for the right to appropriate and use surface water, generally based on a “first in time, first in right” basis. This function is administered by the ADWR, which maintains databases of water right filings, reviews applications and claims, and when appropriate issues permits and certificates of water right. However, water right filings can be made on the same surface water by multiple parties, and at this time almost all Arizona surface waters are over-appropriated with no clear prioritization of overlapping water rights. In addition, the State of Arizona has a bifurcated water rights system in which groundwater and surface water use are considered separately, and state law as of yet provides no clear framework for the interaction between groundwater and surface water uses.

To remedy these issues, a legal proceeding called the General Stream Adjudication of the Gila River is being undertaken through the Arizona court system. Goals of the adjudication include clarifying the validity and priority of surface water rights and providing a clear legal framework for when groundwater withdrawals would impinge on surface water rights. The adjudication has been underway for several decades, and while progress has been made, many issues remain unresolved, including any prioritization or validation of water rights in the analysis area.

Groundwater drawdown associated with the project is anticipated to impact eight GDEs. Known surface water filings associated with these GDEs are summarized in table 3.7.1-6. The Forest Service analysis identifies and discloses possible loss of water to these GDEs; however, the impact on any surface water rights from a legal or regulatory standpoint cannot yet be determined due to the ongoing adjudication.

Table 3.7.1-6. Summary of water right filings associated with GDEs impacted by groundwater drawdown

Specific GDE Potentially Impacted by Groundwater Drawdown	Arizona Water Right Filings
DC-6.6W Spring	Filing of Statement of Claim of Right to Use Public Waters of the State, 36-1757, filed 1986 by Arizona State Land Department
Bitter Spring	Filing of Statement of Claim of Right to Use Public Waters of the State, 36-24054, filed 1979 by Tonto National Forest
Bored Spring	Application for a Permit to Appropriate Public Waters of the State of Arizona #A-2014, filed 1938 by Crook National Forest Permit to Appropriate #A-1376, issued 1939 to Crook National Forest by State Water Commissioner Certificate of Water Right #955, issued 1941 to Crook National Forest by State Water Commissioner
Hidden Spring	Filing of Statement of Claim of Right to Use Public Waters of the State, 36-24052, filed 1979 by Tonto National Forest
Kane Spring	No filings identified
McGinnel Mine Spring	Application for a Permit to Appropriate Public Waters of the State of Arizona, 33-94335, filed 1988 by Tonto National Forest Proof of Appropriation of Water, 33-94335, filed 1989 by Tonto National Forest Permit to Appropriate Public Waters of the State of Arizona, 33-94335, issued 1989 by ADWR Certificate of Water Right 33-94355, issued 1990 by ADWR
McGinnel Spring	Statement of Claim of Right to Use Public Waters of the State, 36-24049, filed 1979 by Tonto National Forest
Walker Spring	No filings identified

ANTICIPATED IMPACTS ON WATER SUPPLY WELLS

Many domestic and stock water supply wells in the area are shallow and likely make use of water stored in shallow alluvium or shallow fracture networks. These wells are unlikely to be impacted by groundwater drawdown from the mine. However, groundwater drawdown caused by the mine could affect groundwater supplies for wells that may draw from either the regional Apache Leap Tuff aquifer or the deep groundwater system. Drawdown from 10 to 30 feet is anticipated in wells in the Superior area, as shown in table 3.7.1-4. In addition, in about 20 percent of sensitivity modeling runs, impacts from 10 to 30 feet could also occur in wells near Top-of-the-World.

The applicant-committed environmental protection measures include remedying any impacts on water supply wells caused by drawdown from the project.

LONGER TERM MODELED IMPACTS – SPRINGS IN THE QUEEN CREEK BASIN

Under the proposed action, drawdown continues to propagate well beyond 200 years. The modeled groundwater level trends generally suggest maximum drawdown does not occur until 600 to 800 years after the end of mining at the distant spring locations (Morey 2018c).

As described earlier in this section, eight of the springs (Bitter, Bored, Hidden, Kane, McGinnel, McGinnel Mine, Walker, and DC6.6W) see impacts great enough under either the no action alternative or proposed action to effectively dry the spring. The remaining springs without anticipated impacts (Iberri, No Name, and Rock Horizontal) may still experience drawdown beyond 200 years, but the magnitude and trends of drawdown observed are unlikely to change the anticipated impacts (see hydrographs in appendix L).

LONGER TERM MODELED IMPACTS – DEVIL'S CANYON

For most of Devil's Canyon (including spring DC-6.6W), drawdown under the proposed action scenario reaches its maximum extent within

50 to 150 years after the end of mining; the impacts shown in table 3.7.1-3 likely represent the maximum impacts under the proposed action scenario.

LONGER TERM MODELED IMPACTS – QUEEN CREEK, TELEGRAPH CANYON, AND ARNETT CREEK

Predicted drawdown at Queen Creek, Telegraph Canyon, and Arnett Creek did not exceed the quantitative 10-foot drawdown threshold, except in a small number of sensitivity modeling runs. However, predicted groundwater level trends indicate that the maximum drawdown would not occur at these locations for roughly 500 to 900 years, suggesting impacts could be greater than those reported in table 3.7.1-3 (Morey 2018c).

For Telegraph Canyon and Arnett Creek, while drawdown may still be occurring beyond 200 years, the magnitude and trends of drawdown observed are unlikely to change the anticipated impacts (see hydrographs in appendix L).

For the flowing reach of Queen Creek below Superior, while the impacts predicted by the best-calibrated model did not exceed the quantitative threshold of 10 feet, trends of drawdown suggest this could occur after 200 years. With consideration to the uncertainties in the analysis, impacts on the groundwater-related flow components of Queen Creek appear to be possible to occur at some point.

LONGER TERM MODELED IMPACTS – WATER SUPPLIES

Potential impacts on groundwater supplies associated with the regional aquifer were already identified as possible for both Top-of-the-World and Superior. The predicted groundwater trends suggest that the impacts shown in table 3.7.1-4 for Top-of-the-World are likely the maximum impacts expected (Morey 2018c). However, the groundwater trends for wells in Superior (represented by well DHRES-16_753) suggest that maximum drawdown would not occur until roughly 600 years after the end of mining. Impacts on groundwater supplies relying on the regional deep groundwater system near Superior may continue to worsen beyond the results report in table 3.7.1-4.

POTENTIAL FOR LAND SUBSIDENCE DUE TO GROUNDWATER PUMPING

Two areas have the potential for land subsidence due to groundwater pumping: the area around the East Plant Site and mining panels where dewatering pumping would continue to occur, and the area around the Desert Wellfield. While small amounts of land subsidence attributable to the dewatering pumping have been observed around the East Plant Site using satellite techniques (approximately 1.5 inches, between 2011 and 2016), once mining operations begin, any land subsidence due to pumping would be subsumed by subsidence caused by the block-caving (estimated to be 800 feet deep, and possibly as deep as 1,100 feet at the end of mining).

Drawdown associated with the Desert Wellfield would contribute to lowering of groundwater levels in the East Salt River valley subbasin, including near two known areas of known ground subsidence. Further detailed analysis of land subsidence resulting from groundwater withdrawal is not feasible beyond noting the potential for any pumping to contribute to drawdown and subsidence. Subsidence effects are a basin-wide phenomenon, and the impact from one individual pumping source cannot be predicted or quantified.

Alternative 2 – Near West Proposed Action

GROUNDWATER-DEPENDENT ECOSYSTEMS IMPACTED

Three GDEs would be directly disturbed by a tailings facility at the Near West site: Bear Tank Canyon Spring, Benson Spring, and Perlite Spring. All three of these GDEs are believed to be disconnected from the regional aquifers, relying on precipitation stored in shallow alluvium or fracture networks. Benson Spring is located near the front of the facility, potentially under the tailings embankment. Bear Tank Canyon Spring is located in the middle of the facility under the NPAG tailings, and Perlite Spring is located at the northern edge of the facility, near the PAG tailings cell.

In total, 16 GDEs are anticipated to be impacted under Alternative 2 (see figure 3.7.1-9):

- Six springs are anticipated to be impacted from continued dewatering under the no action alternative.
- Two additional springs are anticipated to be impacted under the proposed action, because of the block-cave mining.
- Two springs are directly disturbed by the subsidence area.
- Three springs are directly disturbed by the Alternative 2 tailings storage facility.
- One perennial stream (Devil's Canyon) is impacted by reduced runoff from the subsidence area.
- Two perennial stream reaches on Queen Creek are impacted by reduced runoff from both the subsidence area and the tailings.

CHANGES IN TAILINGS WATER BALANCE

The substantial differences in water balance between alternatives are directly related to the location and design of the tailings storage facility. There are five major differences, as shown in table 3.7.1-7:

- **Entrainment.** The tailings deposition method affects the amount of water that gets deposited and retained with the tailings. Alternative 2 entrains about the same amount of water as the other slurry tailings alternatives (Alternatives 3, 5, and 6), but substantially more than Alternative 4.
- **Evaporation.** The tailings deposition method also affects the amount of water lost through evaporation, even among slurry tailings. Alternative 2 evaporates a similar amount of water as Alternatives 5 and 6, but substantially more than Alternatives 3 and 4.
- **Watershed losses.** Watershed losses from the capture of precipitation depend primarily on the location of the tailings storage facility and where it sits in the watershed. Surface runoff losses are summarized in table 3.7.1-5, and are analyzed in greater detail in Section 3.7.3, Surface Water Quantity.
- **Seepage.** Differences in seepage losses are substantial between alternatives. Three estimates of seepage are shown in table 3.7.1-7. The amount of seepage based on the initial tailings designs using only the most basic level of seepage controls is shown, and primarily reflects the type of tailings deposition and geology (WestLand Resources Inc. 2018b). After these initial designs, the engineered seepage controls were refined as part of efforts to reduce impacts on water quality from the seepage (Klohn Crippen Berger Ltd. 2019d). The estimated reduced seepage rates with all engineered seepage controls in place, both during operations and post-closure, are also shown in table 3.7.1-7. Alternative 2 loses more seepage than Alternatives 3 and 4, but less seepage than Alternatives 5 and 6. The effects of seepage on groundwater and surface water quality are analyzed in greater detail in Section 3.7.2, Groundwater and Surface Water Quality.

CHANGES IN DESERT WELLFIELD PUMPING

The water balances for the alternatives are very complex, with multiple water sources and many recycling loops. However, ultimately a certain amount of makeup water is needed, which must be pumped from Desert Wellfield in the East Salt River valley. Alternative 2 requires the most makeup water, roughly 600,000 acre-feet over the life of the mine. The amount of groundwater in storage in the East Salt River valley subbasin (above a depth of 1,000 feet) is estimated to be about 8.1 million acre-feet. Pumping under Alternative 2 represents about 7.3 percent of the available groundwater in the East Salt River valley subbasin.

Table 3.7.1-7. Primary differences between alternative water balances

Alternative	Water Entrained with Tailings (acre-feet, life of mine)	Precipitation or Runoff Intercepted (acre-feet, life of mine)*	Percentage Loss to Downstream Waters†	Water Lost to Evaporation from Tailings Storage Facility (acre-feet, life of mine)*	Water Lost as Seepage from Tailings Storage Facility without Engineered Seepage Controls (acre-feet, life of mine)	Water Lost as Seepage to Aquifer after Engineered Seepage Controls during Operations (acre-feet, life of mine)	Water Lost as Seepage to Aquifer, Post-Closure (acre-feet per year)	Makeup Water Pumped from Desert Wellfield (acre-feet, life of mine)
2	271,839	68,780	6.5	307,903	5,741	849	20.7	586,508
3	305,443	60,531	6.5	174,742	2,891	111	2.7	494,286
4	71,017	110,854	8.9	135,102	3,148	369–680	15.2–31.9	175,800
5	308,404	278,639	0.2	384,702	53,184	10,701	261	544,778
6	277,710	205,297	0.3	384,427	17,940	2,665–7,298	202–258	544,858

Source: Ritter (2018). For seepage losses after engineered seepage controls, during operations and post-closure, see Klohn Crippen Berger Ltd. (2019d) and Gregory and Bayley (2019)

* Alternatives 5 and 6 include total precipitation on and evaporation from the tailings beach. However, precipitation onto the tailings beach that evaporates before contributing to the mine water balance is not included in the estimated precipitation and evaporation volumes for Alternatives 2, 3, and 4. These different accounting methods for evaporation and precipitation do not impact the total makeup water demand estimates for the Desert Wellfield

† Alternatives 2, 3, and 4 reflect change in percentage of annual flow in Queen Creek at Whitlow Ranch Dam. Alternatives 5 and 6 reflect change in percentage of annual flow in the Gila River at Donnelly Wash. These numbers only account for precipitation captured by tailings facilities or subsidence area. Water rerouted around the facilities or seepage reappearing downstream is not incorporated.

Projected drawdown would be greatest in the center of the Desert Wellfield, reaching a maximum drawdown of 228 feet, as shown in figure 3.7.1-2. These groundwater levels recover after mining ceases, eventually recovering to less than 20 feet. Drawdown decreases with distance from the wellfield. At the north and south ends of the wellfield, maximum drawdown ranges from 109 to 132 feet, and farther south within NMIDD, maximum drawdown is roughly 49 feet (Bates et al. 2018; Garrett 2018a).

Alternative 3 – near west – Ultrathickened

GROUNDWATER-DEPENDENT ECOSYSTEMS IMPACTED

The GDEs impacted are identical to those impacted under Alternative 2.

CHANGES IN TAILINGS WATER BALANCE

The following water balance components for Alternative 3 are summarized in table 3.7.1-7:

- **Entrainment.** Alternative 3 entrains about the same amount of water as the other slurry tailings alternatives (Alternatives 3, 5, and 6), but substantially more than Alternative 4.
- **Evaporation.** Alternative 3 evaporates less water than Alternatives 2, 5, and 6, and almost matches the filtered tailings alternative (Alternative 4) for reductions in evaporation.
- **Watershed losses.** Watershed losses are the same as Alternative 2.
- **Seepage.** With engineered seepage controls in place, Alternative 3 loses the least amount of seepage of any alternative, including the filtered tailings alternative (Alternative 4).

CHANGES IN DESERT WELLFIELD PUMPING

Alternative 3 requires less makeup water than Alternative 2, roughly 500,000 acre-feet over the life of the mine. Pumping under Alternative 3 represents about 6.1 percent of the estimated 8.1 million acre-feet of available groundwater in the East Salt River valley subbasin (Garrett 2018a).

Maximum drawdown for Alternative 3 reaches about 177 feet, eventually recovering to less than 20 feet. At the north and south ends of the wellfield, maximum drawdown ranges from 87 to 105 feet, and farther south within NMIDD maximum drawdown is roughly 42 feet (Bates et al. 2018; Garrett 2018a).

Alternative 4 – Silver King

GROUNDWATER-DEPENDENT ECOSYSTEMS IMPACTED

Two GDEs would be directly disturbed by a tailings facility at the Silver King site: Iberri Spring and McGinnel Spring. Both of these springs are assumed to be at least partially connected to the regional aquifers; both are located under the NPAG tailings facility.

In total, 14 GDEs are anticipated to be impacted under Alternative 4 (see figure 3.7.1-9):

- Six springs are anticipated to be impacted from continued dewatering under the no action alternative.
- Two additional springs are anticipated to be impacted under the proposed action, because of the block-cave mining.
- Two springs are directly disturbed by the subsidence area.
- Two springs are directly disturbed by the Alternative 4 tailings storage facility; however, one of these was already impacted under the no action alternative.

- One perennial stream (Devil's Canyon) is impacted by reduced runoff from the subsidence area.
- Two perennial stream reaches on Queen Creek are impacted by reduced runoff from both the subsidence area and the tailings.

For the other action alternatives, there was an anticipated 7 to 15 percent loss in flow in Queen Creek below Superior to Boyce Thompson Arboretum. Because of the location of Alternative 4 at the head of the watershed, these flow losses are more substantial, ranging from 7 percent in Superior, to 20 percent at Boyce Thompson Arboretum, to 9 percent at Whitlow Ranch Dam. Reduction in runoff volume could reduce the amount of water temporarily stored in shallow alluvium or fracture networks.

Impacts at Boyce Thompson Arboretum could include a reduction or loss of spring/stream flow, increased mortality or reduction in extent or health of riparian vegetation, and reduction in the quality or quantity of aquatic habitat from loss of flowing water, adjacent vegetation, or standing pools. Substantial impacts on the riparian vegetation at Whitlow Ranch Dam are still unlikely due to the geological controls, although the reductions in runoff are greater under Alternative 4 than other alternatives.

CHANGES IN TAILINGS WATER BALANCE

The following water balance components for Alternative 4 are summarized in table 3.7.1-7:

- **Entrainment**. Because water is filtered from the tailings before placement, Alternative 4 entrains the least amount of water of all alternatives, approximately only one-quarter of that entrained under Alternative 2.
- **Evaporation**. Because Alternative 4 does not have a standing recycled water pond, Alternative 4 also evaporates the least amount of water of all alternatives, approximately only one-half of that of Alternative 2.
- **Watershed losses**. Watershed losses are higher than Alternatives 2 and 3, due to the position of Alternative 4 higher in the Queen Creek watershed, and the need for stringent stormwater control to avoid contact of water with exposed PAG tailings.
- **Seepage**. Alternative 4 loses the least amount of seepage of all alternatives, except for Alternative 3 (ultrathickened).

CHANGES IN DESERT WELLFIELD PUMPING

Alternative 4 requires the least amount of makeup water of all alternatives, roughly 180,000 acre-feet over the life of the mine, or roughly 30 percent of the makeup water required for the slurry tailings alternatives (Alternatives 2, 3, 5, and 6). Pumping under Alternative 4 represents about 2.2 percent of the estimated 8.1 million acre-feet of available groundwater in the East Salt River valley subbasin (Garrett 2018a).

Alternative 4 also results in the least amount of drawdown, as shown in figure 3.7.1-2. Maximum drawdown for Alternative 4 reaches about 53 feet, eventually recovering to roughly 5 feet. At the north and south ends of the wellfield, maximum drawdown ranges from 30 to 35 feet, and farther south within NMIDD maximum drawdown is roughly 17 feet (Bates et al. 2018; Garrett 2018a).

Alternative 5 – Peg Leg

GROUNDWATER-DEPENDENT ECOSYSTEMS IMPACTED

No GDEs have been identified within the vicinity of the Peg Leg site or are expected to be directly disturbed. In total, 14 GDEs are anticipated to be impacted under Alternative 5 (see figure 3.7.1-9):

- Six springs are anticipated to be impacted from continued dewatering under the no action alternative.

- Two additional springs are anticipated to be impacted under the proposed action because of the block-cave mining.
- Two springs are directly disturbed by the subsidence area.
- Three perennial stream reaches in Devil's Canyon and Queen Creek are impacted by reduced runoff from the subsidence area.
- One perennial stream reach of the Gila River is impacted by reduced runoff from the tailings facility.

CHANGES IN TAILINGS WATER BALANCE

The following water balance components for Alternative 5 are summarized in table 3.7.1-7:

- **Entrainment.** Alternative 5 entrains about the same amount of water as the other slurry tailings alternatives (Alternatives 2, 5, and 6), but substantially more than Alternative 4.
- **Evaporation.** Alternative 5 loses the most amount of water to evaporation of all alternatives, about 25 percent more than Alternative 2.
- **Watershed losses.** Watershed losses (as a percentage change in perennial flow) are relatively low for Alternative 5, largely due to the large watershed and flow of the Gila River.
- **Seepage.** Because of the location over a deep alluvial basin, Alternative 5 loses substantially more seepage than all other alternatives.

CHANGES IN DESERT WELLFIELD PUMPING

Alternative 5 requires more water to move the tailings slurry over long distances, and to make up for seepage losses. Alternative 5 uses only slightly less water than Alternative 2, about 550,000 acre-feet over the life of the mine. Pumping under Alternative 5 represents about 6.7 percent of the estimated 8.1 million acre-feet of available groundwater in the East Salt River valley subbasin (Garrett 2018a).

Maximum drawdown for Alternative 5 reaches about 199 feet, eventually recovering to less than 20 feet. At the north and south ends of the wellfield, maximum drawdown ranges from 96 to 115 feet, and farther south within NMIDD maximum drawdown is roughly 46 feet (Bates et al. 2018; Garrett 2018a).

Alternative 6 – Skunk Camp

GROUNDWATER-DEPENDENT ECOSYSTEMS IMPACTED

No GDEs have been identified within the vicinity of the Skunk Camp site based on site-specific information. In total, 14 GDEs are anticipated to be impacted under Alternative 6, the same as under Alternative 5 (see figure 3.7.1-9):

- Six springs are anticipated to be impacted from continued dewatering under the no action alternative.
- Two additional springs are anticipated to be impacted under the proposed action, because of the block-cave mining.
- Two springs are directly disturbed by the subsidence area.
- Three perennial stream reaches in Devil's Canyon and Queen Creek are impacted by reduced runoff from the subsidence area.
- One perennial stream reach of the Gila River is impacted by reduced runoff from the tailings facility.

CHANGES IN TAILINGS WATER BALANCE

The following water balance components for Alternative 6 are summarized in table 3.7.1-6:

- **Entrainment.** Alternative 6 entrains about the same amount of water as the other slurry tailings alternatives (Alternatives 2, 5, and 6), but substantially more than Alternative 4.

- **Evaporation.** Alternative 6 loses almost as much water to evaporation as the alternative with the greatest evaporative losses (Alternative 5), about 25 percent more than Alternative 2.
- **Watershed losses.** Watershed losses (as a percentage change in perennial flow) are relatively low for Alternative 6, largely due to the large watershed and flow of the Gila River.
- **Seepage.** Because of the location over an alluvial basin, Alternative 6 loses substantially more than Alternatives 2, 3, and 4, but still less than Alternative 5.

CHANGES IN DESERT WELLFIELD PUMPING

Alternative 6 requires more water to move the tailings slurry over long distances, and to make up for seepage losses. Alternative 6 uses only slightly less water than Alternative 2, about 550,000 acre-feet over the life of the mine, and about the same as Alternative 5. Pumping under Alternative 6 represents about 6.7 percent of the estimated 8.1 million acre-feet of available groundwater in the East Salt River valley subbasin (Garrett 2018a).

Drawdown from Alternative 6 is nearly identical to that of Alternative 5.

Cumulative Effects

The Tonto National Forest identified the following reasonably foreseeable future actions as likely, in conjunction with development of the Resolution Copper Mine, to contribute to cumulative impacts on groundwater quantity and GDEs. As noted in section 3.1, past and present actions are assessed as part of the affected environment; this section analyzes the effects of any RFFAs, to be considered cumulatively along with the affected environment and Resolution Copper Project effects.

- *Ripsey Wash Tailings Project.* Mining company ASARCO is planning to construct a new tailings storage facility to support its Ray Mine operations. The environmental effects of the project were analyzed in an EIS conducted by the USACE and approved in a ROD issued in December 2018. As approved, the proposed tailings storage facility project would occupy an estimated 2,574 acres and would be situated in the Ripsey Wash watershed just south of the Gila River approximately 5 miles west-northwest of Kearny, Arizona, and would contain up to approximately 750 million tons of material (tailings and embankment material). ASARCO estimates a construction period of 3 years and approximately 50 years of expansion of the footprint of the tailings storage facility as slurry tailings are added to the facility, followed by a 7- to 10-year period for reclamation and final closure. This project is estimated to result in a reduction of recharge to the Gila River of 0.2 percent. This would be cumulative with losses from either Alternative 5 (estimated reduction in flow in the Gila River at Donnelly Wash of 0.2 percent) or Alternative 6 (estimated reduction in flow in the Gila River at Donnelly Wash of 0.3 percent).
- *LEN Range Improvements.* This range allotment is located near Ray Mine. Under the proposed action, upland perennial sources of water would be provided to supplement the existing upland water infrastructure on the allotment. The supplemental water sources would provide adequate water facilities for existing authorized grazing management activities. While beneficial, these water sources are located in a different geographic area than the GDEs potentially impacted by the Resolution Copper Project.
- *Millsite Range Improvements*. This range allotment is located 20 miles east of Apache Junction, on the southern end of the Mesa Ranger District. The Mesa Ranger District is proposing to add three new 10,000-gallon storage tanks and two 600-gallon troughs to improve range condition through better livestock distribution and to provide additional wildlife waters in three pastures on the allotment. Water developments are proposed within the Cottonwood, Bear Tanks, and Hewitt pastures of the Millsite grazing allotment. These improvements would be beneficial for providing water on the landscape and are within

the same geographic area where some water sources could be lost (Alternatives 2 and 3); they may offset some loss of water that would result because of the Resolution Copper Project tailings storage facility construction.

- *Ray Land Exchange and Proposed Plan Amendment.* ASARCO is also seeking to complete a land exchange with the BLM by which the mining company would gain title to approximately 10,976 acres of public lands and federally owned mineral estate located near ASARCO's Ray Mine in exchange for transferring to the BLM approximately 7,304 acres of private lands, primarily in northwestern Arizona. It is known that at some point ASARCO wishes to develop a copper mining operation in the "Copper Butte" area west of the Ray Mine; however, no details are currently available as to potential environmental effects, including to groundwater quantity and GDEs, resulting from this possible future mining operation. Given the location of this activity, impacts on water could potentially be cumulative with Resolution Copper Project–related impacts on the Gila River for Alternatives 5 and 6.
- *Imerys Perlite Mine*. Imerys Perlite Mine submitted a plan of operations in 2013 which included plans for continued operation of the existing sedimentation basin at the millsite; continued use of segments of NFS Roads 229, 989, and 2403 for hauling; and mining at the Forgotten Wedge and Rosemarie Exception No. 8 claims. Dewatering is necessary to access the ore body in the active mine pit. This groundwater withdrawal would potentially be cumulative with dewatering impacts from the Resolution Copper Project.

Other projects and plans are certain to occur or be in place during the foreseeable life of the Resolution Copper Mine (50–55 years). These, combined with general population increase and ground-disturbing activities, may cumulatively contribute to future changes to groundwater supplies and GDEs.

EAST SALT RIVER VALLEY WATER SUPPLIES

Several reasonably foreseeable future actions were identified during the NEPA process but were determined too speculative to analyze for cumulative effects without detailed plans. These include potential housing developments in the town of Florence, and the ASLD's planned Superstition Vistas development area. A number of approved, assured water supplies were also identified in the East Salt River valley, and these describe future use of water in enough detail to be considered for cumulative effects. All of these potential future actions have the potential to be cumulative in combination with the impacts from the Desert Wellfield, resulting in greater drawdown than projected from the Resolution Copper Project.

RECHARGE AND RECOVERY CREDITS

Arizona water law allows for renewable sources of water to be recharged and stored in aquifers. Ultimately, this water can be recovered for use without needing a groundwater right (minus a 5 percent reduction to improve aquifer conditions).

Resolution Copper has been acquiring storage credits that would offset its future pumping, using various mechanisms. This was identified earlier in this section as an applicant-committed environmental protection measure (to offset approximately half the water supply). However, it is important to note that recharging water and acquiring storage credits is not required under Arizona water law; this is a voluntary measure by Resolution Copper. As such, while Resolution Copper has indicated its intent to do so, there is no guarantee that these credits would be used to offset the mine water supply, nor is there any requirement for the entire water supply to be offset by recharge credits.

- Between 2006 and 2011, Resolution Copper arranged for delivery of about 190,000 acre-feet of CAP water to NMIDD. NMIDD has been permitted as a "groundwater savings facility" through ADWR. At a groundwater savings facility, farmers forgo legal groundwater pumping (allowed with irrigation groundwater rights) and use renewable surface water on crops instead. This mechanism allows groundwater to stay in the aquifer within the same basin from which the Desert Wellfield would eventually withdraw groundwater. Resolution Copper undertook similar measures for Roosevelt Water Conservation District (located in the East Salt River valley, west of the Desert Wellfield) for an additional 14,000 acre-feet of water.

- Resolution Copper has also physically recharged about 20,000 acre-feet of water at the Tonopah Desert Recharge Project; this facility is located west of the Phoenix metropolitan area and not in the same aquifer, but within the Phoenix AMA.
- Between 2012 and 2017, Resolution Copper also purchased an existing 37,000 acre-feet of storage credits, also stored at the NMIDD groundwater savings facility.
- Resolution Copper also has stored about 60,000 acre-feet water in the Pinal AMA, at the Hohokam Irrigation Drainage District groundwater savings facility.
- Resolution Copper continues to deliver treated water from mine infrastructure dewatering to NMIDD. However, because this amounts to a transfer of groundwater within an AMA, no storage credits are obtained in this manner.

All told, Resolution Copper has acquired 256,355 acre-feet of storage credits within the Phoenix AMA, and 313,135 acre-feet of storage credits between both the Phoenix and Pinal AMAs. This offsets roughly 43 to 52 percent of expected pumping for the slurry alternatives (Alternatives 2, 3, 5, and 6) and 143 percent of pumping for Alternative 4.

The impacts from the Desert Wellfield that are described in this section are based on the physical removal of water from the aquifer as it exists today and are not a reflection of the legal availability of that groundwater. Part of the groundwater physically stored in the aquifer is already legally attributable to other long-term storage credit holders; removal of this groundwater in the future would have a cumulative impact with the pumping from the Desert Wellfield.

REGIONAL WATER SUPPLIES

The area analyzed for assured water supplies incorporates Pinal County south of U.S. 60 through the town of Florence. A total of 239 entities presently hold assured water supply analyses or certificates, accounting for over 100,000 lots, and with a total 100-year groundwater demand of 11.1 million acre-feet. Not all of these entities are going to be drawing water from the same aquifer as the Desert Wellfield, nor would all this pumping happen during the mine life, nor does this list include any water use for anticipated development in the Superstitions Vistas planning area. Considering these uncertainties, it is not possible to quantify the cumulative water use in the area, but it is reasonable to note that groundwater demand is substantial and growing.

Resolution Copper’s pumping from the Desert Wellfield represents the use of approximately 2.2 to 7.3 percent of the 8.1 million acre-feet estimated to be physically available in the aquifer (above a depth of 1,000 feet). Cumulatively, the total demand on the groundwater resources in the East Salt River valley is substantial and could be greater than the estimated amount of physically available groundwater.

Mitigation Effectiveness

The Forest Service is in the process of developing a robust mitigation plan to avoid, minimize, rectify, reduce, or compensate for resource impacts that have been identified during the process of preparing this EIS. Appendix J contains descriptions of mitigation concepts being considered and known to be effective, as of publication of the DEIS. Appendix J also contains descriptions of monitoring that would be needed to identify potential impacts and mitigation effectiveness. As noted in chapter 2 (section 2.3), the full suite of mitigation would be contained in the FEIS, required by the ROD, and ultimately included in the final GPO approved by the Forest Service. Public comment on the DEIS, and in particular appendix J, will inform the final suite of mitigations.

This section contains an assessment of the effectiveness of mitigation and monitoring measures found in appendix J that are applicable to groundwater quantity and GDEs.

MITIGATION MEASURES APPLICABLE TO GROUNDWATER QUANTITY AND GDES

Seeps and springs monitoring and mitigation plan (RC-211): One mitigation measure is contained in appendix J that would be applicable to groundwater quantity and GDEs. In April 2019, the Forest Service received from Resolution Copper a document titled "Monitoring and Mitigation Plan for Groundwater Dependent Ecosystems and Water Wells" (Montgomery and Associates Inc. 2019). This document outlines monitoring plan to assess potential impacts on each GDE, identifies triggers and associated actions to be taken by Resolution Copper to ensure that GDEs are preserved, and suggested mitigation measures for each GDE if it is shown to be impacted by future mine dewatering. Note that this plan includes actions both for GDEs and water supply wells.

The plan focuses on the same GDEs described in this section of the EIS, as these are the GDEs that are believed to rely on regional groundwater that could be impacted by the mine. The stated goal of the plan is "to ensure that groundwater supported flow that is lost due to mining activity is replaced and continues to be available to the ecosystem." The plan specifically notes that it is not intended to address water sources associated with perched shallow groundwater in alluvium or fractures.

The specific GDEs addressed by this plan include

- Bitter, Bored, Hidden, Iberri, Kane, McGinnel, McGinnel Mine, No Name, Rock Horizontal, and Walker Springs;
- Queen Creek below Superior (reach km 17.39 to 15.55) and at Whitlow Ranch Dam;
- Arnett Creek in two locations;
- Telegraph Canyon in two locations;
- Devil's Canyon springs (DC4.1E, DC6.1E, DC6.6W, and DC8.2W)
- Devil's Canyon surface water in two locations (reach km 9.1 to 7.5, and reach km 6.1 to 5.4)
- Mineral Creek springs (Government Springs, MC3.4W)
- Mineral Creek surface water in two locations (MC8.4C, and reach km 6.9 to 1.6)

Monitoring frequency and parameters are discussed in the plan, and include such things as groundwater level or pressure, surface water level, presence of water or flow, extent of saturated reach, and phreatophyte area. In general, groundwater level or pressure and surface water level would be monitored daily (using automated equipment), while other methods would be monitored quarterly or annually.

Water supplies to be monitored are Superior (using well DHRES-16_743 as a proxy), Boyce Thompson Arboretum (using the Gallery Well as a proxy), and Top-of-the-World (using HRES-06 as a proxy).

A variety of potential actions are identified that could be used to replace water sources if monitoring reaches a specified trigger. Specific details (likely sources and pipeline corridor routes) are shown in the plan. These include the following:

- Drilling new wells, applicable to both water supplies and GDEs. The intent of installing a well for a GDE is to pump supplemental groundwater that can be used to augment flow. The exact location and construction of the well would vary; it is assumed in many cases groundwater would be transported to GDEs via an overland pipeline to minimize ground disturbance. Wells require maintenance in perpetuity, and likely would be equipped with storage tanks and solar panels, depending on specific site needs.
- Installing spring boxes. These are structures installed into a slope at the discharge point of an existing spring, designed to capture natural flow. The natural flow is stored in a box and

discharged through a pipe. Spring boxes can be deepened to maintain access to water if the water level decreases. Spring boxes require little ongoing maintenance to operate.

- Installing guzzlers. Guzzlers are systems for harvesting rainwater for wildlife consumption. Guzzlers use an impermeable apron, typically installed on a slope, to collect rainwater which is then piped to a storage tank. A drinker allows wildlife and/or livestock to access water without trampling or further degrading the spring or water feature. Guzzlers require little ongoing maintenance to operate.
- Installing surface water capture systems such as check dams, alluvial capture, recharge wells, or surface water diversions. All of these can be used to supplement diminished groundwater flow at GDEs by retaining precipitation in the form of runoff or snowmelt, making it available for ecosystem requirements.
- Providing alternative water supplies from a non-local source. This would be considered only if no other water supply is available, with Arizona Water Company or the Desert Wellfield being likely sources of water.

MITIGATION EFFECTIVENESS AND IMPACTS

Effectiveness of Monitoring

The monitoring as proposed is of sufficient frequency and includes the necessary parameters to not only identify whether changes in GDEs are taking place, but also to inform whether the mine drawdown is responsible. For instance, conducting daily automated monitoring allows for an understanding of normal seasonal and drought-related fluctuations in water level or flow, which can be taken into consideration when evaluating the possible effects from the mine.

Effectiveness of Mitigation

Replacement of water sources using the techniques described (replacement wells or alternative water sources) would be highly effective for public water supplies. For GDEs, the effectiveness would depend on the specific approach. Engineered replacements like pipelines, guzzlers, or spring boxes would be effective at maintaining a water source and maintaining a riparian ecosystem, but the exact type, location, and extent of riparian vegetation could change to adapt to the new discharge location and frequency of the new water source. Changes in water quality are unlikely to be an issue, since new water sources would likely derive from the same source as natural spring flow (i.e., the Apache Leap Tuff aquifer, or stored precipitation).

While water flow, riparian ecosystems, and associated terrestrial and aquatic habitat would be maintained, there would still likely be a noticeable change in the overall environment that could affect both wildlife, recreationists, and the public. The presence of infrastructure like wells and pipes near some natural areas could change the sense of place and nature experienced in these locations.

Impacts from Mitigation Actions

The mitigation actions identified would result in additional ground disturbance, though minimal. Mitigation for any given GDE would likely result in less than 1 acre of impact, assuming a well pad and pipeline installation, or installation of check dams. If all mitigations were installed as indicated in the plan, impacts could total 20 to 30 acres of additional ground disturbance.

UNAVOIDABLE ADVERSE IMPACTS

Given the effectiveness of mitigation, there would be no residual impacts on public water supplies near the mine site. All lost water supplies would be replaced.

For GDEs expected to be impacted by groundwater drawdown, the mitigation measures described would be effective enough that there would be no net loss of riparian ecosystems or aquatic habitat on the landscape, although the exact nature and type of ecosystems would change to adapt to new water sources. However, impacts on the sense of place and nature experienced at these perennial streams and springs, rare in a desert environment, would not be mitigated by these actions.

The mitigation plan would not mitigate any GDEs lost directly to surface disturbance, ranging from two to five, depending on the tailings alternative.

Impacts on water supplies in the East Salt River valley in the form of groundwater drawdown and reduction of regional groundwater supply would not be fully mitigated.

Other Required Disclosures

SHORT-TERM USES AND LONG-TERM PRODUCTIVITY

Groundwater pumping would last the duration of the mine life. At the mine itself, groundwater levels would slowly equilibrate over a long period (centuries). Groundwater drawdown from dewatering of the underground mine workings would constitute a permanent reduction in the productivity of groundwater resources within the long time frame expected for equilibrium. Groundwater in the vicinity of the Desert Wellfield would equilibrate more quickly, but there would still be an overall decline in the regional water table due to the Resolution Copper Project and a permanent loss of productivity of groundwater resources in the area.

Seeps and springs could be permanently impacted by drawdown in groundwater levels, as could the riparian areas associated with springs, but these impacts would be mitigated. GDEs or riparian areas directly lost to surface disturbance would be a permanent impact.

IRREVERSIBLE AND IRRETRIEVABLE COMMITMENT OF RESOURCES

Mine dewatering at the East Plant Site under all action alternatives would result in the same irretrievable commitment of 160,000 acre-feet of water from the combined deep groundwater system and Apache Leap Tuff aquifer over the life of the mine.

Changes in total groundwater commitments at the Desert Wellfield vary by alternative for tailings locations and tailings type. Alternative 4 would require substantially less water overall than the other alternatives (176,000 acre-feet, vs. 586,000 acre-feet for Alternative 2). Loss of this water from the East Salt River valley aquifer is an irretrievable impact; the use of this water would be lost during the life of the mine.

While a number of GDEs and riparian areas could be impacted by groundwater drawdown, these changes are neither irreversible nor irretrievable, as mitigation would replace water sources as monitoring identifies problems. However, even if the water sources are replaced, the impact on the sense of nature and place for these natural riparian systems would be irreversible. In addition, the GDEs directly disturbed by the subsidence area or tailings alternatives represent irreversible impacts.

3.7.2 Groundwater and Surface Water Quality

3.7.2.1 Introduction

The proposed mine could potentially impact groundwater and surface water quality in several ways. The exposure of the mined rock to water and oxygen, inside the mine as well as in stockpiles prior to processing, can create depressed pH levels and high concentrations of dissolved metals, sulfate, and dissolved solids. After processing, the tailings would be transported for disposal into the tailings storage facility. Seepage from the tailings has the potential to enter underlying aquifers and impact groundwater quality. In addition, contact of surface runoff with mined ore, tailings, or processing areas has the potential to impact surface water quality.

This section contains analysis of existing groundwater and surface water quality; results of a suite of geochemical tests on mine rock; predicted water quality in the block-cave zone and potential exposure pathways, including the potential for a lake to form in the subsidence crater; impacts on groundwater and surface water from tailings seepage; impacts on surface water from runoff exposed to tailings; impacts on assimilative capacity of perennial waters; impacts on impaired waters; whether chemicals added during processing would persist in the tailings storage facility; the potential for asbestiform minerals to be present; and the potential for naturally occurring radioactive materials to be present. Some additional details not discussed in detail here are captured in the project record (Newell and Garrett 2018d).

3.7.2.2 Analysis Methodology, Assumptions, and Uncertain and Unknown Information

Analysis Area

The analysis area is shown in figure 3.7.2-1 and encompasses all areas where groundwater or surface water quality changes could potentially occur due to the proposed project and alternatives. This includes the block-cave zone, each alternatives tailings footprint, aquifers downgradient from each tailings facility, and downstream surface waters. The downstream limit of the analysis area is the location of the first perennial water, specifically Queen Creek at Whitlow Ranch Dam and the Gila River either at Donnelly Wash or Dripping Spring Wash. The goal of this section is to identify potential risks to water quality, including surface water. These perennial surface water locations are the point at which seepage would enter the surface water system and represent the location at which surface water quality is most at risk and any impacts on surface water or aquatic habitat would be greatest.

Geochemistry Modeling Process

All tailings storage facilities—including filtered tailings—lose water to the environment in the form of seepage that drains by gravity over time. This seepage into groundwater is the primary source of potential water contamination from the project and has the potential to affect the quality of underlying aquifers as well as downstream surface waters fed by those aquifers. The water quality of tailings seepage reflects a mixture of different water sources used in the mining process (see figure 2.2.2-16) as well as geochemical changes that occur over time within the tailings storage facility and changes that occur as seepage moves downgradient through the aquifer.

Modeling the water quality changes caused by seepage from the tailings storage facility[39] requires a series of interconnected analyses, as shown on figure 3.7.2-2. These analyses include the following:

- The amount of water that must be removed from the block-cave zone during operations to allow mining. This is estimated using the **groundwater flow model** discussed in detail in section 3.7.1.
- The geochemical changes of the groundwater within the underground block-cave zone caused by the interaction of

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[39] For details of the geochemistry modeling workgroup formed to direct and review the water quality modeling, see Newell and Garrett (2018d).

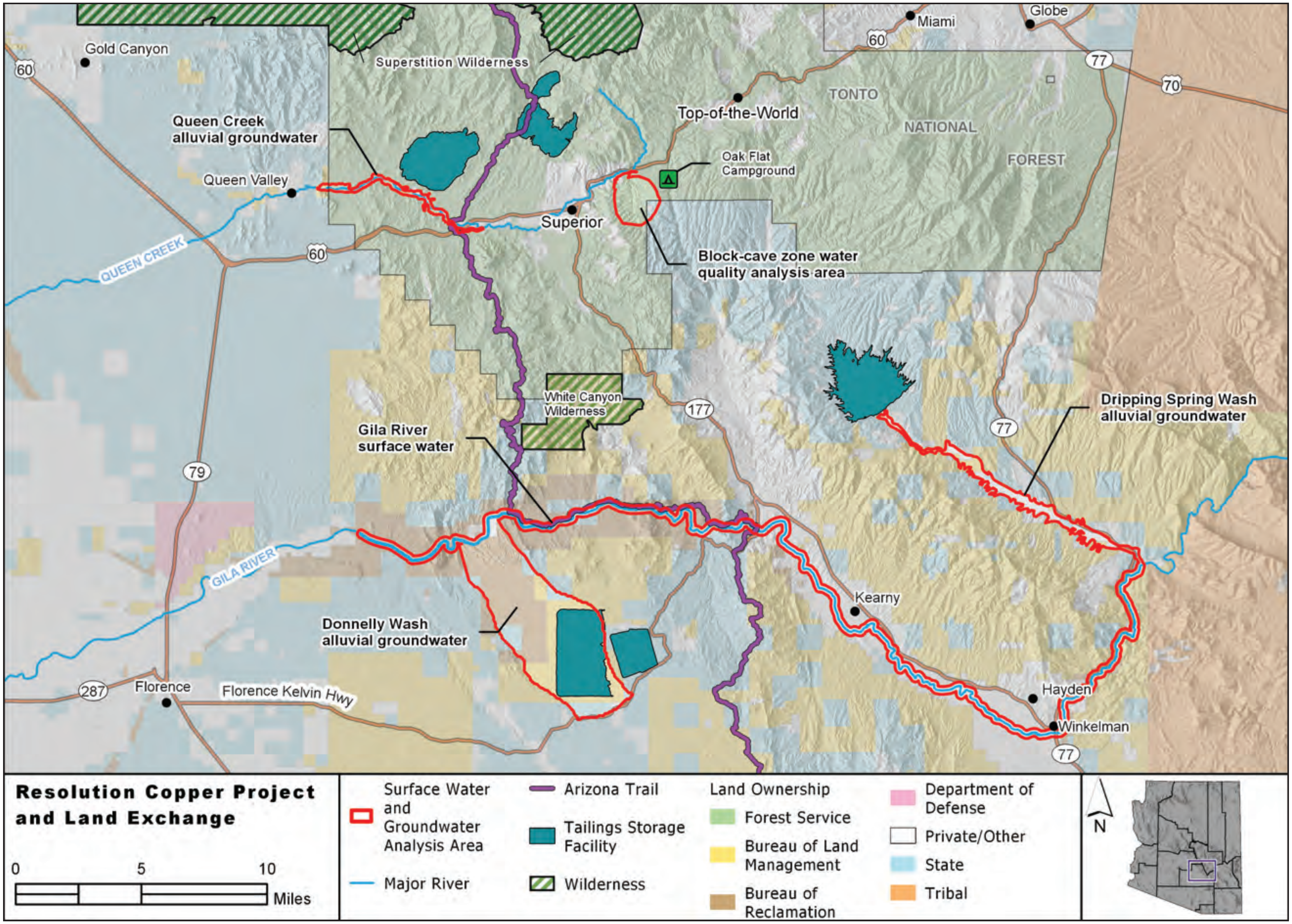

Figure 3.7.2-1. Analysis area for groundwater and surface water quality

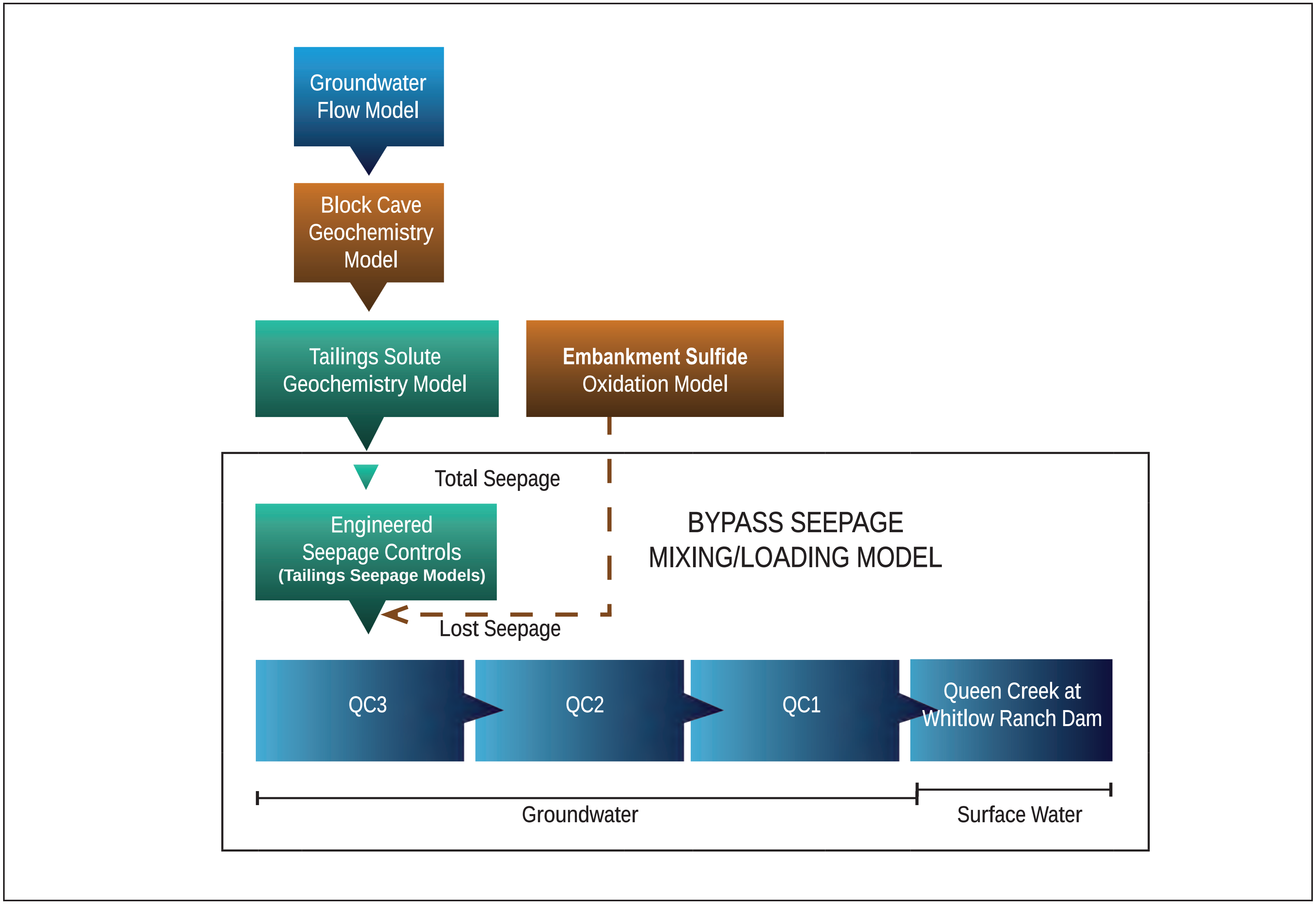

Figure 3.7.2-2. General components and process flow for water quality modeling analysis shown for Alternative 2

exposed rock surfaces to water and oxygen. These changes are estimated using a **block-cave geochemistry mode**l.

- The tailings slurry that leaves the processing facility is a mix of tailings and process water. As the tailings are deposited in the tailings storage facility, some process water is collected in the recycled water pond and sent back to the West Plant Site, but some process water stays trapped in the pore space of the tailings (this is known as “entrainment”). Eventually some of this water can seep or drain out of the tailings facility. The water quality at various locations in the tailings facility is estimated using a **tailings solute geochemistry model**.[40]
- Some of the tailings that are deposited in the tailings storage facility would remain saturated indefinitely with little possibility of oxidation occurring. However, within the embankment and beach areas, sulfide-containing minerals in the tailings would be exposed to oxygen over time, which would cause geochemical changes. These changes are estimated using the **embankment sulfide oxidation model**.
- A wide variety of engineered seepage controls are in place to intercept and collect entrained water that seeps out of the tailings facility, but despite these controls some seepage still enters the environment. The effectiveness of engineered seepage controls is estimated using a variety of **tailings seepage models**.
- The seepage not captured and entering the environment causes water quality changes in the downgradient aquifers and eventually in surface waters fed by those aquifers. The changes in groundwater and surface water quality are estimated using a series of **bypass seepage mixing/loading models**. Figure 3.7.2-2 shows the groundwater modeling cells (QC3, QC2, and QC1) and surface water modeling cells (Queen Creek at Whitlow Ranch Dam) downstream of Alternatives 2 and 3 – Near West tailings storage facility. The groundwater and surface water modeling cells would vary based on alternative tailings storage facility location.

Assumptions, Uncertain and Unknown Information for Geochemistry Models

BLOCK-CAVE GEOCHEMISTRY MODEL

Modeling Details

Water collects in the sump of the block-cave zone during operations and is derived from several sources:

- Groundwater inflow from the Apache Leap Tuff,
- Groundwater inflow from the deep groundwater system,
- Blowdown water from ventilation and cooling systems, and
- Excess mine service water.[41]

The block-cave sump water is pumped out during operations and incorporated into the processing water stream and therefore is one of the sources ultimately contributing to the water in the tailings facility. A block-cave geochemistry model was constructed to blend these flows and their associated chemical composition over the time of operation of the mine (Eary 2018f). Groundwater flow modeling was used to assign the flow rate for how much groundwater flows into the block-cave zone (WSP USA 2019). The rate of supply of blowdown water from ventilation systems is based on the overall water balance for the mine (WestLand Resources Inc. 2018b).

Apache Leap Tuff and deep groundwater chemistries are based upon analysis of site groundwater samples. The chemical composition of

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[40] The term “solute” refers to substances that are dissolved in water, such as metals like arsenic or selenium, or inorganic molecules like sulfate or nitrate.

[41] Mine service water is used for a variety of tasks underground, including dust suppression and cooling. Much of this water evaporates or leaves with the ore; any excess water left over would likely find its way to the sump.

blowdown water is based upon analysis of CAP water and groundwater sourced from the Arizona Water Company (Arizona Water Company 2017). Resolution Copper projects this blended water to be composed of 25 percent CAP water and 75 percent Arizona Water Company water. Owing to evaporation associated with cooling, this water mixture is concentrated to an assumed value for total dissolved solids of 2,500 milligrams per liter (mg/L).

The model time frame is 41 years and ends with the cessation of mining. Inflows to the block-cave sump vary over time, but their chemical composition does not. The mixed waters reporting to the sump from their individual sources are equilibrated with any chemical precipitates that are oversaturated and likely to precipitate from solution. This precipitation of solids removes chemical mass from the mixed water. Results for model year 41, at the end of mining, are reported in table 3.7.2-1. Chemical weathering of wall rock and uneconomic mineralized fractured rock in the collapsed block-cave zone are assumed to not supply any chemical load to the sump water; this assumption is reflected in the column titled “Eary Block-Cave Geochemistry Model Predicted Concentrations” and is discussed in more detail after the table.

Assumptions, Uncertain and Unknown Information

The block-cave geochemistry model, like all models, necessarily includes assumptions in its effort to forecast future conditions. Assumptions are made to constrain model components that cannot be conclusively known and therefore represent uncertainty in the model results. The key assumptions in the block-cave geochemistry model, the level of uncertainty, and their potential implications are summarized here:

- The model assumes the chemistry of various water sources (Apache Leap Tuff, deep groundwater system, CAP water, Desert Wellfield) remains constant over time. In reality, the chemical load[42] from these sources could increase or decrease over time.
    - Applies to: all action alternatives.
    - Possible outcome if real-world conditions differ from the assumption: Modeled tailings seepage concentrations could be higher or lower.
    - Likely magnitude of effect for all action alternatives: Low. Water sources are primarily from large aquifers that change slowly in response to climatic trends and are not the primary source of chemical loading to the block-cave zone.
- The model assumes fractured rock in the collapsed block-cave zone does not contact oxygen and chemical weathering does not supply any chemical load to the sump water. If chemical weathering occurs, percolation of groundwater through these rocks could transport weathering products to the sump.
    - Applies to: all action alternatives.
    - Possible outcome if real-world conditions differ from the assumption: Sump water and modeled tailings seepage concentrations could be higher.
    - Likely magnitude of effect for all action alternatives: High. Possible outcomes are bracketed by the two sump chemistries shown in table 3.7.2-1 (Eary 2018f; Hatch 2016). The sump water only makes up between 20 and 24 percent of the inflow to the West Plant Site (see Ritter (2018)), but the loads for all constituents of concern could substantially increase if this assumption does not match real-world conditions. See section “Overall Effect of Uncertainties on the Model Outcomes” later in this section for more discussion.

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[42] The word “loading” is used throughout this section. In this context, “chemical loading” or “pollutant loading” refers to the total amount, by weight, of a chemical, metal, or other pollutant that enters the environment over some time period (usually a day or year). For example, the total selenium load entering the environment from Alternative 2 seepage has been estimated as 0.0242 kilograms per day.

Table 3.7.2-1. Modeled block-cave sump water chemistry

Constituent	Eary Block-Cave Geochemistry Model* Predicted Concentrations (mg/L)	Hatch Block-Cave Geochemistry Model† Predicted Concentrations (mg/L)	Arizona Aquifer Water Quality Standard (mg/L)
Ca	237	434	–
Mg	63	147	–
Na	130	181	–
K	28	85	–
Cl	46	85	–
HCO_3	114	19.9	–
SO_4	934	2,247	–
SiO_2	22.4	17	–
F	2.3	Not reported	4
N	0.8	Not reported	–
Al	0.0857	9.3	–
Sb	0.0047	**0.035**	0.006
As	0.0227	0.013	0.05
Ba	0.0199	0.02	2
Be	0.0003	**0.036**	0.004
B	0.342	0.48	–
Cd	0.0008	**0.19**	0.005
Cr	0.0027	**0.241**	0.1
Co	0.0063	2.72	–
Cu	0.0158	141	–
Fe	0.0025	0.1	–
Pb	0.005	**0.088**	0.05
Mn	0	14.2	–
Hg	Not reported	0.018	0.002
Mo	0.0135	0.000012	–
Ni	0.0076	**2.5**	0.01
Se	0.0051	**0.5**	0.05
Ag	0.0039	0.165	–
Tl	**0.0043**	**0.009**	0.002
Zn	0.221	8.2	–

continued

Table 3.7.2-1. Modeled block-cave sump water chemistry *(cont'd)*

Constituent	Eary Block-Cave Geochemistry Model* Predicted Concentrations (mg/L)	Hatch Block-Cave Geochemistry Model† Predicted Concentrations (mg/L)	Arizona Aquifer Water Quality Standard (mg/L)
pH s.u.	8.58	5.05	–
TDS	1528	Not reported	–

Notes: Modeled concentrations that are above Arizona aquifer water quality standards are show in bold and shaded. Model data are not specific to total or dissolved fractions.

Dash indicates no Arizona numeric aquifer water quality standard exists for this constituent.

* Eary (2018f)

† Hatch (2016)

- The model assumes that weathering products from ore remain with the ore and report to the tailings storage facility. These weathering products could rinse off ore and report to the sump.
  - Applies to: all action alternatives.
  - Possible outcome if real-world conditions differ from the assumption: Sump chemical load could be higher, but whether traveling with ore or reporting to sump, the weathering products enter the process stream either way, and there would be no change to the overall tailings seepage models.
  - Likely magnitude of effect for all action alternatives: None.

TAILINGS SOLUTE GEOCHEMISTRY MODEL

Modeling Details

The water balance for the mine is complex, with multiple sources and recycling loops, and how these sources mix forms the fundamental basis for predicting the water quality in the tailings facility. The water balance differs for each tailings alternative (Golder Associates Inc. 2018a; Klohn Crippen Berger Ltd. 2018a, 2018b, 2018c, 2018d; WestLand Resources Inc. 2018b). Chemical loading inputs are applied to each water source, and the resulting water quality is calculated with a mixing model (PHREEQC) for the entire operational life of the mine, with a different analysis conducted for each alternative (Eary 2018a, 2018b, 2018c, 2018d, 2018e, 2018g). Water quality is modeled for six different locations:

- the mixture of water entering the West Plant Site;
- the PAG recycled water pond (not applicable to Alternative 4 – Silver King);
- the NPAG recycled water pond (not applicable to Alternative 4 – Silver King);
- the water within the pore space of the tailings embankment;
- the seepage collection ponds; and
- the seepage lost to underlying aquifers not captured by the seepage collection ponds.

The tailings solute geochemistry model determines the chemistry of all water and chemicals reporting to the tailings storage facility, and the degree of evaporative concentration. It produces estimates of dissolved constituent concentrations in the tailings storage facility, a portion of which is lost seepage that is used in modeling impacts on downgradient water resources. The tailings solute geochemistry model results are strongly affected by the water balance for the tailings storage facility, which provides flows for the various components reporting to the tailings storage facility and accommodates for evaporative loss. This loss is used in the tailings solute geochemistry model to concentrate dissolved chemical constituents.

Assumptions, Uncertain and Unknown Information

The tailings solute geochemistry model is largely a mathematical process of tracking and combining chemical masses, given various input flow rates and chemical concentrations. While the inputs have uncertainty (such as the block-cave sump chemistry), the model itself highly certain. The release of chemical mass from the ore during processing is also part of the tailings solute geochemistry model; this is based on rates observed during site-specific metallurgical testing and is considered reasonable with relatively low uncertainty.

EMBANKMENT SULFIDE OXIDATION MODEL

Modeling Details

During operations, the tailings that are most likely to experience oxidation of sulfide minerals—the PAG tailings—would be kept in a subaqueous state with an overlying water cap (a minimum of 10 feet deep) to prevent oxygen from reaching and interacting with the tailings. During closure, the water cap would gradually be replaced with a cover of NPAG tailings and a reclamation cover to achieve the same result. The fine-grained tailings on the interior of the facility are expected to exhibit a low vertical permeability and a high moisture content, and oxygen is not expected to penetrate the tailings at rates sufficient to affect seepage chemistry for hundreds of years (Wickham 2018). This would eliminate (or greatly reduce) the risk of acid rock drainage from the PAG tailings, which would otherwise have the potential to impact downstream waters and aquifers.

However, the embankments of the NPAG tailings facility would be constructed of well-drained cyclone sands. Oxygen would be able to enter these areas and react with sulfide minerals over time. The same is true of the entirety of the filtered tailings facility (Alternative 4 – Silver King). The embankment sulfide oxidation model determines the chemical quality of seepage derived from the oxidation occurring in the tailings embankment for the 41 years of operation and an additional 204-year post-closure period[43] (Wickham 2018).

Assumptions, Uncertain and Unknown Information

Chemical loading is calculated using theoretical concepts regarding oxygen movement into the tailings that make up the embankment, and an experimentally derived rate equation for the oxidation of sulfide minerals. The rate equation’s validity is supported by field and laboratory testing, and the movement of oxygen is supported by literature-based studies; both assumptions are considered reasonable for the estimate of embankment seepage water quality with relatively low uncertainty.

TAILINGS SEEPAGE MODELS

Modeling Details

Management of water in the tailings storage facility must accomplish a variety of outcomes. For structural integrity, it is desirable to allow water to leave the NPAG tailings storage facility and the tailings embankment in the form of seepage (see section 3.10.1 for a further discussion of tailings stability). However, it is undesirable to allow that seepage to enter downstream aquifers or surface waters in amounts that can cause water quality problems. For PAG tailings, which tend to generate the worst seepage water quality, not only is it undesirable to allow seepage from PAG tailings to enter the environment but it is also necessary to prevent seepage in order to maintain saturation of the PAG tailings to prevent oxidation.

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[43] The duration of the geochemical modeling matches a global decision made by the Tonto National Forest with input from the Groundwater Modeling Workgroup that quantitative modeling results are not reliable longer than 200 years in the future. This is described more in section 3.7.1.

Each alternative would use a specific set of engineered seepage controls that are built into the design in order to accomplish these goals. These include such controls as liners, blanket and finger drains, seepage collection ponds, and pumpback wells. The specific controls incorporated into each alternative design are described in section 3.7.2.4.

For a given tailings storage facility, estimates have been made of the "total seepage" and the "lost seepage." Total seepage is all water that drains from the tailings storage facility by gravity. Lost seepage is seepage that is not recovered with the engineered seepage controls. Lost seepage is assumed to discharge to the environment. The role of consolidation of the tailings over time was incorporated into the seepage estimates, described further in Garrett and Newell (2018d).

All alternative designs use a strategy of layering on engineered seepage controls to reduce the amount of lost seepage to acceptable levels. Some of these controls, such as foundation preparation, liners, drains, and seepage collection ponds, are implemented during construction of the facility. Other controls, such as auxiliary pumpback wells, grout curtains, or additional seepage collection ponds, would be added as needed during operations depending on the amounts of seepage observed and the observed effectiveness of the existing controls.

The amount of seepage entering the environment is modeled in a variety of ways, depending on alternative (Klohn Crippen Berger Ltd. 2019d).[44] Common to all of these models is that the engineered seepage controls described in section 3.7.2.4 are assumed to be in place, and the combined effectiveness of the layered engineered seepage controls is a key assumption in the ultimate predicted impacts on water.

The level of engineered seepage controls for each alternative was assigned based on practicability and initial modeling estimates of the "allowable seepage" (Gregory and Bayley 2018a). Allowable seepage is the estimated quantity, as a percentage of total seepage, that can be released without resulting in groundwater concentrations that are above Arizona aquifer water quality standards, or surface water concentrations that are above Arizona surface water quality standards. The allowable seepage target is a significant driver for the design of each facility; engineered seepage controls were increased in the design as needed to limit lost seepage to the allowable amount.

Comparison of Engineered Seepage Controls to a Fully Lined Facility

During alternatives development, the concept of a fully lined tailings storage facility was pursued. Eventually this concept was eliminated from detailed analysis, although liners are still used in some areas and some of the techniques used to control seepage that have been incorporated into the design accomplish similar results as a liner. A full description of this evolution is contained in Garrett and Newell (2018d), as are calculations of expected seepage from a fully lined facility. These calculations are used for comparison in section 3.7.2.4.

Assumptions, Uncertain and Unknown Information

Engineered seepage controls incorporated into the tailings storage facility design serve to ensure geotechnical stability/safety and recover a percentage of the total seepage released, in order to meet the limits of allowable seepage. The bypass seepage mixing/loading model is reliant on the amount of lost seepage, and therefore reliant on both the feasibility and effectiveness of the engineered seepage controls. Details of the engineered seepage controls (broken out by Levels 0 through 4) and an assessment of their ability to control seepage are discussed in section 3.7.2.4. The key assumptions in the tailings seepage models, and the level of uncertainty are summarized here:

- The tailings seepage models calculate seepage during the mine life under full-buildout conditions, with gradual increases in acreage and tapering of seepage over time.
    - Applies to: all action alternatives.

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[44] The choice of models used to estimate seepage for each alternative was based on the specific location, design, level of information, and seepage controls. Further details of the models are contained in Newell and Garrett (2018d).

  - Possible outcome if real-world conditions differ from the assumption: Modeled tailings seepage during operations is overestimated.
  - Likely magnitude of effect for all action alternatives: Low to none. This approach overestimates chemical loading, rather than underestimates it, and therefore is conservative. In addition, this applies only during the operational life and would not affect the post-closure seepage estimates.
- Incomplete removal of alluvial channels within the interior of the tailings storage facility would allow for faster transport of seepage.
  - Applies to: Alternatives 2, 3, and 4.
  - Possible outcome if real-world conditions differ from the assumption: Seepage reaches finger drains and blanket drains faster.
  - Likely magnitude of effect for Alternatives 2, 3, and 4: Low to none. This would only enhance the operation of the finger and blanket drainage system, which captures seepage and pumps it back to the recycled water pond.
- The seepage estimates do not account for possible preferential flow along minor faults in the bedrock underlying the tailings storage facility footprint.
  - Applies to: Alternatives 2, 3, and 4.
  - Possible outcome if real-world conditions differ from the assumption: Seepage bypasses drains and seepage collection ponds, increasing amount of lost seepage and chemical load to downstream aquifer.
  - Likely magnitude of effect for Alternatives 2 and 3: Low to none. While seepage would bypass the drains and seepage collection ponds, for seepage to enter the environment assumes that all foundation treatments (Level 1, Level 4) were ineffective as well as the downstream grout curtain (Level 2, Level 4) and auxiliary pumpback wells (Level 4). The variety of layered controls have a high likelihood of capturing this seepage.
  - Likely magnitude of effect for Alternative 4: Moderate. This alternative has fewer layered seepage controls, and places sole reliance on the drains and seepage collection ponds.
- The modeling used to estimate seepage efficiency assumes ideal placement of all pumpback wells, embankments, and grout curtains. Pumpback wells might not be located in ideal locations and therefore allow more flow to escape than modeled.
  - Applies to: Alternatives 2 and 3.
  - Possible outcome if real-world conditions differ from the assumption: More seepage escapes, increasing chemical load to downstream aquifer.
  - Likely magnitude of effect for Alternatives 2 and 3: Low. The primary ring of seepage collection dams (Level 1) is located along alluvial drainages which are highly likely to be the preferential flow paths. The secondary ring of seepage collection dams (Level 3), auxiliary pumpback wells (Level 4), and grout curtains (Level 2, Level 4) are controls that would be installed during operations as needed. Placement of these would be driven by direct observation, and it is reasonable to assume they would be targeted to areas of concern.
- The modeled efficiencies for Alternative 2 (99 percent) and Alternative 3 (99.5 percent) could be difficult to achieve in practice. For instance, the length of the Level 4 grout curtain for both alternatives (approximately 7.5 miles) is believed to be larger by a factor of 10 than any other grout curtain in the United States. Similarly, for comparison, the full suite of

engineered seepage controls would result in 97 percent less seepage than a fully lined facility.

  - Applies to: Alternatives 2 and 3
  - Possible outcome if real-world conditions differ from the assumption: More seepage escapes, increasing chemical load to downstream aquifer.
  - Likely magnitude of effect for Alternatives 2 and 3: Moderate to high. The overall reliance on a variety of engineered seepage controls in a layered defense reduces the likelihood that the failure of any one control would change the outcome. For the Near West location, however, the proximity to Queen Creek provides little room for flexibility to add or modify controls during operations.

- Unlike Alternatives 2 and 3, there is limited information on the hydrology and geology of the proposed Silver King tailings location (Alternative 4). Seepage capture was not modeled, but instead based on professional judgment of the design engineers and an understanding of the potential flow pathways for seepage. Results could vary widely based on field conditions encountered.
  - Applies to: Alternative 4.
  - Possible outcome if real-world conditions differ from the assumption: More seepage escapes, increasing chemical load to downstream aquifer.
  - Likely magnitude of effect for Alternative 4: Moderate. Filtered tailings involve less initial seepage to control, but concentrations of metals are generally higher. Complex and poorly understood geology complicates control efforts. However, at this location there is also potentially room to layer on additional seepage controls downstream.

- Alternative 5 has limited site-specific information on the foundation conditions. However, the general characteristics of the aquifer are reasonably well understood from site-specific geophysics (resistivity, seismic, and gravity surveys), surface geology mapping, review of records and logs from 20 to 30 wells in the near vicinity, and site-specific water levels from nine wells in the near vicinity (Fleming, Kikuchi, et al. 2018; hydroGEOPHYSICS Inc. 2017).
  - Applies to: Alternative 5.
  - Possible outcome if real-world conditions differ from the assumption: More seepage escapes, increasing chemical load to downstream aquifer.
  - Likely magnitude of effect for Alternative 5: Low to none. Unlike Alternatives 2, 3, and 4, the large volume of groundwater flow in the substantial alluvial aquifer downstream creates dilution and can accept larger amounts of seepage without resulting in concentrations above water quality standards. In addition, the lost seepage as modeled is based on a reduced pumping amount from the pumpback well system. Additional pumping could take place as needed. In addition, the nearest perennial water is several miles downstream, so there is substantial room to add or modify seepage controls.
  - Alternative 6 has limited site-specific information on the foundation conditions. The general characteristics of the aquifer are understood based on surface geology mapping, review of records and logs from 35 wells in the area (10 within the footprint), including six with driller's logs, and site-specific water levels from 11 wells in the near vicinity (Fleming, Shelley, et al. 2018). In addition, the geological units (Gila Conglomerate) at this location are similar to Alternatives 2 and 3, allowing some reasonable extrapolation of their characteristics. However, this site is not as well understood as

  Alternatives 2 and 3, nor does it have as large a downstream aquifer as Alternative 5.
  - Applies to: Alternative 6.
  - Possible outcome if real-world conditions differ from the assumption: More seepage escapes, increasing chemical load to downstream aquifer.
  - Likely magnitude of effect for Alternative 6: Moderate to low. Although not as large as Alternative 5, the volume of groundwater flow in the alluvial aquifer downstream creates dilution and can accept larger amounts of seepage without resulting in concentrations above water quality standards. The flow characteristics of the downstream alluvial aquifer are relatively straightforward, and the spatial extent is well-defined from surface geological mapping. The thickness of the aquifer is uncertain, however, which could affect the overall amount of water available for dilution in the modeling. Seasonal fluctuations in water levels could affect the aquifer capacity. Countering these uncertainties, the relatively narrow aquifer width likely makes existing planned controls (like the grout curtain) simpler to implement, and with the nearest perennial water over a dozen miles downstream, there is substantial room to add or modify seepage controls.

BYPASS SEEPAGE MIXING/LOADING MODELS

Modeling Details

The water quality of the tailings seepage (estimated using the tailings solute geochemistry models), the changes in water quality from the embankment (estimated using the embankment sulfide oxidation model), and the predicted amounts of lost seepage from the facility (estimated using the tailings seepage models), are input into a series of bypass seepage mixing/loading models. These models predict the changes in aquifer water quality as lost seepage flows downgradient from each tailings storage facility. The bypass seepage mixing/loading model uses the Goldsim software package to calculate the mass balance and account for dilution from groundwater present in a series of connected mixing cells. The model cells and framework are slightly different for each alternative; all models are run for the 41 years of operation and an additional 204 years post-closure.

- **Near West (Alternatives 2 and 3)**. The mixing/loading model for Alternatives 2 and 3 estimates groundwater quality in five different mixing cells, starting with Roblas Canyon and Potts Canyon, then flowing into Queen Creek. Queen Creek is represented by three mixing cells, which lead downstream to where the model ends at Whitlow Ranch Dam, where groundwater emerges as surface water (Gregory and Bayley 2018e). Background groundwater quality is derived from a well located adjacent to Queen Creek, using the median of nine samples collected between May 2017 and February 2018. Background surface water quality is derived from the median of 15 samples collected at Whitlow Ranch Dam between March 2015 and December 2017.
- **Silver King (Alternative 4)**. Even though this alternative is composed of filtered tailings, some seepage is still expected to occur with Alternative 4, though a very small amount, compared with Alternatives 2, 3, 5 and 6. The downstream mixing model estimates groundwater quality in nine cells, which start with Potts Canyon, Silver King Wash, and Happy Camp Wash East and West, then flowing into Queen Creek. Queen Creek is represented by five mixing cells, which lead downstream to where the model ends at Whitlow Ranch Dam, where groundwater emerges as surface water (Gregory and Bayley 2018b). Background groundwater and surface water quality are derived from the same sources as Alternatives 2 and 3.
- **Peg Leg (Alternative 5)**. The Peg Leg location is fundamentally different from Alternatives 2, 3, and 4 in that much of the facility overlies a large alluvial aquifer, resulting in relatively large seepage rates, compared with other alternatives.

The downstream mixing model estimates groundwater quality in five cells along Donnelly Wash, leading to the Gila River where groundwater emerges as surface water (Gregory and Bayley 2018c). Background groundwater quality is derived from a single sample in September 2017 from a well located adjacent to Donnelly Wash. Background surface water quality is derived from a single sample in November 2018 from the Gila River at the confluence with Donnelly Wash.

- **Skunk Camp (Alternative 6)**. The Skunk Camp model is similar to the Peg Leg model, with the alluvial aquifer associated with Dripping Spring Wash located downstream. The downstream mixing model estimates groundwater quality in five cells along Dripping Spring Wash, leading to the Gila River, where groundwater emerges as surface water (Gregory and Bayley 2018d). Background groundwater quality is derived from a single sample in November 2018 from a well located adjacent to Dripping Spring Wash. Background surface water quality is derived from a single sample in November 2018 from the Gila River at the confluence with Dripping Spring Wash.

A relatively straightforward mixing cell model is used to evaluate the impact on water, as shown in figure 3.7.2-2. Lost seepage from a given tailings storage facility alternative mixes with the flow of underlying groundwater in the first model cell. The flow of water and dissolved chemicals from this cell passes to the next cell downgradient and is combined with any other flows reporting to that cell. Flows are passed from one groundwater cell to the next until it discharges to a receiving surface water, which is the last cell in the model. At each step, the concentrations of chemical constituents are calculated. The model dimensions of the groundwater cells dictate the amount of dilution that is achieved on mixing with lost seepage; the larger the cells, the greater the diluting effect.

The specific geographic points selected to represent the aquifer and surface water modeled impacts are shown in figure 3.7.2-3.

Assumptions, Uncertain and Unknown Information

The uncertainties described for the block-cave geochemistry model, the tailings solute geochemistry model, and the embankment sulfide oxidation model also add to the uncertainty of the bypass seepage mixing/loading model. Specific uncertainties that affect the bypass seepage mixing/loading model include the following:

- The size of the groundwater cells in the model affects the amount of dilution and the outcome.
    - Applies to: all action alternatives.
    - Possible outcome if real-world conditions differ from the assumption: More or less dilution occurs, changing chemical load to downstream aquifers and perennial waters.
    - Likely magnitude of effect for Alternatives 2 and 3: Low. Substantial site-specific investigation has taken place at the Near West location; this location has the most hydrologic and geological information of any of the alternatives.
    - Likely magnitude of effect for Alternative 4: Low. While the hydrology and geology near the Silver King location is uncertain, the groundwater mixing component happens downstream in Queen Creek, which is relatively well-defined.
    - Likely magnitude of effect for Alternative 5: Low to none. Substantial site-specific investigations have occurred at the Peg Leg location that define the size of the aquifer, which even with uncertainties is substantial.
    - Likely magnitude of effect for Alternative 6: Moderate. The spatial extent of the downstream aquifer is well defined, and characteristics of the aquifer are reasonably understood. However, the thickness of the aquifer is

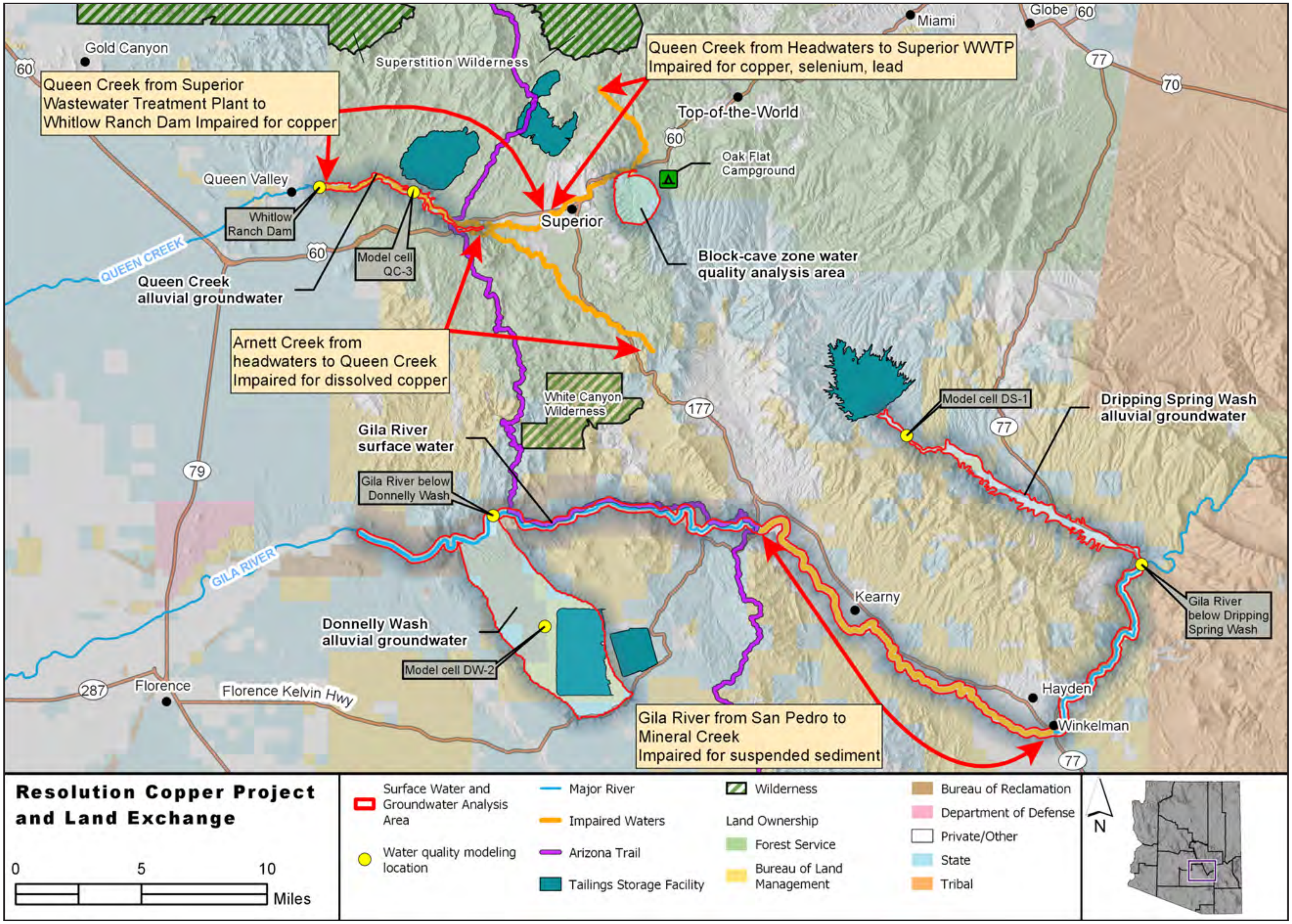

Figure 3.7.2-3. Water quality modeling locations and impaired waters

uncertain, which would directly affect the amount of water available for dilution in the model.

- There is a limited knowledge of baseline aquifer water chemistry.
  - Applies to: all action alternatives.
  - Possible outcome if real-world conditions differ from the assumption: Baseline chemistry may be higher or lower, leading to different combined concentrations in downstream aquifers.
  - Likely magnitude of effect for Alternatives 2, 3, and 4: Low. Water quality modeling used the median results from nine different samples collected from the nearest downstream well.
  - Likely magnitude of effect for Alternative 5: Moderate. The water quality modeling was based on a single groundwater sample. While water quality modeling did not result in concentrations near aquifer water quality standards for most constituents, selenium approaches the standard late in the modeling run. Even moderate changes in selenium based on additional groundwater sampling could change the outcome of the models.
  - Likely magnitude of effect for Alternative 6: Moderate to low. The water quality modeling was based on a single groundwater sample. However, water quality modeling did not result in concentrations near aquifer water quality standards, allowing some room for variation as future samples are collected.
- There is a limited knowledge of baseline surface water chemistry.
  - Applies to: all action alternatives.
  - Possible outcome if real-world conditions differ from the assumption: Baseline chemistry may be higher or lower, leading to different assimilative capacity and different predicted concentrations in downstream perennial waters.
  - Likely magnitude of effect for Alternatives 2, 3, and 4: Low. Water quality modeling used the median results from 15 different samples collected from Queen Creek at Whitlow Ranch Dam.
  - Likely magnitude of effect for Alternatives 5 and 6: Low. The water quality modeling was based on a single surface water sample for each alternative, driven by the necessity to have recent surface water quality results at two specific locations (Donnelly Wash and Dripping Spring Wash). A longer period of record exists for the Gila River at other locations and these samples have been assessed against the values used; the model outcomes would not substantially change if surface water quality varied similar to the historic record (see Newell and Garrett (2018d)).
- Modeling idealizes mixing and assumes that seepage fully mixes across the full width of the alluvium of Queen Creek, Donnelly Wash, or Dripping Spring Wash. Should only partial mixing occur, this would also increase concentrations in parts of the alluvial aquifer. Modeling also does not take into account seasonal flow patterns of water levels.
  - Applies to: all action alternatives.
  - Possible outcome if real-world conditions differ from the assumption: Preferential mixing or flow paths would effectively reduce the amount of dilution of seepage, resulting in higher downstream concentrations. Changing water levels could result in more or less dilution.
  - Likely magnitude of effect for all action alternatives: Moderate. Flow through alluvial aquifers is relatively straightforward to model as an idealized system, but real-world conditions (like the periodic recharge effects

of stormflow) could greatly affect the outcomes. These types of uncertainties are inherent; no amount of hydrologic investigation is likely to resolve these uncertainties.

OVERALL EFFECT OF UNCERTAINTIES ON THE MODEL OUTCOMES

As with all modeling, the modeling used to estimate water quality impacts for each alternative contains assumptions and uncertainty that limit the accuracy and reliability of the associated results.

The model construction includes some intentional bias to skew results that produce a greater negative impact and therefore provide the greatest environmental protection. Examples include the following:

- The assumption that life-of-mine discharge from the tailings storage facility remains at the highest levels associated with the drain down process, rather than decreasing over time. This maximizes the modeled chemical discharge from the tailings storage facility.
- The model does not consider any geochemical processes in the groundwater and surface water flow that might lower concentrations. Examples include potential chemical precipitation of oversaturated solids, or adsorption of chemical constituents onto aquifer solids, which can both lower concentrations in the water.
- For comparisons against surface water standards, median flow values were used which is appropriate when replicating baseflow. Concentrations during runoff events would be expected to be lower due to dilution from stormflows. However, it should be noted that lower flow conditions can occur during the year that would not be reflected by median flow conditions, and for some constituents like copper, studies suggest that stormflows might increase in copper concentrations (Louis Berger Group Inc. 2013).
- Variations in hardness can change surface water quality standards for some metals, with increasing hardness resulting in a higher water quality standard; for the comparisons in section 3.7.2.4, the best available information on existing hardness was used (as calculated from calcium and magnesium concentrations).

A number of uncertainties have been disclosed in this section that affect the ultimate outcome of the water quality modeling. These are summarized in table 3.7.2-2.

Many of the uncertainties identified could result in either higher or lower concentrations in modeled outcomes, or overall would be expected to have a low (or no) impact on the outcomes.

A number of uncertainties reflect limited information on the geology and hydrology at alternative tailings locations or limited baseline water quality samples. This does not mean that the models are unrealistic or unreasonable. They rely on the best available hydrologic and geological information and make reasonable assumptions about aquifer conditions. Future hydrologic and geological investigations at these locations would reduce some uncertainty and refine some model parameters; the overall flow regime of the downstream aquifers and surface waters is understood well enough that the model framework would likely remain the same.

One of the most uncertain aspects of the modeling is the assumption about oxidation in the block-cave zone. Two different models of the geochemistry of the block-cave zone have been conducted, one assuming that oxidation occurs (Hatch 2016) and one assuming that it does not (Eary 2018f). The block-cave geochemistry model used as a basis for the water quality modeling (Eary 2018f) represents the current conception of the mechanics of block-caving and ventilation of the mine and how that would affect the presence of oxygen in the cave zone; this is considered a reasonable interpretation. However, the earlier interpretation—while not as advanced—is also a reasonable interpretation, and this source of uncertainty could result in higher concentrations that would cascade through the water quality modeling.

Table 3.7.2-2. Compilation of magnitude of uncertainties disclosed for water quality modeling

Modeling Component/ Uncertainty	**Potential Effect on Modeled Tailings Seepage**	**Alternative 2 Likely Magnitude of Effect on Outcomes**	**Alternative 3 Likely Magnitude of Effect on Outcomes**	**Alternative 4 Likely Magnitude of Effect on Outcomes**	**Alternative 5 Likely Magnitude of Effect on Outcomes**	**Alt 6 Likely Magnitude of Effect on Outcomes**
Block-cave model						
Source water chemistry could vary	Higher or lower	Low	Low	Low	Low	Low
Cave-zone in-situ weathering could occur	Higher	High	High	High	High	High
Weathering products stay with ore	None	None	None	None	None	None
Tailings seepage models						
Full-buildout seepage during operations	Lower	Low to none	Low to none	Low to none	Low to none	Low to none
Alluvial channels could remain in footprint	None	Low to none	Low to none	Low to none	–	–
Minor faults could cause preferential flow	Higher	Low to none	Low to none	Moderate	–	–
Ideal placement of controls assumed	Higher	Low	Low	–	–	–
Seepage efficiency difficult to meet	Higher	Moderate to high	Moderate to high	–	–	–
Limited site-specific hydrologic/geological information	Higher	–	–	Moderate	Low to None	Moderate to Low
Bypass seepage mixing/ loading models						
Mixing cells could be different sizes	Higher or lower	Low	Low	Low	Low to None	Moderate
Limited baseline aquifer water quality	Higher or lower	Low	Low	Low	Moderate	Moderate to Low
Limited baseline surface water quality	Higher or lower	Low	Low	Low	Low	Low
Idealized mixing	Higher	Moderate	Moderate	Moderate	Moderate	Moderate

Note: A dash indicates that this was not identified as a specific concern for this alternative

It is possible further field tests could be designed to explore this phenomenon, though these would be experimental in nature and are not industry-standard practices. The real-world effect of chemical weathering in the block-cave zone is likely bracketed by the two different models.

Conclusion as to reasonableness of models

The CEQ regulations provide guidance for dealing with incomplete or uncertain information:

> When an agency is evaluating reasonably foreseeable significant adverse effects on the human environment in an environmental impact statement and there is incomplete or unavailable information, the agency shall always make clear that such information is lacking. . . . If the incomplete information relevant to reasonably foreseeable significant adverse impacts is essential to a reasoned choice among alternatives and the overall costs of obtaining it are not exorbitant, the agency shall include the information in the environmental impact statement. (40 CFR 1502.22)

While future work or additional information could reduce some of these uncertainties, the water quality modeling results disclosed in the EIS (section 3.7.2.4) are sufficiently different between alternatives that such refinements are not “essential to a reasoned choice among alternatives.” The broad conclusions in section 3.7.2.4 are not likely to change, specifically:

- It is difficult to meet water quality objectives at Alternatives 2, 3, and 4 without extensive engineered seepage controls.
- Alternatives 5 and 6 not only meet water quality objectives as modeled but have substantial additional capacity to do so, and flexibility

Forest Service disclosure and ADEQ permitting requirements

The State of Arizona has the authority to determine whether or not the proposed project would violate State water quality regulations. The person or entity seeking authorization for a regulated discharge (in this case Resolution Copper) has the responsibility to demonstrate to the State of Arizona that the regulated discharge would not violate water quality standards. This demonstration takes place through the application for and issuance of permits. Resolution Copper would be required to obtain a permit under the Arizona Pollutant Discharge Elimination System (AZPDES) program for any discharges to surface waters, including stormwater runoff, as well as an Aquifer Protection Permit (APP) for any discharges to groundwater, or discharges to the ground that could seep into groundwater.

The Forest Service is responsible for ensuring that mine operators on NFS lands obtain the proper permits and certifications to demonstrate they comply with applicable water quality standards. This constitutes compliance with the Clean Water Act (CWA). The ROD would require that Resolution Copper obtain the applicable State permits prior to approval of the final mining plan of operations, which authorizes mine activities. If the permits are issued, then ADEQ has determined that the project would be compliant with State law and identified the steps that would occur if monitoring indicates noncompliance.

While the permitting process provides an assurance to the public that the project would not cause impacts on water quality, it does not relieve the Forest Service of several other responsibilities:

- The Forest Service has a responsibility to analyze and disclose to the public any potential impacts on surface water and groundwater as part of the NEPA process, separate from the State permitting process.
- The role of the Tonto National Forest under its primary authorities is to ensure that mining activities minimize adverse environmental effects on NFS lands and comply with all applicable laws and regulations. As such, the Forest Supervisor

> ultimately cannot select an alternative that is unable to meet applicable laws and regulations.[45] However, it may be after the EIS is published when permits are issued by ADEQ that demonstrate that the project complies with state laws. In the meantime, it would be undesirable for the Forest Service to pursue and analyze alternatives that may not be able to comply. Therefore, a second goal of the analysis in this EIS is to inform the Forest Supervisor of alternatives that may prove difficult to permit.

The analysis approaches used by the Forest Service in this EIS likely differ from those that ADEQ would use in assessing and issuing permits. ADEQ would use the assumptions, techniques, tools, and data deemed appropriate for those permits. The Forest Service has selected to use a series of simpler mixing-cell models to provide a reasonable assessment of potential water quality impacts that is consistent with the level of hydrologic and geological information currently available for the alternative tailings sites. This approach is sufficient to provide the necessary comparison between alternatives and assess the relative risk of violation of water quality standards. It is understood different analysis may be conducted later when ADEQ is reviewing permit applications for the preferred alternative.

There are two specific additional aspects of the analysis in this section of the EIS that have a bearing on the ADEQ permitting process: assimilative capacity, and impaired waters.

ASSIMILATIVE CAPACITY

Assimilative capacity is the ability for a perennial water to receive additional pollutants without being degraded; assimilative capacity is calculated as the difference in concentration between the baseline water quality for a pollutant and the most stringent applicable water quality criterion for that pollutant.

Under Arizona surface water regulations, the addition of a pollutant may be considered "significant degradation" of a perennial water if, during critical flow conditions, the regulated discharge consumes 20 percent or more of the available assimilative capacity for each pollutant of concern (Arizona Administrative Code R18-11-107.01(B)). The addition of contaminants to surface waters through seepage could result in a reduction in the assimilative capacity of perennial waters. The EIS therefore contains an analysis of reductions in assimilative capacity.

The regulatory determination of significant degradation of perennial waters is under the purview of the State of Arizona. This determination is usually made when a permit is requested for a discharge directly to surface waters. However, Resolution Copper is not proposing any direct discharges to surface waters. Alternatively, ADEQ could consider the indirect effects of seepage from the tailings storage facility to surface waters under the APP program, or under a CWA Section 401 water quality certification (which is only done if a CWA Section 404 permit is required).

The 20 percent threshold that defines significant degradation is not absolute; if ADEQ decides to assess antidegradation standards as part of a permitting action, there are also provisions in Arizona regulations for degradation to be allowed, provided certain criteria are met (Arizona Administrative Code R18-11-107.C).

In other words, neither the regulatory need to assess assimilative capacity, nor the consequences of exceeding the 20 percent threshold can be assessed outside of a specific permitting decision by ADEQ. Regardless, the Forest Service responsibility for the DEIS is to disclose possible water quality concerns. This includes the reduction in

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45. Note that Alternative 6 would involve a tailings facility located off of Federal lands, and permitting the tailings facility would not be part of the Federal decision. In this case, the State permitting process that would ensue would require that applicable laws and regulations be met.

assimilative capacity of a perennial water. For this purpose, a threshold of 20 percent loss in assimilative capacity is used.[46]

IMPAIRED WATERS

Under the CWA, the State of Arizona must identify waters that are impaired for water quality.[47] As with assimilative capacity, the regulatory determination of how impaired waters could be affected by a discharge is solely under the purview of the State of Arizona.

For the purposes of disclosure, the Forest Service approach in the EIS is to identify what surface waters have been determined to be impaired, where contaminants from the project could enter these surface waters and exacerbate an already impaired water, and the estimated loading for constituents associated with the impairment.

Constituents of Concern

While the background references and reports contain information for the full suite of metals, inorganic constituents, and field measurements, the analysis we present in this section focuses on selected "constituents of concern." For example, appendix M of this EIS only includes graphs for the following constituents (these are constituents that are typically known to be issues for tailings facilities, or that the bypass seepage mixing/loading models have indicated may be a problem). These include the following:

- Total dissolved solids
- Sulfate
- Nitrate
- Selenium, cadmium, antimony, and copper

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[46] The calculation of assimilative capacity depends in part on the specific numeric surface water standard being used. Several surface water quality standards for metals change based on the hardness of the water. A hardness of 307 mg/L $CaCO_3$ was used for Queen Creek, which is based on the lowest hardness observed (sample date August 25, 2017); a hardness of 290 mg/L $CaCO_3$ was used for the Gila River below Donnelly Wash (sample date November 13, 2018); and a hardness of 242 mg/L $CaCO_3$ was used for the Gila River below Dripping Spring Wash (sample date November 9, 2018). The addition of the modeled seepage does increase hardness but only slightly (less than 2%). The values of hardness used are based on the best available information at this time; ADEQ could choose to apply different hardness values during permitting.

The calculation of assimilative capacity also depends on specific "critical flow conditions." One technique (often called 7Q10) is to choose the lowest flow over 7 consecutive days that has a probability of occurring once every 10 years. By contrast, the seepage modeling in the EIS uses the median flow for surface waters, which is a common method of estimating baseflow conditions, because it tends to exclude large flood events. While assessing typical baseflow conditions (using the median flow) were determined to be the most appropriate method for the EIS disclosure, ADEQ could choose to apply different flow conditions during permitting.

[47] "Impaired" refers to a regulatory designation under the CWA, and generally means that existing water quality is degraded to the point that an applicable water quality standard is not being attained.

Primary Legal Authorities Relevant to the Groundwater and Surface Water Quality Analysis

- Clean Water Act and Federal primary and secondary water quality standards
- State of Arizona Aquifer Water Quality Standards and the Aquifer Protection Permit program
- State of Arizona Surface Water Quality Standards and the Arizona Pollutant Discharge Elimination System program (delegated primacy for Clean Water Act Section 402)

3.7.2.3 Affected Environment

Relevant Laws, Regulations, Policies, and Plans

For the most part, impacts on groundwater and surface water quality fall under State of Arizona regulations, which are derived in part from the CWA. Additional details of the regulatory framework for groundwater and surface water quality are captured in the project record (Newell and Garrett 2018d).

Existing Conditions and Ongoing Trends

This section discusses three aspects of the affected environment:

- Existing groundwater quality for various aquifers, including what types and quantity of data have been collected to date; the general geochemistry of the groundwater for major constituents; the occurrence and concentrations of constituents of concern, compared with water quality standards; the age of the groundwater; and existing trends in groundwater quality.
- Existing surface water quality for various streams, including what types and quantity of data have been collected to date; the general geochemistry of surface waters for major constituents; and the occurrence and concentrations of constituents of concern, compared with water quality standards.
- Characterization of mine rock ore, and tailings, including the types and quantity of data for different geological units and alteration types that have been collected to date, and the static and kinetic laboratory testing undertaken to describe the likely changes in water quality when exposed to oxygen in the presence of sulfide minerals.

EXISTING GROUNDWATER QUALITY

Types of Groundwater Present

As more fully described in Section 3.7.1, Groundwater Quantity and Groundwater-Dependent Ecosystems, three types of groundwater exist in the area: shallow groundwater occurring in shallow alluvial materials, perched zones, or shallow fractures; the Apache Leap Tuff aquifer; and the deep groundwater system (units generally below the Whitetail Conglomerate, and extending into the Superior Basin) as seen in figure 3.7.1-4. These groundwater systems are identified as separate based on the different ages of the water within them and because they do not appear to be hydraulically connected based on aquifer testing.

The tailings facilities for Alternatives 2, 3, and 4 in the Superior Basin include shallow alluvial materials along washes and underlying fractured hard rock units like the Gila Conglomerate, which are assumed to be in hydraulic connection with the deep groundwater system. The tailings facilities for Alternatives 5 and 6 are geographically separate from the Superior Basin and overlie alluvial aquifers associated with Donnelly Wash and Dripping Spring Wash, respectively, with some hard rock units along the margins of the facilities.

Period of Record for Groundwater Quality Data

Groundwater quality data have been collected since monitor well drilling and development was initiated in 2003, and collection continues into the present. Groundwater samples from each monitoring well are analyzed for common dissolved constituents when the wells are completed, and then periodically thereafter. Overall, 31 wells in the project area have been sampled since 2003, and a total of 150 samples has been collected to characterize groundwater in the project area through 2015. These samples are largely focused on the East Plant Site and surrounding areas.

Near the West Plant Site, 48 wells have been developed and sampled, yielding 102 samples of groundwater (including duplicate samples). This sampling has largely been the result of ongoing voluntary cleanup activities at the West Plant Site, and the results are generally geared toward assessing contamination rather than hydrogeological conditions and general water quality.

Additional piezometers and monitoring wells were constructed in the Near West area in 2016 and 2017, where the tailings storage facility for Alternatives 2 and 3 would be located. Groundwater quality results from these wells have not yet been submitted.

Several other sampling locations provide the basis for background water quality in the bypass seepage mixing/loading models. These include a well near Queen Creek (nine samples between 2017 and 2018), a well near Donnelly Wash (one sample in 2018), and a well near Dripping Spring Wash (one sample in 2018).

Types of Groundwater Quality Data Collected

All samples were analyzed for a wide range of chemical constituents, including water quality measurements made on water samples in the field at the point of collection (e.g., pH, temperature) and analyses conducted by Arizona-certified analytical laboratories. Some of the constituents analyzed are directly related to water quality, including those that have regulatory standards in the state of Arizona. Other constituents such as isotopes were sampled to help understand groundwater dynamics and the potential for interaction with local surface water resources (Garrett 2018d). The number, date range, and types of samples collected are shown in table 3.7.2-3. A summary of existing groundwater quality for each aquifer is shown in appendix N, table N-1.

Table 3.7.2-3. Number of groundwater samples available for analysis

Type of Analysis	Shallow Groundwater Samples	Apache Leap Tuff Samples	Deep Groundwater Samples
General chemistry	25 (June 1986–Nov 2015)	104 (March 2004–Dec 2015)	19 (Nov 2008–Feb 2015)
Metals	25 (June 1986–Nov 2015)	105 (March 2004–Dec 2015)	19 (Nov 2008–Feb 2015)
Isotopes	24 (June 1986–May 2012)	90 (March 2004–Dec 2015)	19 (Nov 2008–Feb 2015)
Radionuclides	12 (June 2007–Dec 2008)	63 (June 2007–Dec 2015)	19 (Nov 2008–Feb 2015)

Chemical Quality of Groundwater

There are differences in water quality among the three principal groundwater sources (shallow, Apache Leap Tuff, deep groundwater system) in the project area (Montgomery and Associates Inc. 2012, 2016).[48] The shallow groundwater system can be described as a calcium/magnesium bicarbonate type with varying amounts of sulfate. The total dissolved solids content is generally low (median of 290 mg/L). Constituents in water samples from the shallow groundwater system rarely have concentrations above Arizona numeric Aquifer Water Quality Standards (AWQS) and EPA primary maximum contaminant levels, with nitrate and lead being the only constituents with concentrations above these standards. Samples also rarely have concentrations above EPA secondary maximum contaminant levels,

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[48] For a complete summary of the number of samples with concentrations over Arizona or EPA standards to support the qualitative terms used in this section (i.e., “rarely,” “occasionally,” “often”), see Newell and Garrett (2018d).

but this does occur for iron, manganese, sulfate, aluminum, and total dissolved solids; secondary standards are generally established for aesthetics and taste, rather than safety.

The Apache Leap Tuff aquifer has been sampled much more than either the shallow or deep groundwater systems, since it is the aquifer from which most springs and stream derive their flow. Overall the Apache Leap Tuff is a calcium-magnesium-bicarbonate water type, with low total dissolved solids (median of 217 mg/L). Constituents in water samples from the Apache Leap Tuff rarely appear in concentrations above Arizona numeric AWQS or EPA primary standards, although this has occurred for antimony, thallium, and beryllium. Concentrations above EPA secondary standards occur occasionally for aluminum, iron, and manganese, and rarely for total dissolved solids.

The overall water quality of the deep groundwater system is more variable than the shallow and Apache Leap Tuff systems, with greater total dissolved solids (median of 410 mg/L) that often can be above the EPA secondary standard. Only one sample (in 2011) exhibited concentrations above AWQS values. Concentrations often are above EPA secondary standards for aluminum, iron, manganese, sulfate, and fluoride. Samples with elevated sulfate, total dissolved solids, iron, and manganese appear to be within the proposed mineralized ore zone (Montgomery and Associates Inc. 2012).

Groundwater is also extracted from Shaft 9 as part of the ongoing dewatering. Groundwater associated with discharge from Shaft 9 has very high sulfate concentrations and, by extension, elevated total dissolved solids. Numerous constituents can be found in concentrations above Arizona numeric AWQS and EPA primary and secondary standards. This sampling location should not, however, be considered representative of the deep groundwater system, as it is affected by historical mine activity. The impacts at this location appear to be influenced by sulfide mineral oxidation, although the solution is routinely near neutral pH.

Age of Groundwater

Chemical characteristics of groundwater (isotopes) that may be used to assess age do not have explicit regulatory standards. Carbon-14 (^{14}C) and tritium have both been measured in shallow system, Apache Leap Tuff aquifer, and deep groundwater system sources to constrain age and provide understanding of water movement. These isotopic measurements indicate that shallow groundwater is typically estimated to be less than 700 years old, whereas Apache Leap Tuff and deep groundwater are 3,000–5,000 and 6,000–15,000 years old, respectively.

Trends in Groundwater Quality

Based on groundwater samples collected roughly between 2003 and 2015, over time the groundwater quality, in terms of major chemical constituents (e.g., calcium, magnesium, bicarbonate, sulfate) has remained generally stable in the shallow groundwater system and Apache Leap Tuff aquifer. The shallow system has displayed the greatest amount of variation, largely confined to variations in sulfate concentration. Although data for deep groundwater show significant variation with location, available data indicate there is little seasonal variability.

EXISTING SURFACE WATER QUALITY

Surface water occurs broadly across the entire project area. The settings in which surface water occurs span a wide range, from small to large drainage areas and channels and with highly variable flow rates. The kinds of surface water present (including springs and perennial streams) are described in further detail in both the “Groundwater Quantity and Groundwater-Dependent Ecosystems” and “Surface Water Quantity” resource sections in this chapter.

Period of Record for Surface Water Quality Data

The surface water baseline monitoring program for the project area was initiated in 2003 and has continued through present, with a 2-year hiatus in 2006 and 2007. Although surface water data have been collected since 2003, the number of samples collected varies from location to location. Water quality data are available for a total of 47 locations. Through 2015, 505 samples of surface water have been collected and chemically analyzed for 37 water quality parameters.

Most surface water monitoring has been conducted in the Devil's Canyon watershed (main canyon and two tributaries). Queen Creek, along the northern margin of Oak Flat prior to entering the Superior area, has also been extensively characterized (Montgomery and Associates Inc. 2013, 2017d).

Several other sampling locations provide the basis for background water quality in the bypass seepage mixing/loading models. These include Queen Creek at Whitlow Ranch Dam (15 samples between 2017 and 2018), the Gila River below Donnelly Wash (one sample in 2018), and the Gila River below Dripping Spring Wash (one sample in 2018).

Types of Surface Water Quality Data Collected

As with groundwater, all samples were analyzed for a wide range of chemical constituents, including water quality measurements made on water samples in the field at the point of collection (e.g., pH, temperature) and analyses conducted by State-certified analytical laboratories. Some of the constituents analyzed are directly related to water quality, including those that have regulatory standards in the state of Arizona. Other constituents such as isotopes were sampled to help understand groundwater dynamics and the potential for interaction with local surface water resources (Garrett 2018d).

Chemical Quality of Surface Waters

In general, surface water in the area is a calcium-sodium-bicarbonate type, with a neutral to alkaline pH. Based on sampling conducted by Resolution Copper, the basic chemistry of surface water does not vary widely across the project site and does not show any identifiable long-term trends, either increasing or decreasing. For the three principal drainages associated with the project—Devil's Canyon, Queen Creek, and Mineral Creek—water quality is generally considered to be of acceptable quality, although all three have exhibited concentrations above Arizona surface water quality standards at different times for several different constituents (Montgomery and Associates Inc. 2013, 2017d). A summary of the number of surface water samples with concentrations above Arizona numeric surface water standards is included in appendix N, table N-4; the constituents most often noted are arsenic, thallium, copper, lead, and selenium.

Appendix N, table N-2 presents a summary of water quality for defined reaches of the principal drainages, for filtered water samples (dissolved concentrations). Appendix N, table N-3 presents the same types of data for unfiltered samples (total concentrations). A summary of Arizona numeric surface water standards and which bodies they are applicable to is included in appendix N, table N-5. The State of Arizona has conducted more extensive sampling throughout the watershed since 2002–2003, with a focus on identifying sources of pollutants affecting impaired reaches of Queen Creek, Arnett Creek, and several tributary washes. ADEQ found that copper and lead vary across the watershed, with the highest concentrations of copper observed in runoff from Oak Flat and subwatersheds generally north of the West Plant Site. ADEQ also observed variations in runoff hardness (which is important for calculating surface water quality standards) and lead across the watershed (Louis Berger Group Inc. 2013).

Impaired Waters

The objective of the CWA is to restore and maintain the chemical, physical, and biological integrity of the nation's waters. To fulfill this objective, the State of Arizona is required to assess the existing quality of surface waters and identify any water bodies that do not meet State surface water quality standards. Each pollutant (i.e., copper, lead, suspended sediment) is looked at individually.

When a water body is identified that does not meet water quality standards, the next step taken by ADEQ is to develop a total maximum daily load (TMDL) for that pollutant. The TMDL is the amount to of a pollutant that a stream or lake can receive and still meet water quality standards. The studies to support developing a TMDL look at the point sources (i.e., discharge from municipalities or industries) and nonpoint sources (i.e., stormwater runoff from agriculture or the natural landscape).

Within the Queen Creek, Mineral Creek, and Gila River watersheds, several streams appear on the 303(d) Impaired Waters List (Arizona Department of Environmental Quality 2018a). The most recent list (2018) includes the following streams within the analysis area:

- Queen Creek, from headwaters to Superior Wastewater Treatment Plant discharge. Impaired for dissolved copper (since 2002), total lead (since 2010), and total selenium (since 2012). Two unnamed tributaries to this reach are also impaired for dissolved copper (since 2010).
- Queen Creek, from Superior Wastewater Treatment Plant discharge to Potts Canyon. Impaired for dissolved copper (since 2004).
- Queen Creek, from Potts Canyon to Whitlow Canyon. Impaired for dissolved copper (since 2010).
- Arnett Creek, from headwaters to Queen Creek. Impaired for dissolved copper (since 2010).
- Gila River, from San Pedro River to Mineral Creek. Impaired for suspended sediment (since 2006).

Of these, the only two reaches with the potential to receive additional pollutants caused by the Resolution Copper Project are Queen Creek below the Superior Wastewater Treatment Plant, due to runoff or seepage from Alternatives 2, 3, and 4, and the Gila River from the San Pedro River to Mineral Creek, due to runoff or seepage from Alternative 6.

In investigating the potential sources of copper in the watershed, ADEQ identified that the dominant source of copper to Queen Creek was runoff from the soils and rocks in the watershed, not point source discharges, and was a combination of natural background copper content and historic fallout from copper smelting (Louis Berger Group Inc. 2013). Part of the copper contribution looked at specifically by ADEQ was from Oak Flat. About 20 percent of the runoff reaching Superior would be captured by the subsidence crater and potentially could reduce copper loads to Queen Creek. For the purposes of the EIS, no such reductions are being assumed, in order to ensure that the impacts from copper loads from tailings seepage are not underestimated. Copper loads to Queen Creek due to the Resolution Copper Project are discussed in section 3.7.2.4.

MINE ROCK ANALYSIS

Rock within the proposed subsurface zone of mining is highly mineralized. However, not all the rock that is mineralized is ore grade and identified for proposed recovery. Much mineralized rock would remain in place during, and after mining. This rock contains sulfide minerals (e.g., pyrite, iron disulfide) and other metal-containing material. During mining, and after mining for some time, exposure of these minerals to oxygen could lead to their chemical weathering. This weathering may contribute acidity and metals to contact water and diminish its overall quality. The mine rock has been sampled and analyzed to assess the extent to which it might affect water that accumulates and is removed during mining, as well as the potential effects on groundwater that floods the mine void after mining is completed.

Amount of Geochemistry Tests Conducted

MWH Americas (2013) reports the rock units and alteration types that have been evaluated, and the number of samples for each. This information is summarized in table 3.7.2-4. Overall, 226 samples were submitted for analysis of Tier 1 procedures, with 13 duplicates for a total of 239 samples. A total of 54 samples were identified and submitted for Tier 2 evaluation using humidity cells; these cells were run for periods lasting from 16 to 74 weeks. Saturated column tests were then performed on samples from 14 of the 54 humidity cell tests, and were

Table 3.7.2-4. Rock units, alteration types, and number of samples submitted for Tier 1 geochemical evaluation

Code	**Rock Unit**	**Count**
Tal	Tertiary Apache Leap Tuff (Ignimbrite)	7
Tw	Tertiary Whitetail Conglomerate	11
Kvs	Cretaceous volcanics and sediments (undifferentiated)	101
Kqs	Cretaceous quartz-rich sediments	1
QEP	Quartz eye porphyry; rhyodacite porphyry	37
FP/LP	Felsic porphyry; latite porphyry	3
Dm	Devonian Martin limestone (skarn)	21
Andesite	Andesite	1
Diabase	Diabase	22
Qzite	Quartzite	17
Breccia/Hbx	Heterolithic breccia	3
Fault	Fault	2
	Total	**226**
Code	Alteration Type	**Count**
AA	Advanced argillic	19
ARG	Argillic	1
HFLRET	Retrograde hornfels	5
PHY	Phyllic	111
POT	Potassic	31
PRO	Propylitic	16
SA	Supergene argillic	7
SIL	Siliceous	1
SKN/SKRET	Skarn/Retrograde skarn	16
UNALT	Unaltered	18
ZEO	Zeolite	1
	Total	**226**

run for a 12-week period. Specific Tier 1 and Tier 2 tests are described in the next section

Types of Geochemistry Tests Conducted

Mine rock has been evaluated using a range of established, standard (best practices) methods for the mining industry (International Network for Acid Prevention 2018) as well as those that are regulatorily mandated procedures (Arizona Department of Environmental Quality 2004). These methods assess

- the potential for rock to generate acidic drainage,
- the rate at which such acid generation may occur, and
- what constituents of concern might be released and their associated concentrations.

Specific methods include

- whole rock chemical composition (concentration of wide range of elements),
- acid-base accounting (Sobek et al. 1978),
- net acid generation test (Stewart et al. 2006),
- synthetic precipitation leaching procedure (U.S. Environmental Protection Agency 1994),
- particle size analysis,
- humidity cell testing (American Society for Testing and Materials 1996), and
- saturated column testing (a project-specific test to leach the residual humidity cell testing procedure material.

The first five procedures (whole rock chemical composition, acid-base accounting, net acid generation test, synthetic precipitation leaching procedure, and particle size analysis) are Tier 1 procedures required in the Arizona Best Available Demonstrated Control Technology (BADCT) guidance (Arizona Department of Environmental Quality 2004). The last two are called for in the Tier 2 test-level requirements, which are generally conducted on fewer samples but take place over a longer period of time. Humidity cells are designed to mimic chemical weathering in the laboratory, and assess the rate of acid generation over time, and changes in water quality over time as a sample weathers. Saturated column tests are designed to mimic what would happen when the block-cave zone refloods after mining.

Beyond these chemical testing methods that directly assess potential impacts on the quality of contacting water, mine rock has been evaluated using mineralogical techniques such as

- petrography (microscopic evaluation of mineral grain sizes and contact boundaries),
- X-ray diffraction (identifies actual minerals present and their abundance), and
- scanning electron microscopy (evaluation of mineral formulas and textures).

Geochemical testing fundamentally is meant to determine if a given rock sample is potentially acid generating or not, and if so, to what extent. The geochemical tests indicate that there are numerous rock units associated with the project that have acid generation potential; geochemical tests on simulated tailings samples similarly have demonstrated the potential for acid generation.

Results of Geochemistry Tests – Mine Rock

Acid-base account testing of mine rock indicates that overall, most rock is classified as likely to generate acid rock drainage. ADEQ (2004) provides guidance for using acid-base account measurements to classify mine rock as either acid generating, non-potentially acid generating (NPAG), or potentially acid generating (PAG). To do this, the net neutralizing potential (NNP) is calculated, which is simply the acid neutralizing potential of the sample minus the acid generating potential of the sample. These prescriptive guidelines (Arizona Department of Environmental Quality 2004) for classifying mine materials use the following definitions:

- If NNP is less than −20, the rock can be considered acid generating.
- If NNP is greater than +20, the rock can generally be considered NPAG.
- Samples that fall between −20 and +20 are considered uncertain and may be tested further using kinetic testing methods.

Table 3.7.2-5 summarizes the percentage of each major rock type, according to hydrothermal alteration type, that is classified as either acid generating, NPAG, or PAG.

Humidity cell testing (a type of kinetic testing) has been conducted for assessing PAG and NPAG material. The kinetic testing is less for identifying the potential for acid generation, but more importantly for estimating specific weathering rates for developing chemical loading terms to be used in the seepage modeling. Humidity cell testing confirmed that samples identified as PAG in Tier 1 testing continued to produce acid leachates over time.

Results of Geochemistry Tests – Tailings

Tailings samples have been produced as part of metallurgical processing investigations and have been characterized for the potential to produce acid. Tailings would be produced in a such a way that part of the production stream would be highly enriched in acid-generating pyrite (the PAG tailings), and the balance would be depleted in pyrite as a result (the NPAG tailings). As summarized by Duke HydroChem LLC (2016), and reported in table 3.7.2-6, as would be expected all the PAG tailings are classified as acid-generating, whereas NPAG tailings are roughly equal parts non-acid generating and potentially acid generating, with a small percentage considered acid generating.

3.7.2.4 Environmental Consequences of Implementation of the Proposed Mine Plan and Alternatives

No Action Alternative

Under the no action alternative, seepage would not develop from a tailings facility and contribute to chemical loading in downgradient aquifers or surface waters, and stormwater would not potentially contact tailings, ore, or process areas. Water quality in the block-cave zone and surrounding aquifers would continue to match current conditions.

Impacts Common to All Action Alternatives

EFFECTS OF THE LAND EXCHANGE

The land exchange would have effects on groundwater and surface water quality.

The Oak Flat Federal Parcel would leave Forest Service jurisdiction. The role of the Tonto National Forest under its primary authorities in the Organic Administration Act, Locatable Regulations (36 CFR 228 Subpart A), and Multiple-Use Mining Act is to ensure that mining activities minimize adverse environmental effects on NFS surface resources; this includes water quality. The removal of the Oak Flat Federal Parcel from Forest Service jurisdiction negates the ability of the Tonto National Forest to regulate effects on these resources.

The offered lands parcels would enter either Forest Service or BLM jurisdiction. A number of perennial water features are located on these lands and entering Federal management would offer additional protection for the water quality of these resources.

FOREST PLAN AMENDMENT

The Tonto National Forest Land and Resource Management Plan (1985b) provides guidance for management of lands and activities within the Tonto National Forest. It accomplishes this by establishing

Table 3.7.2-5. Acid-generating ion classification of mine rock samples based on geological unit and alteration type

Geological Unit*	Alteration Type	Acid Generating	Non-acid Generating	Potentially Acid Generating
Andesite	Potassic	0.0%	0.0%	100.0%
Breccia	Advanced Argillic	100.0%	0.0%	0.0%
Breccia	Phyllic	50.0%	50.0%	0.0%
Diabase	Phyllic	100.0%	0.0%	0.0%
Diabase	Potassic	73.7%	0.0%	26.3%
Martin limestone	Retrograde Hornfels	16.7%	83.3%	0.0%
Martin limestone	Skarn	40.0%	53.3%	6.7%
Cretaceous volcanics & sediments (undifferentiated)	Advanced Argillic	36.4%	45.5%	18.2%
Cretaceous volcanics & sediments (undifferentiated)	Phyllic	70.8%	12.3%	16.9%
Cretaceous volcanics & sediments (undifferentiated)	Propylitic	85.7%	0.0%	14.3%
Quartz eye porphyry	Advanced Argillic	100.0%	0.0%	0.0%
Quartz eye porphyry	Phyllic	75.0%	12.5%	12.5%
Quartz eye porphyry	Potassic	75.0%	25.0%	0.0%
Quartz eye porphyry	Siliceous	100.0%	0.0%	0.0%
Quartzite	Advanced Argillic	100.0%	0.0%	0.0%
Quartzite	Phyllic	100.0%	0.0%	0.0%
Quartzite	Zeolite	100.0%	0.0%	0.0%
Apache Leap Tuff	Unaltered	0.0%	83.3%	16.7%
Overall		**63.7%**	**22.4%**	**13.9%**

* The percentage of the ore body of each rock type are generally: diabase (30%); quartzite (11%); quartz eye porphyry (15%); breccia (19%); Cretaceous volcanics and sediments (26%); Apache Leap Tuff (0%) (see Garrett (2017b)).

Table 3.7.2-6. Acid-generation classification of tailings samples

Tailings Type	Acid Generating	Non-acid Generating	Potentially Acid Generating
NPAG tailings (84% of total amount)	15%	41%	44%
PAG tailings (16% of total amount)	100%	0%	0%

a mission, goals, objectives, and standards and guidelines. Missions, goals, and objectives are applicable on a forest-wide basis. Standards and guidelines are either applicable on a forest-wide basis or by specific management area.

A review of all components of the 1985 forest plan was conducted to identify the need for amendment due to the effects of the project, including both the land exchange and the proposed mine plan (Shin 2019). A number of standards and guidelines (16) were identified applicable to management of water resources. None of these standards and guidelines were found to require amendment to the proposed project, either on a forest-wide or management area-specific basis. For additional details on specific rationale, see Shin (2019).

SUMMARY OF APPLICANT-COMMITTED ENVIRONMENTAL PROTECTION MEASURES

A number of environmental protection measures are incorporated into the design of the project that would act to reduce potential impacts on groundwater and surface water quality. These are non-discretionary measures and their effects are accounted for in the analysis of environmental consequences.

- Stormwater controls (described in detail in “Potential Surface Water Quality Impacts from Stormwater Runoff”)
- Engineered seepage controls (described in detail under each alternative in “Potential Water Quality Impacts from Tailings Storage Facility”)

POTENTIAL GROUNDWATER QUALITY IMPACTS WITHIN BLOCK-CAVE ZONE

Predicted Block-Cave Water Quality at Closure

The water quality in the block-cave sump at the end of active mining was modeled using the block-cave geochemistry model (Eary 2018f), as shown previously in table 3.7.2-1. At the end of mine life, no constituents in the block-cave sump are anticipated to have concentrations above Arizona numeric AWQS except for thallium. Several constituents are anticipated to have concentrations above EPA secondary standards, including aluminum, fluoride, sulfate, and total dissolved solids, and arsenic is anticipated to be above the EPA primary standard (which is lower than the Arizona numeric AWQS).

Post-Closure Trends in Block-Cave Water Quality

Even if ventilation assumptions used in Eary (2018f) bear out during operations, weathering products may accumulate on collapsed, mineralized rock in the block cave during mining due to the exposure to humid air and oxygen. If the oxygenated conditions of Hatch (2016) predominate, some of these products would dissolve in downward-migrating Apache Leap Tuff groundwater. Some can, however, be expected to be retained on unrinsed rock. These products would be dissolved in water that floods the block cave post-mining. Because these products are not associated with the block-cave water quality model, their release to reflooding waters would increase the concentration of chemical constituents and the water quality would worsen over time, potentially resulting in concentrations of metals (antimony, beryllium, cadmium, chromium, lead, nickel, selenium, thallium) above Arizona aquifer water quality standards, as shown in table 3.7.2-1.

Potential for Subsidence Lake Development

The Groundwater Modeling Workgroup recognized that three simultaneous events would take place that suggest there could be the potential for the creation of a surface lake on Oak Flat after closure of the mine:

- The subsidence crater would develop. The base case model run indicates the subsidence crater would be about 800 feet deep. Most of the sensitivity runs of the subsidence model are similar, although one sensitivity model run reached about 1,100 feet deep (Garza-Cruz and Pierce 2018).

Table 3.7.2-7. Comparison of rebounding groundwater levels and subsidence crater elevation

Well	Current Land Surface Elevation (from well schematics)	Estimated Elevation of Bottom of Subsidence Crater (based on a total crater depth of 800–1,100 feet)	Estimated Water Level Elevation at End of Mining	Estimated Water Level Elevation After 1,000 Years	Elevation of MSD One Portal	Elevation of Never Sweat Tunnel	Elevation of Umbrella Cave
DHRES-01	4,076	3,276–2,976	−2,799	2,666	2,930	3,200	2,992
DHRES-02	3,976	3,176–2,876	−2,798	2,666	2,930	3,200	2,992
DHRES-08	4,120	3,320–3,020	−2,798	2,666	2,930	3,200	2,992

Note: All elevations are given in feet above mean sea level (amsl).

- Groundwater levels would rebound and rise as the aquifer equilibrates after dewatering is curtailed after closure of the mine.
- Block-caving would have created a hydraulic connection from the surface to the deep groundwater system and eliminated any intervening layers like the Whitetail Conglomerate that formerly were able to prevent or slow vertical groundwater flow.

The Groundwater Modeling Workgroup explored the potential for a subsidence lake to form. Ultimately the Forest Service determined that the presence of a subsidence lake was speculative and not reasonably foreseeable, and as such it would therefore be inappropriate to analyze in the EIS. For a subsidence lake to form, groundwater levels would have to rebound to an elevation greater than the bottom of the subsidence crater. Table 3.7.2-7 summarizes the modeled groundwater levels for the three wells within the area of the subsidence crater. The best-calibrated model indicates that after 1,000 years, groundwater levels are still at least 200 feet below the bottom of the subsidence crater, and possibly as much as 650 feet below the bottom of the subsidence crater. Relative positions of the subsidence crater and recovering groundwater levels are shown in figure 3.7.2-4.

Potential for Other Exposure Pathways for Block-Cave Groundwater

The Groundwater Modeling Workgroup explored the potential for exposure to block-cave groundwater at the surface other than through a subsidence lake. The Magma Mine workings connect the block-cave area to the ground surface, and questions arose if the historic workings of the Magma Mine could be a pathway for block-cave groundwater to emerge at the surface. There is also at least one natural cave in the area (Umbrella Cave) that could represent an exposure pathway. Elevations for possible exposure points are shown in table 3.7.2-7.

Ultimately the group determined that block-cave groundwater would not rise to an elevation that would allow it to daylight through the Magma Mine workings, and thus there would be little potential for exposure to block-cave groundwater. The Groundwater Modeling Workgroup determined this based on the following rationale:

- During operations, pumping would dewater the Magma Mine workings. After dewatering ends, collected water in the Magma Mine workings would drain toward the block-cave zone, and not outward.
- The Magma Mine portal that comes to surface at the lowest elevation (MSD One Portal) daylights at an elevation of 2,930 feet amsl. At 1,000 years, this remains over 260 feet above recovered groundwater levels.

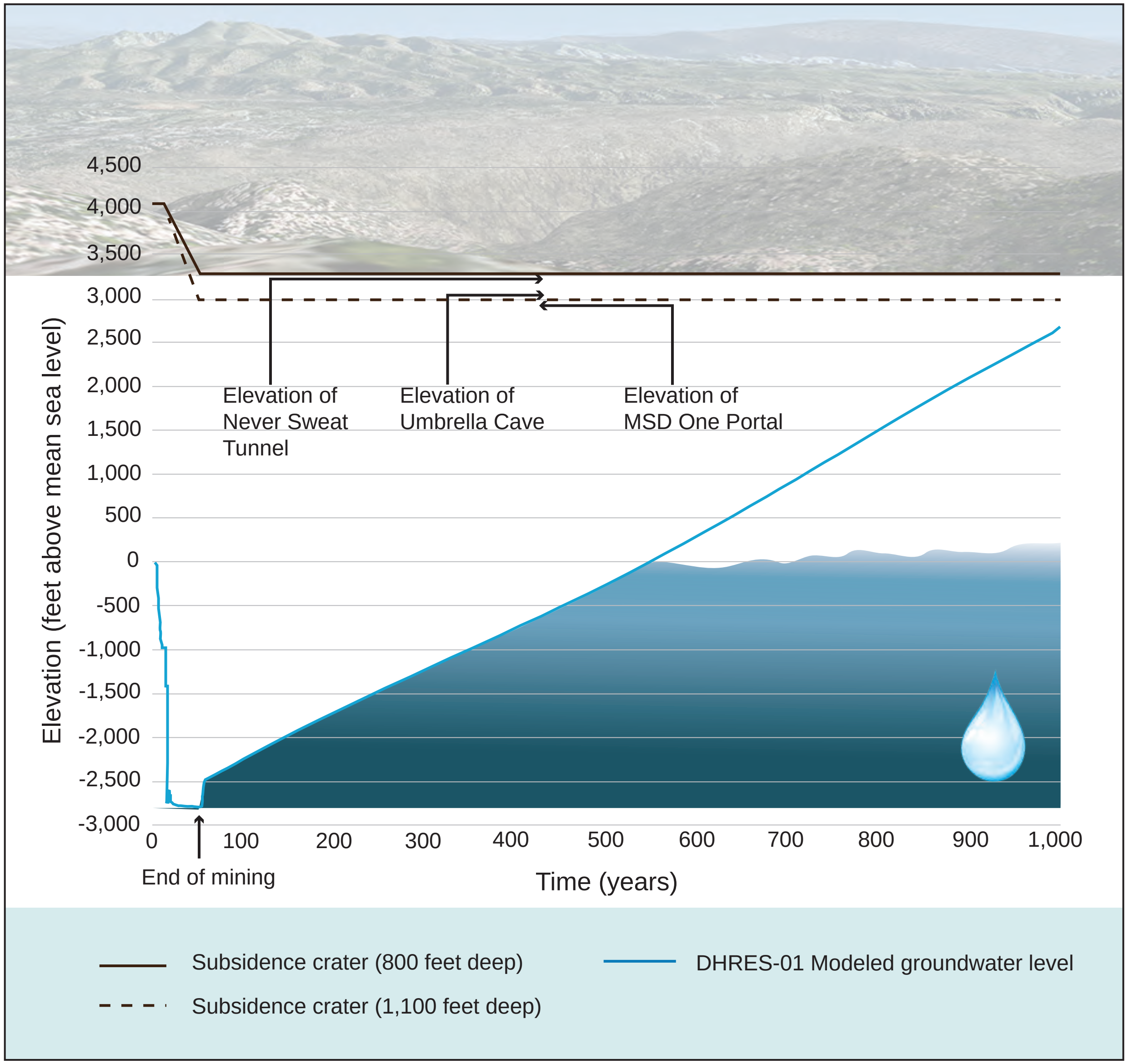

Figure 3.7.2-4. Potential for subsidence lake and other points of exposure of block-cave water

Table 3.7.2-8. Representative values of possible subsidence lake water sources (mg/L)

Constituent	Apache Leap Tuff Groundwater (see appendix N)	Deep Groundwater (see appendix N)	Block-Cave Sump Geochemistry at Closure (see table 3.7.2-1)	Precipitation*	Surface Water Quality Standard[†]
Total dissolved solids	248	638	1,528	10–20	–
Sulfate	18	252	934–2,247	2.2	–
Antimony	Non-detect	0.01	0.0047–0.035	Non-detect	0.030
Cadmium	Non-detect	Non-detect	0.0008–0.19	Non-detect	0.00068–0.0062
Selenium	Non-detect	Non-detect	0.0051–0.5	Non-detect	0.002
Copper	0.01	0.10	0.0148–141	Non-detect	0.0023–0.0293
Nitrate	0.52	0.43	Not modeled	0.27–1.05	–
Hardness (as $CaCO_3$)	126	335	851–1,690	4	–

* Carroll (1962); Root et al. (2004); metal loads in precipitation are assumed to be insignificant for comparison

† For comparison, the standard for Aquatic and Wildlife-Warmwater, chronic exposure is shown. Where hardness is required to calculate the standard, a range is shown. Antimony, cadmium, and copper standards are for dissolved concentrations, selenium is for total concentrations. Model data are not specific to total or dissolved fractions; for the purposes of comparison to surface water standards it can be assumed to apply to both.

- A tunnel that drains away from the block-cave zone (Never Sweat Tunnel) intercepts the subsidence crater at approximately 3,200 feet amsl. At 1,000 years, this remains over 530 feet above recovered groundwater levels.
- Umbrella Cave has an elevation of 2,992 feet amsl and remains over 320 feet above recovered groundwater levels at 1,000 years.
- The cone of depression in the aquifer created by the mine dewatering would persist for hundreds of years, creating hydraulic conditions that prevent subsurface flow away from the block-cave area.

The relative positions of the subsidence crater, other potential exposure points, and the modeled rise of groundwater levels is shown in figure 3.7.2-4.

Possible Water Quality Outcomes from a Subsidence Lake

While the fundamental processes needed to create a subsidence lake are reasonably foreseeable—rebounding water levels, subsiding ground surface, fracturing of intervening geological layers—the relative elevations based on the modeling conducted does not support that these processes would come together in a way that would actually create a lake within the subsidence crater.

Similarly, if a lake developed, it is not possible to predict the details that would be necessary to conduct even a rudimentary analysis of effects. For instance, the depth of the lake cannot be known with any accuracy. That single parameter would affect both the amount of inflow of native groundwater and the amount of evaporation that would occur from the lake surface, and it is the interplay of these two parameters that largely determines how constituents would concentrate in the lake and whether the ultimate water quality would be hazardous to wildlife.

Formation of a lake is speculative, but some context can be provided for the possible water quality in the subsidence lake. Water quality for the basic inputs is generally known, even if the relative amounts, how they would mix, and what evaporation would take place are not known. Representative values are shown in table 3.7.2-8, with comparison to Arizona surface water standards for wildlife. The broad conclusion that can be drawn is that if a subsidence lake were to form, a potential exists for concentrations above Arizona surface water standards, particularly copper. However, the potential also exists for water quality to be acceptable. These represent the bounds of possible outcomes.

POTENTIAL SURFACE WATER QUALITY IMPACTS FROM STORMWATER RUNOFF

Stormwater Controls and Potential for Discharge of Stormwater

Construction and Operation Phases

Stormwater control measures for each alternative are described in Newell and Garrett (2018d). During construction, temporary sediment and erosion controls would be implemented as required under a stormwater permit issued by ADEQ. These controls would include physical control structures as well as best management practices. Physical control structures could include diversions, berms, sediment traps, detention basins, silt fences, or straw wattles. Best management practices could include limiting vegetation removal, good housekeeping, proper material storage, and limiting ground disturbance. Stormwater control measures are generally kept in place until disturbed areas are stabilized either through revegetation or by permanent constructed facilities.

Generally speaking, during operations any precipitation or runoff that comes into contact with tailings, ore, hazardous material storage areas, or processing areas is considered “contact water.” During operations contact water would be captured, contained in basins, pumped out after storm events, and recycled back into the process water stream. This type of containment would be required by both the stormwater and aquifer protection permits that would be issued for the project. Contact water would not be released to the environment at any time during operations.

There are areas of the West Plant Site and filter plant and loadout facility that are undisturbed or contain only ancillary facilities. Stormwater from these areas is considered “non-contact” stormwater. In many cases, upstream runoff would be diverted around the project facilities to prevent the stormwater from becoming contact water and would be allowed to continue flowing into downstream drainages. Non-contact stormwater would be allowed to leave the property.

The tailings storage facility generally follows the same strategy during operations. For all alternatives, runoff from upstream of the facility would be diverted around the facility to prevent any contact with tailings. For Alternatives 2, 3, 5, and 6, any precipitation falling within the facility would run into the recycled water pond, and any runoff from the external embankments would be routed to the downstream seepage collection ponds, then pumped back and recycled into the process water stream. For Alternative 4, with filtered tailings, the tailings surface is designed to minimize ponding, and all contact water would be routed to downstream seepage collection ponds. As with the other alternatives, the water from the Alternative 4 seepage collection ponds would be pumped back and recycled in the process water stream; however, with Alternative 4, the water quality running off of the PAG tailings facility may be such that it requires further treatment prior to reuse.

Closure and Post-closure Phases

With respect to stormwater, the goal upon closure is to stabilize disturbed areas, minimize long-term active management, and return as much flow as possible to the environment. This is readily accomplished at the East Plant Site, West Plant Site, and filter plant and loadout facility once facilities are demolished and removed, and the sites are revegetated. Closure details for these areas are included in sections 6.5, 6.6, 6.8, and appendix Y of the GPO (Resolution Copper 2016d).

The tailings storage facility represents a more complex closure problem, regardless of alternative. The specific goals of closing the tailings storage facility are as follows:

- Develop a stable landform
- Develop a stable vegetated cover that limits infiltration and protects surface water quality by preventing contact of stormwater with tailings
- Minimize ponded water on the closed tailings surface
- Limit access of oxygen to PAG tailings to prevent oxidation of pyrite materials (acid rock drainage)
- Protect the reclaimed surface against wind or water erosion
- Provide a growth medium for vegetation to establish and be sustained in perpetuity

Closure of the tailings facilities for Alternatives 2, 3, 5, and 6 is a long-term phased process that involves gradually reducing the size of the recycled water pond and then encapsulating the PAG tailings with NPAG tailings. Eventually the tailings embankments and top surface of the facility are given a soil cover with a thickness of at least 1 to 2 feet and revegetated. Stormwater conveyance channels and armoring would be used where appropriate to protect the reclaimed surface. Once surfaces are covered and stable, stormwater could be allowed to discharge downstream if water quality meets release criteria.

For some time after closure, the seepage collection ponds would be maintained downstream of the tailings storage facility to collect drainage from the facility. This time could vary from years to decades, depending on the alternative. There would be no discharge from the collection ponds to downstream waters, neither seepage nor stormwater that collects within the ponds. For some time the recycled water pond would still exist within the tailings facility, and during this time collected water in the seepage ponds could be pumped back to the recycled water pond for evaporation. Once the recycled water pond disappears, the seepage collection ponds are designed to be large enough to evaporate any collected seepage and stormwater. The seepage collection ponds are meant to stay in place until all water reporting to the ponds is of adequate quality to allow discharge downstream.

Closure of the filtered tailings facility (Alternative 4) is similar but simplified by the lack of any recycled water pond. Instead, all surfaces of the PAG and NPAG facilities would be given a soil cover and revegetated. Stormwater from upstream in the watershed would be diverted around the facilities in perpetuity, and once surfaces are covered and stable, stormwater from the facilities could be allowed to discharge downstream as well if water quality meets release criteria.

For some time after closure (estimated to be about 5 years), the seepage collection ponds for Alternative 4 would be maintained downstream of the tailings storage facility. The seepage collection ponds are meant to stay in place until all water reporting to the ponds is of adequate quality to allow discharge downstream. Unlike Alternatives 2, 3, 5, and 6, any excess water in the seepage collection ponds during closure cannot be pumped back to a recycled water pond; these ponds therefore could require active water treatment. In the long term, the ponds are designed to be large enough to evaporate any collected seepage and stormwater.

The potential for ponds to impact wildlife is assessed in section 3.8.4.2.

Summary of Stormwater Controls

At no point during construction, operation, closure, or post-closure would stormwater coming into contact with tailings, ore, or processing areas be allowed to discharge downstream. After closure, precipitation falling on the tailings facilities would interact with the soil cover, not tailings. The seepage collection ponds represent a long-term commitment for managing seepage and stormwater, but eventually would either become passive systems fully evaporating collected water, or would be removed after demonstrating that collected water is of adequate quality to discharge.

Stormwater mixes with collected seepage in collection ponds and some would be lost to the environment; this occurrence is incorporated into the bypass seepage mixing/loading model.

Predicted Quality of Stormwater Runoff

Stormwater contacting tailing would not be released downstream; however, the potential water quality of this runoff has been estimated.

The quality of stormwater runoff from tailings and the soil cover can be predicted in several ways. In the aquifer protection permitting process, ADEQ often relies on a test called the synthetic precipitate leaching procedure (SPLP). This test measures contaminants in a slightly acidic water solution that has interacted with a rock or tailings sample. One drawback of relying solely on the SPLP test is that it is usually conducted only using fresh core or lab-created tailings samples that have not weathered. By contrast, in reality, precipitation could interact with embankment tailings that could have been weathering for years or decades.

Two additional methods reflect the water quality from interaction with weathered materials. As part of the geochemical characterization activities, Resolution Copper conducted a series of “barrel” tests, in which barrels of material were left exposed to natural precipitation over the course of several years. The resulting leachate from the barrels was periodically collected and analyzed. Numerous humidity cell tests also were run for long periods of time. These tests involve periodic exposure of samples to water over many weeks, even years. An estimate of the potential runoff water quality from PAG and NPAG tailings was produced, drawing on the results of these various geochemical tests (Eary 2018g). Runoff from NPAG tailings was calculated by combining the results of 12 humidity cell tests conducted on tailings samples representing different lithologies. Potential runoff water quality from PAG tailings (applicable to Alternative 4 only) was estimated from barrel tests conducted on filtered PAG tailings (specifically Barrel #3), supplemented with results from barrel tests conducted on paste PAG tailings (specifically Barrel #1).

Resolution Copper also sampled natural runoff quality, specifically during a storm event in February 2018 in the vicinity of the Near West location (specific to Alternatives 2 and 3).

Water quality results for SPLP tests, Resolution Copper estimates of runoff quality, and natural runoff are shown in table 3.7.2-9 and compared with the surface water quality standards for the most restrictive use.[49]

All methods of estimating stormwater runoff quality suggest that both NPAG and PAG tailings may have concentrations of some constituents that are above Arizona surface water standards. As stated above, this stormwater would not be discharged to the environment at any time; the results shown in table 3.7.2-9 reinforce the need for requiring stormwater controls during operations. Post-closure runoff water quality, after the soil cover is in place and revegetated, should be similar to natural runoff water quality and concentrations above surface water quality standards would not be anticipated.

Alternative 2 – Near West Proposed Action

POTENTIAL WATER QUALITY IMPACTS FROM TAILINGS STORAGE FACILITY

Seepage Controls Incorporated into Design

A tailings storage facility creates seepage. Total seepage is all water that drains from the tailings storage facility by gravity. Lost seepage is seepage that is not recovered with the engineered seepage controls. Lost seepage is assumed to discharge to the environment.

The design of engineered seepage controls for each alternative has been approached in stages. For Alternatives 2 and 3:

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[49] Surface water quality standards are difficult to succinctly summarize, as the standards vary by specific designated use of the water body and in some cases vary by hardness of the water. For reference, table N-5 in appendix N summarizes all surface water standards for water bodies in the area, as well as aquifer water quality standards.

Table 3.7.2-9. Predicted stormwater runoff water quality (mg/L)

	Estimated Runoff Water Quality from NPAG Tailings (Alternatives 2, 3, 5, 6)*	Estimated Runoff Water Quality from PAG Tailings (Alternative 4)*	Water Quality Measured in Natural Runoff†	SPLP Results for NPAG Tailings‡	SPLP Results for PAG Tailings‡	Surface Water Standard for Most Restrictive Use (Gila River or Queen Creek)	Surface Water Standard for Most Restrictive Use (Ephemeral Tributaries)
Regulated Constituents							
Antimony	0.00073	0.00062	0.00027	0.003	0.003	0.030	0.747
Arsenic	0.00016	**0.576**	0.0052			0.030	0.280
Barium	0.0128	0.208	0.0128	0.0122	0.0275	98	98
Beryllium	0.0022	**0.192**	0.0005	0.002	0.002	0.0053	1.867
Boron	0.0028	0.104	0.03			1	186.667
Cadmium	0.00097	**0.106**	0.000019	0.0002	0.0002	0.0043	0.2175
Chromium, Total	0.00036	**9.107**	0.00095	0.006	0.006	1	–
Copper	**9.81**	**3,294**	0.012	0.01	0.01	0.0191	0.0669
Fluoride	0	**424.6**	0.13			140	140
Iron	0.177	**5,353.8**	0.0225	0.06	0.06	1	–
Lead	0.00026	**0.0095**	0.0001	**0.0115**	0.003	0.0065	0.015
Manganese	0.693	**43**	0.017	0.0106	0.0313	10	130.667
Mercury				**0.0002**	**0.0002**	0.00001	0.005
Nickel	**0.112**	**26.39**	0.0013			0.1098	10.7379
Nitrate	0	0	3.1			3733.333	3733.333
Nitrite						233.333	233.333
Selenium	**0.0088**	**0.322**	0.00027	**0.003**	0.0043	0.002	0.033
Silver	0.000006	**1.78**	0.000018	0.005	0.005	0.0147	0.0221
Thallium	0.00008	**0.0177**	0.000015	0.001	0.001	0.0072	0.075
Uranium				0.001	0.001	2.8	2.8
Zinc	0.171	**17.29**	**0.0015**	**0.01**	0.01	0.2477	2.8758
pH	**5.48**	**2.13**	7.59	6.53	6.72	**6.5–9.0**	**6.5–9.0**

continued

Table 3.7.2-9. Predicted stormwater runoff water quality (mg/L) *(cont'd)*

	Estimated Runoff Water Quality from NPAG Tailings (Alternatives 2, 3, 5, 6)*	**Estimated Runoff Water Quality from PAG Tailings (Alternative 4)***	**Water Quality Measured in Natural Runoff**†	**SPLP Results for NPAG Tailings**‡	**SPLP Results for PAG Tailings**‡	**Surface Water Standard for Most Restrictive Use (Gila River or Queen Creek)**	**Surface Water Standard for Most Restrictive Use (Ephemeral Tributaries)**
Constituents without Numeric Standards							
Sulfate	264	28,452	6.8	229	115	–	–
Total Dissolved Solids	–	–	–	294	186	–	–

Notes:

See appendix N, table N-5, for details regarding the water quality standards used in this table.

All values shown in milligrams per liter. Shaded cell and bolded text indicate concentrations above at least one water quality standard.

For all analyses, values below the laboratory detection limit are calculated as equal to the detection limit. There are other valid methods that could be used, such as using a zero value, or more commonly, using half the detection limit. Because surface water standards for some constituents—particularly mercury—can be extremely low, it is important to use the detection limit when looking at non-detect results. To use any lower value could yield results that meet the water quality standard, even when the detection limit was actually too high to draw this conclusion.

Some water quality standards for metals are specific to total recoverable metals or dissolved metals. Predicted results are compared with standards regardless of whether the standard specifies total or dissolved.

* From Enchemica, Common Inputs Memorandum, 7/18/18, table 3-4 (Eary 2018g).

† From Enchemica, Common Inputs Memorandum, 7/18/18, table 3-2; from stormwater samples collected at Near West location (Eary 2018g).

‡ NPAG results taken from “7/7A 7C Scavenger” sample from Verberg and Harvey (2008); PAG results taken from “7/7A 7C Cleaner” sample from Verberg and Harvey (2008)

- Level 0: Controls that are inherent in the design of the embankment itself and required for stability, but also function to control seepage.
- Level 1: A suite of engineered seepage controls always envisioned to be part of the design, that served as the starting point for the seepage modeling.
- Levels 2–4: These represent additional layers of engineered seepage control considered during the design process in order to reduce seepage to meet water quality objectives. Some of these controls would have to be built into the facility from the start, such as low-permeability liners for the PAG tailings. Others are expected to be necessary but can be implemented if real-world observations indicate existing seepage controls are not sufficient, such as downstream grout curtains and additional seepage collection ponds.

The following describes the various engineered seepage controls assessed in the Alternative 2 alternative design, and table 3.7.2-10 summarizes how these are expected to be applied. A conceptual diagram of the seepage controls is shown in figure 3.7.2-5. The initial suite of engineered seepage controls includes blanket and finger drains, foundation treatment, and downstream seepage collection dams and pumpback wells.

- Primary seepage control measures for stability (Level 0) include blanket and finger drains built into the facility. Sand and gravel blanket drains are required beneath the cyclone sand embankment; the blanket drain was modeled as a 3-foot-thick, highly conductive layer consisting of coarse gravel that drains the embankment and conveys seepage to the seepage collection ponds downstream of the facility. Finger drains would also collect water from beneath the tailings and convey it beneath the starter dam via a series of lined channels to the seepage collection ponds. Finger drains were modeled as channels 10 feet thick by 30 feet wide, and filled with highly conductive coarse gravel, following the topography of the existing alluvial tributaries.
    - Enhancements: For Level 1 controls, the blanket drain was expanded further beneath the facility to increase seepage control, ultimately extending 200 feet upstream.
- The foundation would be treated during construction to reduce seepage and encourage flow into the drain system. Foundation treatment can include a variety of techniques such as dental concrete,[50] cut-offs, grouting, or engineered low-permeability layers such as compacted fine tailings, engineered low-permeability liners, asphalt, slurry bentonite, and/or cemented paste tailings. Specific treatments would be designed based on real-world conditions encountered during site preparation. For the purposes of the alternative design, it is assumed that engineered low-permeability layers would be used with geological units with relatively higher conductivities (Tertiary perlite, Tertiary tuff, and Precambrian Apache Group units) that underlie approximately one-third of the tailings footprint.
    - Enhancements: For Level 1 controls, the full starter PAG cell was assumed to be underlain by an engineered low-permeability layer. For Level 4 controls, this was expanded to the entire PAG cell.
- Eleven primary seepage collection dams with associated seepage collection ponds would be constructed in natural valleys downstream of the cycloned sand embankment. All alluvial soil underneath the crest of the seepage collection dams would be excavated until competent foundation material is reached. Dams are then covered on the upstream side with an engineered low-permeability layer and built with grouted cut-off walls to help intercept subsurface flow. Pumpback wells would be installed upstream of the grout curtain and would return seepage to the recycled water pond.

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[50] ”Dental concrete” is conventional concrete that is used to shape surfaces and fill irregularities, much like filling a cavity in a tooth.

Table 3.7.2-10. Effectiveness of Alternative 2 engineered seepage controls

Seepage Control Levels and Components	Uncaptured Seepage from Facility	Source
Uncontrolled seepage from tailings facility	2,132 acre-feet/year	Groenendyk and Bayley (2018b) and Klohn Crippen Berger Ltd. (2018a)
Level 0 (seepage controls for geotechnical stability)		
- Modified centerline cyclone sand embankment - Blanket drain under embankment; finger drains	Not explicitly modeled; incorporated into Level 1 modeling	
Level 0–1		
- Blanket drain extends into facility under NPAG beach; finger drains (blanket/finger drains account for roughly 88% of seepage collected) - Seepage collection ponds with pumpback wells and cut-off walls	194 acre-feet/year	Groenendyk and Bayley (2018a)
Level 1		
- Blanket drain extends 200-feet into facility - Foundation treatment and selected areas of engineered low-permeability layers, for all areas not Gila Conglomerate - Engineered low-permeability layer for starter PAG facility - Seepage collection ponds with pumpback wells, cut-off walls, and grout curtain to 100-foot depth	Not explicitly modeled; incorporated into Level 4 modeling	N/A
Level 2		
- Grout curtain extended to target high-permeability zones and seepage pathways	Not explicitly modeled; incorporated into Level 4 modeling	N/A
Level 3		
- Add second perimeter of seepage collection ponds downstream	Not explicitly modeled; incorporated into Level 4 modeling	N/A
Level 4 (includes Levels 0 through 4)		
- Add pumpback wells, cut-off walls, and grout curtains to second perimeter of seepage collection ponds - Engineered low-permeability layer for entire PAG cell - Downgradient grout curtain extending to 100-foot depth - Additional pumpback wells in targeted areas to maximize capture	20.7 acre-feet/year†	Groenendyk and Bayley (2019)
- For comparison: fully lined facility (3,300 acres)*	792 acre-feet/year	Rowe (2012)

* See Newell and Garrett (2018d) for details of calculations; assumes 1 foot of head over liner.

† Initial estimate of post-closure seepage based on infiltration of precipitation was 17 acre-feet per year; post-closure seepage was later changed to match operational seepage of 20.7 acre-feet per year.

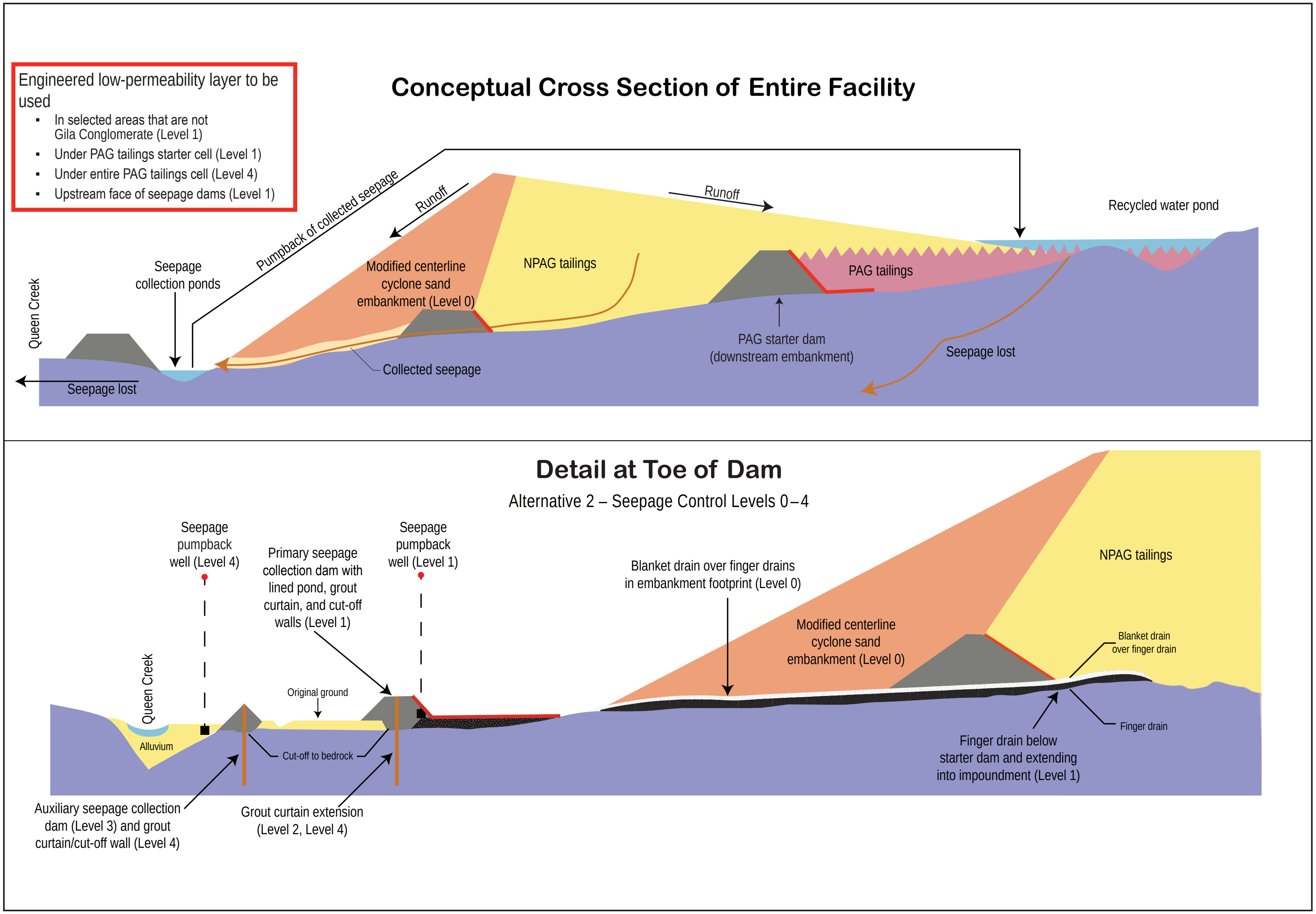

Figure 3.7.2-5. Alternative 2 seepage controls

    - Enhancements: Under Level 1 controls, grout curtains were expanded to 100-foot depth. Under Level 2 controls, grout curtains were expanded to the bedrock ridges between seepage collection dams and any high-permeability zones.

In addition to the basic suite of engineered controls, three additional concepts were brought into the design for further seepage control:

- Five auxiliary seepage collection dams would be constructed downstream of the primary seepage collection dams (Level 3). These could be further enhanced with pumpback wells, cut-off walls, and grout curtains (Level 4).
- A 7.5-mile-long and 100-foot-deep grout curtain would be installed downgradient of the tailings facility (Level 4).
- Twenty-one auxiliary pumpback wells would be installed beyond the grout curtain with depths of approximately 200 feet, wherever deemed useful (Level 4).

Anticipated Effectiveness of Seepage Controls

Total seepage was estimated during the initial design phase using a one-dimensional, unsaturated flow model (Klohn Crippen Berger Ltd. 2018a). Total seepage estimates start with a water balance calculation of flow through the tailings during full buildout, based on assumptions about weather (precipitation and evaporation), consolidation, and area and depth of the tailings.

A three-dimensional groundwater flow model was then used to model the amount of this total seepage that would be captured by various engineered seepage controls, leaving some amount of lost seepage to enter the environment downgradient (Groenendyk and Bayley 2018b, 2019).

During operations, total seepage created by the tailings was estimated at 2,132 acre-feet per year (1,912 and 220 acre-feet per year of NPAG and PAG seepage, respectively) and lost seepage was modeled to be 194 acre-feet per year with Level 1 seepage controls, and 21 acre-feet per year with all enhanced engineered seepage controls (Level 4).

Modeling indicates the Level 4 seepage controls would reach a seepage capture efficiency of 99 percent. Most of this seepage is captured by blanket and finger drains (88 percent).

Risk of Seepage Impacting Groundwater or Surface Water Quality

Modeled results for groundwater and surface water impacts are reported by Gregory and Bayley (2019). The detailed results of the bypass seepage mixing/loading model were supplied as an Excel spreadsheet, and can be found in Garrett (2019c). Table 3.7.2-11 presents model results for all modeled chemical constituents in the first groundwater cell along Queen Creek (cell QC-3)[51] and the ultimate, final surface water cell (Queen Creek at Whitlow Ranch Dam), for model years 41, 100, and 245.[52] This provides perspective on trends and expected conditions at the end of mining and in the long term. Table 3.7.2-11 also presents Arizona water quality standards and baseline chemistry for added perspective.

Figures M-1 through M-7 in appendix M illustrate model results for seven chemical constituents of concern that either are regulated constituents that helped drive the required level of engineered seepage controls incorporated into the design (cadmium, selenium, antimony, copper) or offer other significant perspective on water quality (nitrate,

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[51] Results are included in the modeling for several washes that would receive lost seepage (Potts and Roblas Canyon), which are upgradient from cell QC-3. It is not likely that substantial groundwater exists in these alluvial channels; these modeled results are indicative of seepage itself, rather than groundwater concentrations expected in the aquifer.

[52] Note that model year 41 represents the end of mining, the end of tailings production, and the start of facility closure.

Table 3.7.2-11. Seepage water quality modeling results for Alternative 2 (mg/L)

	Aquifer Water Quality Standard	Baseline Groundwater Quality (Well DS17-17*)	QC-3 Model Cell Year 41	QC-3 Model Cell Year 100	QC-3 Model Cell Year 245	Surface Water Standard for the Most Restrictive Use	Baseline Surface Water Quality (Whitlow Ranch Dam*)	Queen Creek at Whitlow Ranch Dam Modeled Surface Water Year 41	Queen Creek at Whitlow Ranch Dam Modeled Surface Water Year 100	Queen Creek at Whitlow Ranch Dam Modeled Surface Water Year 245
Constituents with Numeric Standards										
Antimony	0.006	0.00021	0.00026	0.00034	0.00036	0.030	0.00052	0.00054	0.00059	0.00065
Arsenic	0.05	0.0013	0.0013	0.0013	0.0014	0.030	0.00235	0.0024	0.0024	0.0024
Barium	2	0.0261	0.0263	0.0263	0.0263	98	0.0350	0.035	0.035	0.035
Beryllium	0.004	0.00100	0.00100	0.00101	0.00101	0.0053	0.0010	0.0010	0.0010	0.0010
Boron	–	0.069	0.073	0.078	0.078	1	0.057	0.059	0.062	0.066
Cadmium	0.005	0.00004	0.0001	0.0002	0.0002	0.0051	0.00005[‡]	0.00007[‡]	0.00015‡	0.00020‡
Chromium, Total	0.1	0.0019	0.0022	0.0029	0.0027	1	0.0015	0.0016	0.0020	0.0023
Copper	–	0.00076	0.004	0.004	0.003	0.0234	0.00230[‡]	0.0041[‡]	0.0039‡	0.0045[‡]
Fluoride	4	0.529	0.56	0.57	0.56	140	0.4	0.42	0.43	0.43
Iron	–	0.045	0.0450	0.0450	0.0450	1	0.048	0.048	0.048	0.048
Lead	0.05	0.000065	0.00008	0.00009	0.00009	0.0083	0.00008[‡]	0.00008[‡]	0.0000[9‡]	0.00010[‡]
Manganese	–	0.0049	0.011	0.028	0.025	10	0.150	0.153	0.162	0.169
Mercury	0.002	N/A	N/A	N/A	N/A	0.00001	N/A	N/A	N/A	N/A
Nickel	0.1	0.0027	0.003	0.005	0.005	0.1343	0.0027[‡]	0.0030[‡]	0.0041[‡]	0.0050[‡]
Nitrate	10	0.38[†]	0.43	0.46	0.45	3,733.333	1.900	1.93	1.94	1.97
Nitrite	1	N/A	N/A	N/A	N/A	233.333	N/A	N/A	N/A	N/A
Selenium	0.05	0.0009	0.002	0.005	0.004	0.002	0.0007	0.0012	**0.0027**	**0.0038**
Silver	–	0.000036	0.0003	0.0009	0.0007	0.0221	0.000036	0.00016	0.00049	0.00071
Thallium	0.002	0.00003	0.00006	0.00009	0.00008	0.0072	0.000030	0.00004	0.00006	0.00008
Uranium	–	N/A	N/A	N/A	N/A	2.8	N/A	N/A	N/A	N/A
Zinc	–	0.005	0.018	0.045	0.039	0.3031	0.0030[‡]	0.0088[‡]	0.0238[‡]	0.0353[‡]
pH	–	N/A	N/A	N/A	N/A	6.5–9.0	N/A	N/A	N/A	N/A

continued

Table 3.7.2-11. Seepage water quality modeling results for Alternative 2 (mg/L) *(cont'd)*

	Aquifer Water Quality Standard	Baseline Groundwater Quality (Well DS17-17*)	QC-3 Model Cell Year 41	QC-3 Model Cell Year 100	QC-3 Model Cell Year 245	Surface Water Standard for the Most Restrictive Use	Baseline Surface Water Quality (Whitlow Ranch Dam*)	Queen Creek at Whitlow Ranch Dam Modeled Surface Water Year 41	Queen Creek at Whitlow Ranch Dam Modeled Surface Water Year 100	Queen Creek at Whitlow Ranch Dam Modeled Surface Water Year 245
Constituents without Numeric Standards										
Sulfate	–	173	186	208	209	–	136	144	154	168
Total Dissolved Solids	–	589	614	652	652	–	546	561	579	603

Notes: N/A = not analyzed in seepage modeling

Shaded cell and bolded text indicate concentrations above water quality standard.

Model data are not specific to total or dissolved fractions; for the purposes of comparison to surface water standards it can be assumed to apply to both.

* Results shown represent median values from water quality measurements

† No available data for well DS17-17. NO_3-N value calculated as median of three samples collected from Bear Tank and Benson Springs between November 2014 and March 2015

‡ Standards are hardness dependent and were calculated using lowest (most stringent) hardness value recorded for Whitlow Ranch Dam (307 mg/L $CaCO_3$ on 8/25/2017); see appendix N, table N-5, for details on how these standards were selected

total dissolved solids, sulfate). These figures depict the model results for all groundwater and surface water cells.

Modeling results for Alternative 2 indicate the following:

- Modeling estimates that engineered seepage controls can recover 99 percent of total seepage. All levels of control (Levels 0 through 4) have been applied to Alternative 2 for the purposes of estimating the effects of tailings seepage on water quality.
- For all constituents, concentrations decrease with distance from the tailings storage facility, but increase over time.
- There are no concentrations above aquifer water quality standards for the first model cell corresponding to groundwater (cell QC-3) or subsequent downgradient cells.
- Concentrations of selenium are above the surface water regulatory standard for the most restrictive use in model year 64 and onward for Queen Creek at Whitlow Ranch Dam (see appendix M, figure M-3), despite incorporation of engineered seepage controls estimated to capture 99 percent of total seepage. No other constituents are modeled to have concentrations above surface water regulatory standards. The model result is above the standard by a very small amount, and the uncertainty in the model does not allow a strict comparison. It can only be concluded that concentrations are expected to be near the standard.
- Sulfate and total dissolved solids are significant constituents in tailings seepage and can alter the potential use of downstream water resources, but do not have numeric standards. Over time, sulfate concentrations in groundwater closest to the tailings storage facility are expected to rise slightly above the 250 mg/L secondary standard, to 340 mg/L (see appendix M, figure M-1).
- Most constituents increase in concentration in groundwater and surface water above existing baseline conditions.
- The risk of not being able to meet desired seepage capture efficiencies is high. While the determination of whether water quality standards would be met is under the jurisdiction of ADEQ, the disclosure undertaken by the Forest Service suggests that the high capture efficiency required of the engineered seepage controls could make meeting water quality standards under this alternative challenging. The number and types of engineered seepage controls represent significant economic and engineering challenges.

Practicability for Additional Seepage Controls

The site-specific suite of engineered seepage controls designed for Alternative 2 is substantially more effective at controlling seepage than a fully lined facility with no other controls. The estimated loss through a full liner due to defects is 792 acre-feet per year (see Rowe (2012) and Newell and Garrett (2018d) for details of this estimate). This estimate is specifically for geomembrane as specified under Arizona BADCT; composite liners are able to reach better performance, but there are substantial logistical concerns about the ability to successfully install a full liner of any kind (see Newell and Garrett (2018d) for a summary of concerns).

Under the suite of engineered seepage controls considered (Levels 0 through 4), all parts of the foundation except those on Gila Conglomerate would already use low-permeability layers which have similar permeabilities to the Arizona BADCT specifications. The comparison to a full liner illustrates the need for layered seepage controls, particularly downstream seepage collection dams and pumpback wells, to control seepage that would be generated from within the facility, regardless of the foundation treatment.

Alternative 2 has limited ability to add further layers of seepage controls during operations. The envisioned seepage controls (Levels 0 through 4) already would extend downstream to the edge of Queen Creek. Logistically, there is little physical room to add additional controls.

RAMIFICATIONS FOR LONG-TERM CLOSURE

Post-closure Water Quality, Seepage Rates, and Closure Timing

Modeling indicates that the concentrations of constituents of concern continue to increase over time, post-closure. In addition, the estimated long-term post-closure seepage rate of 17 acre-feet per year (Gregory and Bayley 2018a) is close to the seepage rate only achieved with all Level 4 engineered seepage controls in place (20.7 acre-feet per year), including the active pumpback wells. This suggests that passive closure of the tailings storage facility may be difficult, and active management may be required.

In the alternative design, Klohn Crippen Berger Ltd. (2018a) estimated that active closure would be required up to 100 years after the end of operations. Up to 25 years after closure, the recycled water pond still is present and therefore all engineered seepage controls could remain operational, with seepage pumped back to the tailings storage facility. After 25 years, the recycled water pond is no longer present. At this time the seepage collection ponds would be expanded to maximize evaporation, and then active water management (either enhanced evaporation or treatment prior to release) would take place until the ponds could passively evaporate all incoming seepage. The sludge containing concentrated metals and salts from evaporation would eventually require cleanup and handling as solid or hazardous waste.

Financial Assurance for Closure and Post-closure Activities

Alternative 2 potentially involves long time periods of post-closure monitoring and mitigation related to stormwater or seepage water quality. This raises concern regarding the possibility of Resolution Copper going bankrupt or otherwise abandoning the property after operations have ceased. If this were to happen, the responsibility for these long-term activities would fall to the Forest Service. The Forest Service would need to have financial assurance in place to ensure adequate funds to undertake these activities for long periods of time—for decades or even longer.

The authority and mechanisms for ensuring long-term funding is discussed in section 1.5.5. The types of activities that would likely need to be funded could include the following:

- Active (such as water treatment plant) or passive (such as wetlands) water treatment systems, including design, operational maintenance, and replacement costs
- Treatment and disposal of any sludge generated by water treatment plants, or through passive evaporation
- Monitoring of water quality of seepage and downstream waters
- Maintenance and monitoring of post-closure stormwater control features
- Monitoring the water quality of stormwater runoff associated with the closure cover, to determine ability to release stormwater back to the downstream watershed

Additional financial assurance requirements for long-term maintenance and monitoring are part of the Arizona APP program:

> [T]he applicant or permittee shall demonstrate financial responsibility to cover the estimated costs to close the facility and, if necessary, to conduct postclosure monitoring and maintenance by providing to the director for approval a financial assurance mechanism or combination of mechanisms as prescribed in rules adopted by the director or in 40 Code of Federal Regulations section 264.143 (f)(1) and (10) as of January 1, 2014. (Arizona Revised Statutes 49-243; also see Arizona Administrative Code R18-9-A203 for specific regulations and methods allowed for financial assurance)

The Arizona State Mine Inspector also has authority to require a mine reclamation plan and financial assurance for mine closure (Arizona Administrative Code Title 11, Chapter 2). The regulations for these focus primarily on surface disturbance and revegetation, rather than water quality.

POTENTIAL IMPACTS ON IMPAIRED WATERS

As noted, in the project area Queen Creek is currently considered impaired for copper. The overall estimated current copper loading on this reach of Queen Creek is 0.101 kg/day. The draft TMDL for dissolved copper estimated for this reach of Queen Creek is 0.080 kg/day; this represents the total allowable amount of dissolved copper that would not result in surface water quality standards being exceeded. Note that these calculations include Resolution Copper's current permits for the West Plant Site and East Plant Site, but no discharges from a future tailings facility. ADEQ has identified the need for more than a 20 percent reduction in dissolved copper loading in order for this reach of Queen Creek to not be impaired (Arizona Department of Environmental Quality 2017).

Seepage from Alternative 2 would represent an additional dissolved copper load to Queen Creek of 0.0227 kg/day during operations and 0.0072 kg/day post-closure (see Newell and Garrett (2018d) for calculations of pollutant loading from each alternative). Alternative 2 would increase the dissolved copper load in Queen Creek by 7 to 22 percent and would interfere with efforts to reduce dissolved copper loads to Queen Creek.

PREDICTED REDUCTIONS IN ASSIMILATIVE CAPACITY

The calculated reductions in assimilative capacity are shown in table 3.7.2-12. For Alternative 2, since concentrations for selenium were already predicted to be above the surface water quality standards, by definition no assimilative capacity remains for this pollutant (table 3.7.2-12).

Table 3.7.2-12. Predicted changes in assimilative capacity due to seepage entering surface waters

Alternative	Receiving Water	Remaining Assimilative Capacity After Seepage Enters Surface Water
Alternative 2	Queen Creek at Whitlow Ranch Dam	Selenium (0%); the selenium concentration is above the numeric surface water quality standard
Alternative 3	Queen Creek at Whitlow Ranch Dam	No changes in assimilative capacity greater than 20 percent are anticipated
Alternative 4	Queen Creek at Whitlow Ranch Dam	Selenium (0%); the selenium concentration is above the numeric surface water quality standard
Alternative 5	Gila River below Donnelly Wash	Copper (77%); Selenium (63%)
Alternative 6	Gila River below Dripping Spring Wash	Selenium (67%)

Note: For full calculations, see Newell and Garrett (2018d); this document also contains an assessment of potential changes in assimilative capacity due to reductions in stormwater runoff discussed in section 3.7.3.

Alternative 3 – Near West – Ultrathickened

POTENTIAL WATER QUALITY IMPACTS FROM TAILINGS STORAGE FACILITY

Seepage Controls Incorporated into Design

The various engineered seepage controls assessed in the Alternative 3 design and how they are expected to be applied are shown in table 3.7.2-13. A conceptual diagram of the seepage controls is shown in figure 3.7.2-6. These are almost entirely identical to Alternative 2, except in Alternative 3 a low-permeability layer is used for the entire PAG cell starting with Level 1 controls.

Anticipated Effectiveness of Seepage Controls

As with Alternative 2, total seepage was estimated during the initial design phase using a one-dimensional, unsaturated flow model (Klohn

Table 3.7.2-13. Effectiveness of Alternative 3 engineered seepage controls

Seepage Control Levels and Components	Uncaptured Seepage from Facility	Source
Uncontrolled seepage from tailings facility	728 acre-feet/year	Groenendyk and Bayley (2018b) and Klohn Crippen Berger Ltd. (2018b)
Level 0 (seepage controls for geotechnical stability)		
- Modified centerline cyclone sand embankment - Blanket drain under embankment; finger drains	Not explicitly modeled; incorporated into Level 1 modeling	
Level 0-1		
- Blanket drain extends into facility under NPAG beach; finger drains (blanket/finger drains account for roughly 88% of seepage collected) - Seepage collection ponds with pumpback wells and cut-off walls	116 acre-feet/year	Groenendyk and Bayley (2018a)
Level 1		
- Foundation treatment and selected areas of engineered low-permeability layers, for all areas not Gila Conglomerate - Engineered low-permeability layer for entire PAG facility - Seepage collection ponds with pumpback wells, cut-off walls, and grout curtain to 100-foot depth	Not explicitly modeled; incorporated into Level 4 modeling	N/A
Level 2		
- Grout curtain extended to target high-permeability zones and seepage pathways	Not explicitly modeled; incorporated into Level 4 modeling	N/A
Level 3		
- Add second perimeter of seepage collection ponds downstream	Not explicitly modeled; incorporated into Level 4 modeling	N/A
Level 4 (includes Levels 0 through 4)		
- Add pumpback wells, cut-off walls, and grout curtains to second perimeter of seepage collection ponds - Downgradient grout curtain extending to 100-foot depth - Additional pumpback wells in targeted areas to maximize capture	2.7 acre-feet/year	Groenendyk and Bayley (2019)

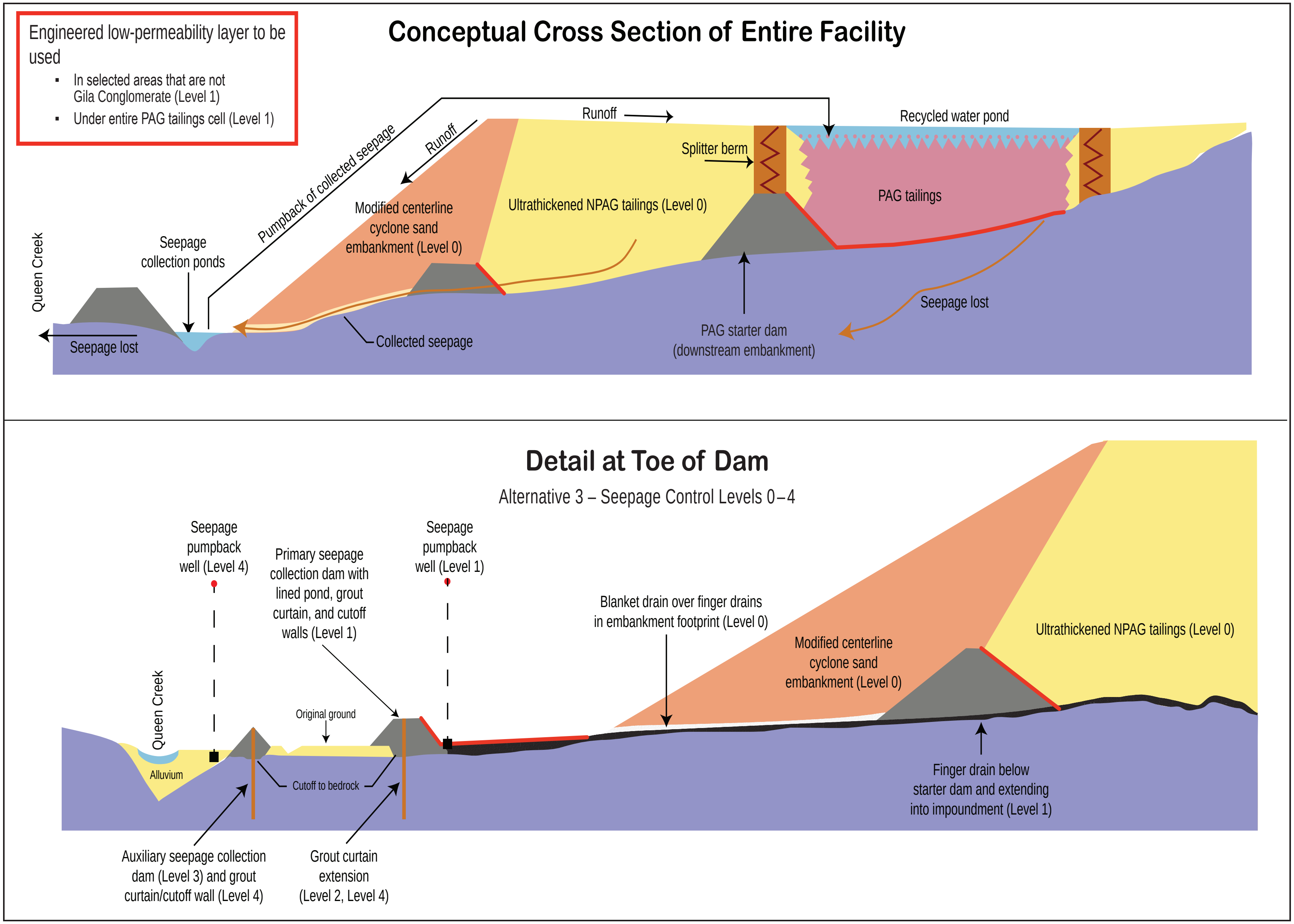

Figure 3.7.2-6. Alternative 3 seepage controls

Crippen Berger Ltd. 2018b), and a three-dimensional groundwater flow model was used to model the amount of total seepage that would be captured by various engineered seepage controls, leaving some amount of lost seepage to enter the environment downgradient (Groenendyk and Bayley 2018b, 2019).

During operations, total seepage created by the tailings was estimated at 728 acre-feet per year (508 and 220 acre-feet per year of NPAG and PAG seepage, respectively) and lost seepage was modeled to be 116 acre-feet per year with Level 1 seepage controls, and 2.7 acre-feet per year with all enhanced engineered seepage controls (Level 4).

Modeling indicates the Level 4 seepage controls would reach a seepage capture efficiency of 99.5 percent. Most of this is captured by blanket and finger drains (88 percent).

Risk of Seepage Impacting Groundwater or Surface Water Quality

Modeled results for groundwater and surface water impacts are reported by Gregory and Bayley (2019). The detailed results of the bypass seepage mixing/loading model were supplied as an Excel spreadsheet, and can be found in Garrett (2019c). Table 3.7.2-14 presents model results for all modeled chemical constituents in the first groundwater cell along Queen Creek (cell QC-3)[53] and the ultimate, final surface water cell (Queen Creek at Whitlow Ranch Dam), for model years 41, 100, and 245. This provides perspective on trends and expected conditions at the end of mining and in the long term. Table 3.7.2-14 also presents Arizona water quality standards and baseline chemistry for added perspective.

Figures M-8 through M-14 in appendix M illustrate model results for the seven constituents of concern.

Modeling results for Alternative 3 indicate the following:

- Modeling estimates that engineered seepage controls can recover 99.5 percent of total seepage. All levels of control (Levels 0 through 4) have been applied to Alternative 3 for the purposes of estimating the effects of tailings seepage on water quality.
- For all constituents, concentrations decrease with distance from the tailings storage facility, but increase over time.
- No chemical constituent are anticipated in concentrations above groundwater or surface water standards.
- Selenium and cadmium are increased slightly above baseline conditions in groundwater and surface water (see appendix M, figures M-10 and M-11).
- The risk of not being able to meet desired seepage capture efficiencies is high. While the determination of whether water quality standards would be met is under the jurisdiction of ADEQ, the disclosure undertaken by the Forest Service suggests that the high capture efficiency required of the engineered seepage controls could make meeting water quality standards under this alternative challenging. The number and types of engineered seepage controls represent significant economic and engineering challenges.

Practicability for Additional Seepage Controls

The assessment of practicability of using a full liner, or adding extra layers of seepage controls during operations, is the same as for Alternative 2.

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[53] Similar to Alternative 2, results are included in the modeling for several washes that would receive lost seepage (Potts and Roblas Canyons), which are upgradient from cell QC-3. It is not likely that substantial groundwater exists in these alluvial channels; these modeled results are indicative of seepage itself, rather than groundwater concentrations expected in the aquifer.

Table 3.7.2-14. Seepage water quality modeling results for Alternative 3 (mg/L)

	Aquifer Water Quality Standard	Baseline Groundwater Quality (Well DS17-17*)	QC-3 Model Cell Year 41	QC-3 Model Cell Year 100	QC-3 Model Cell Year 245	Surface Water Standard for Most Restrictive Use	Baseline Surface Water Quality (Whitlow Ranch Dam*)	Queen Creek at Whitlow Ranch Dam Modeled Surface Water Year 41	Queen Creek at Whitlow Ranch Dam Modeled Surface Water Year 100	Queen Creek at Whitlow Ranch Dam Modeled Surface Water Year 245
Constituents with Numeric Standards										
Antimony	0.006	0.00021	0.00021	0.00021	0.00022	0.030	0.00052	0.00052	0.00052	0.00053
Arsenic	0.05	0.0013	0.0013	0.0013	0.0013	0.030	0.00235	0.0024	0.0024	0.0024
Barium	2	0.0261	0.0261	0.0261	0.0261	98	0.035	0.035	0.035	0.035
Beryllium	0.004	0.00100	0.00100	0.00100	0.00100	0.0053	0.0010	0.0010	0.0010	0.0010
Boron	–	0.069	0.069	0.069	0.069	1	0.057	0.057	0.057	0.057
Cadmium	0.005	0.00004	0.0000	0.0000	0.0001	0.0051	0.00005‡	0.00005‡	0.00005‡	0.00006‡
Chromium, Total	0.1	0.0019	0.0019	0.0019	0.0020	1	0.0015	0.0015	0.0015	0.0015
Copper	–	0.00076	0.001	0.001	0.001	0.0234	0.00230‡	0.0023‡	0.0024‡	0.0024‡
Fluoride	4	0.529	0.53	0.53	0.53	140	0.4	0.41	0.41	0.41
Iron	–	0.045	0.0450	0.0450	0.0450	1	0.048	0.048	0.048	0.048
Lead	0.05	0.000065	0.00007	0.00007	0.00007	0.0083	0.00008‡	0.00008‡	0.00008‡	0.00008‡
Manganese	–	0.0049	0.005	0.005	0.007	10	0.150	0.150	0.150	0.151
Mercury	0.002	N/A	N/A	N/A	N/A	0.00001	N/A	N/A	N/A	N/A
Nickel	0.1	0.0027	0.003	0.003	0.003	0.1343	0.0027‡	0.0027‡	0.0027‡	0.0028‡
Nitrate	10	0.38†	0.38	0.38	0.39	3,733.333	1.90	1.90	1.90	1.90
Nitrite	1	N/A	N/A	N/A	N/A	233.333	N/A	N/A	N/A	N/A
Selenium	0.05	0.0009	0.001	0.001	0.001	0.002	0.0007	0.0007	0.0007	0.0009
Silver	–	0.000036	0.0000	0.0001	0.0001	0.0221	0.000036	0.00004	0.00005	0.00007
Thallium	0.002	0.00003	0.00003	0.00003	0.00004	0.0072	0.000030	0.00003	0.00003	0.00003
Uranium	–	N/A	N/A	N/A	N/A	2.8	N/A	N/A	N/A	N/A
Zinc	–	0.005	0.005	0.006	0.008	0.3031	0.0030‡	0.0030‡	0.0034‡	0.0045‡
pH	–	N/A	N/A	N/A	N/A	6.5–9.0	N/A	N/A	N/A	N/A

continued

Table 3.7.2-14. Seepage water quality modeling results for Alternative 3 (mg/L) *(cont'd)*

	Aquifer Water Quality Standard	Baseline Groundwater Quality (Well DS17-17*)	QC-3 Model Cell Year 41	QC-3 Model Cell Year 100	QC-3 Model Cell Year 245	Surface Water Standard for Most Restrictive Use	Baseline Surface Water Quality (Whitlow Ranch Dam*)	Queen Creek at Whitlow Ranch Dam Modeled Surface Water Year 41	Queen Creek at Whitlow Ranch Dam Modeled Surface Water Year 100	Queen Creek at Whitlow Ranch Dam Modeled Surface Water Year 245
Constituents without Numeric Standards										
Sulfate	–	173	173	174	176	–	136	136	136	138
Total Dissolved Solids	–	589	589	590	594	–	546	546	546	549

Notes: N/A= not analyzed in seepage modeling

Model data are not specific to total or dissolved fractions; for the purposes of comparison to surface water standards it can be assumed to apply to both.

* Results shown represent median values from water quality measurements.

† No available data for well DS17-17. NO_3-N value calculated as median of three samples collected from Bear Tank and Benson Springs between November 2014 and March 2015.

‡ Standards are hardness dependent and were calculated using lowest (most stringent) hardness value recorded for Whitlow Ranch Dam (307 mg/L $CaCO_3$ on 8/25/2017); see appendix N, table N-5, for details on how these standards were selected

RAMIFICATIONS FOR LONG-TERM CLOSURE

Post-closure Water Quality, Seepage Rates, and Closure Timing

Modeling indicates that the concentrations of constituents of concern continue to increase over time, post-closure. In the alternative design, KCB (2018b) estimated that active closure would only be required up to 9 years after the end of operations. At that time, the seepage collection ponds would be expanded to maximize evaporation; passive evaporation of all incoming seepage was anticipated. The sludge of concentrated metals and salts from evaporation would likely eventually require cleanup and handling as solid or hazardous waste.

The final seepage modeling assumes that long-term lost seepage rates would match those during operations (2.7 acre-feet per year), which is much lower than original estimates of long-term recharge through the tailings storage facility caused by infiltration of precipitation (25 acre-feet per year (Gregory and Bayley 2018a)). This suggests that active management may be needed indefinitely post-closure.

Financial Assurance for Closure and Post-closure Activities

The regulatory framework to require financial assurance to ensure closure and post-closure activities are conducted is the same as for Alternative 2.

POTENTIAL IMPACTS ON IMPAIRED WATERS

As noted, in the project area Queen Creek is currently considered impaired for copper. The overall estimated current loading on this reach of Queen Creek is 0.101 kg/day. The draft TMDL for dissolved copper estimated for this reach of Queen Creek is 0.080 kg/day; this represents the total allowable amount of dissolved copper that would not result in surface water quality standards being exceeded. Note that these calculations include Resolution Copper's current permits for the West Plant Site and East Plant Site, but no discharges from a tailings facility. ADEQ has identified the need for more than a 20 percent reduction in dissolved copper loading in order for this reach of Queen Creek to not be impaired (Arizona Department of Environmental Quality 2017).

Seepage from Alternative 3 would represent an additional dissolved copper load to Queen Creek of 0.0018 kg/day during operations and 0.0010 kg/day post-closure (see Newell and Garrett (2018d) for calculations of pollutant loading from each alternative). Alternative 3 would increase the dissolved copper load in Queen Creek by 1 to 2 percent and would minimally interfere with efforts to reduce dissolved copper loads to Queen Creek.

PREDICTED REDUCTIONS IN ASSIMILATIVE CAPACITY

The calculated reductions in assimilative capacity are shown in table 3.7.2-12. For Alternative 3, seepage is not anticipated to use up more than 20 percent of the assimilative capacity in Queen Creek.

Alternative 4 – Silver King

POTENTIAL WATER QUALITY IMPACTS FROM TAILINGS STORAGE FACILITY

Seepage Controls Incorporated into Design

Alternative 4 includes the following seepage controls, similar in nature to those described for Alternative 2. A conceptual diagram of the seepage controls is shown in figure 3.7.2-7. Table 3.7.2-15 summarizes how these are expected to be applied:

- Blanket drains and/or finger drains beneath the embankment and the tailings facility (Level 0).
- Lined collection ditches and five seepage collection ponds downstream of PAG and NPAG facilities designed to cut off the alluvium (Level 1).
- Grouting of fractures in the bedrock foundation, and pumpback wells (Level 2).

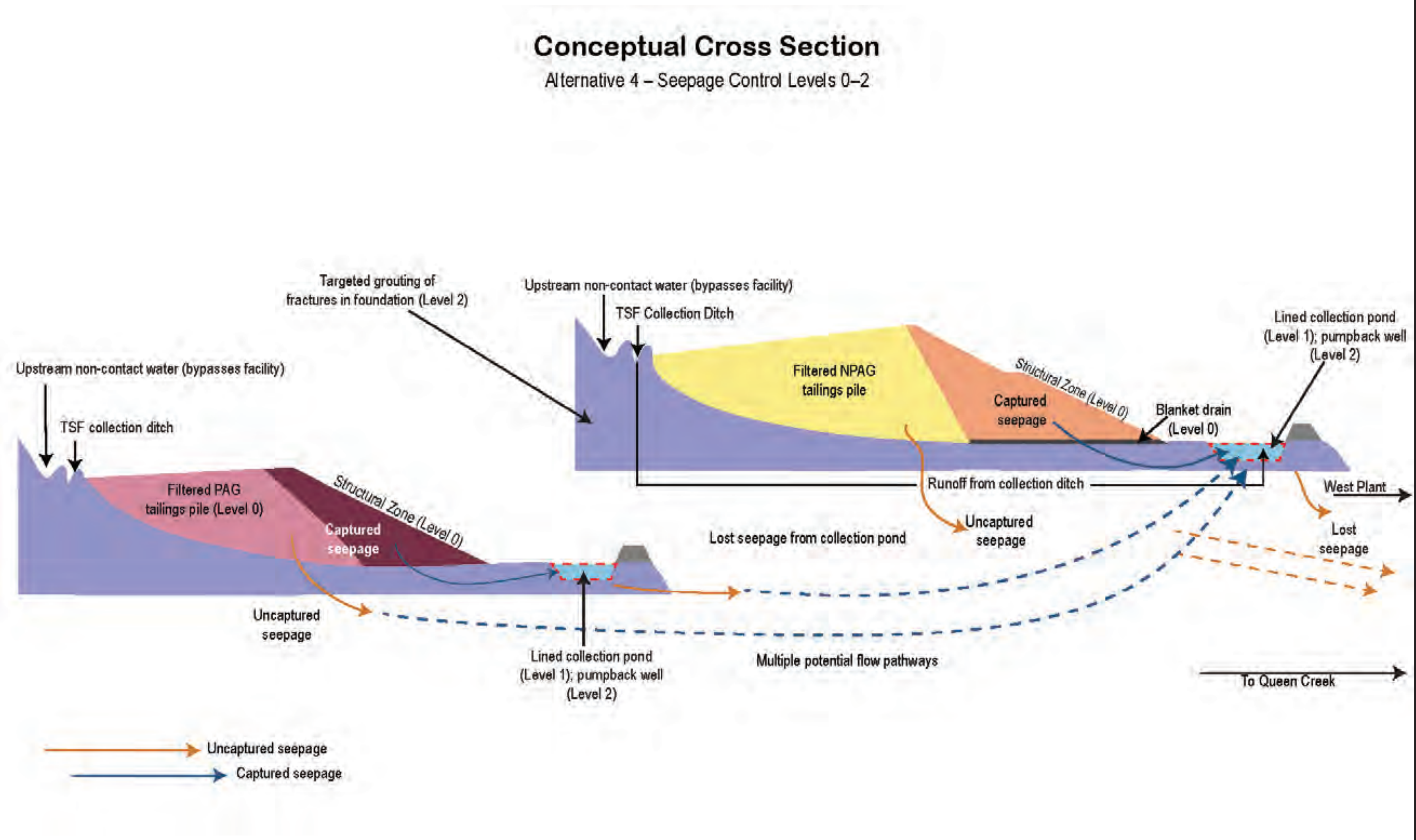

Figure 3.7.2-7. Alternative 4 seepage controls

Table 3.7.2-15. Effectiveness of Alternative 4 engineered seepage controls

Seepage Control Levels and Components	Uncaptured Seepage from Facility	Source
Uncontrolled seepage from tailings facility	79 acre-feet/year	Klohn Crippen Berger Ltd. (2019b)
Level 0 (seepage controls for geotechnical stability)		
- Dewatered (filtered) tailings - Compacted structural zone - Blanket drain under structural zone; finger drains	Not explicitly modeled; incorporated into Level 1 modeling	N/A
Level 1		
- Lined collection ditches and ponds in alluvial channels - Based on professional judgement, estimated to have no greater than 80% efficiency at seepage control	17 acre-feet per year or more	Klohn Crippen Berger Ltd. (2019b)
Level 2		
- Targeted grouting of fractures in foundation - Pumpback wells for seepage return - Based on professional judgment, estimated to have no greater than 90% efficiency at seepage control	9 acre-feet per year or more	Klohn Crippen Berger Ltd. (2019b)

Anticipated Effectiveness of Seepage Controls

For Alternative 4 – Silver King, total seepage was estimated during the initial design phase using a one-dimensional, unsaturated flow model (Klohn Crippen Berger Ltd. 2018c). Unlike Alternatives 2 and 3, there is limited information on the hydrology and geology of the proposed Silver King tailings location and constructing a similar three-dimensional steady-state flow model is not feasible. The efficiency of seepage capture was estimated instead, based on professional judgment of the design engineers and an understanding of the potential flow pathways for seepage. Based on the professional judgement of the design engineers, it is estimated that these seepage controls would capture no more than 80 percent of seepage using Level 1 controls and no more than 90 percent of seepage using Level 2 controls (Klohn Crippen Berger Ltd. 2019b).

During operations, total seepage created by the tailings was estimated at 79 acre-feet per year (77.5 and 1.9 acre-feet per year of NPAG and PAG seepage, respectively) and lost seepage was modeled to be 17 or more acre-feet per year with Level 1 seepage controls, and 9 or more acre-feet per year with all enhanced engineered seepage controls (Level 2).

Risk of Seepage Impacting Groundwater or Surface Water Quality

Modeled results for groundwater and surface water impacts are reported by Gregory and Bayley (2019). The detailed results of the bypass seepage mixing/loading model were supplied as an Excel spreadsheet, and can be found in Garrett (2019c). Table 3.7.2-16 presents model results for all modeled chemical constituents in the first groundwater cell along Queen Creek (cell QC-1)[54] and the ultimate surface water cell (Queen Creek at Whitlow Ranch Dam), for model years 41, 100, and 245. This provides perspective on trends and expected conditions at the end of mining and in the long term. Table 3.7.2-16 also presents Arizona water quality standards and baseline chemistry for added perspective.

Figures M-15 through M-21 in appendix M illustrate model results for the seven constituents of concern.

Modeling results for Alternative 4 indicate the following:

- The model results rely on the 90 percent estimated efficiency of engineered seepage controls, which is not based on technical analysis (unlike Alternatives 2, 3, 5, and 6) but on professional judgment.
- For all constituents, concentrations decrease with distance from the tailings storage facility, but increase over time.
- There are no concentrations above aquifer water quality standards for the first model cell corresponding to groundwater (cell QC-1) or subsequent downgradient cells. Note that although Gregory and Bayley (2019) report that concentrations are above groundwater standards for Alternative 4, their conclusion is based upon the interpretation of first groundwater occurring in the alluvial channels very close to the tailings storage facility. As noted above, it is not likely that groundwater actually occurs until further downgradient, near Queen Creek.
- Concentrations of selenium are above the surface water regulatory standard for the most restrictive use in model years 59 and onward for Queen Creek at Whitlow Ranch Dam (see appendix M, figure M-17), despite incorporation of engineered seepage controls estimated to capture 90 percent of total seepage. No other constituents are modeled to have concentrations above surface water regulatory standards. The model result is above the standard by a very small amount, and the uncertainty in the model does not allow a strict comparison. It can only be concluded that concentrations are expected to be near the standard.

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[54] Results are included in the modeling for several washes that would receive lost seepage (Happy Camp Wash East and West, Silver King Wash, Potts Canyon), which are upgradient from cell QC-1. It is not likely that substantial groundwater exists in these alluvial channels; these modeled results are indicative of seepage itself, rather than groundwater concentrations expected in the aquifer.

Table 3.7.2-16. Seepage water quality modeling results for Alternative 4 (mg/L)

	Aquifer Water Quality Standard	Baseline Groundwater Quality (Well DS17-17*)	QC-3 Model Cell Year 41	QC-3 Model Cell Year 100	QC-3 Model Cell Year 245	Surface Water Standard for Most Restrictive Use	Baseline Surface Water Quality (Whitlow Ranch Dam*)	Queen Creek at Whitlow Ranch Dam Modeled Surface Water Year 41	Queen Creek at Whitlow Ranch Dam Modeled Surface Water Year 100	Queen Creek at Whitlow Ranch Dam Modeled Surface Water Year 245
Constituents with Numeric Standards										
Antimony	0.006	0.00021	0.00022	0.00052	0.00074	0.030	0.00052	0.00052	0.00068	0.00080
Arsenic	0.05	0.0013	0.0013	0.0016	0.0018	0.030	0.00235	0.0024	0.0025	0.0026
Barium	2	0.0261	0.0263	0.0263	0.0264	98	0.0350	0.035	0.035	0.035
Beryllium	0.004	0.00100	0.00102	0.00102	0.00104	0.0053	0.0010	0.0010	0.0010	0.0010
Boron	–	0.069	0.069	0.082	0.091	1	0.057	0.057	0.064	0.069
Cadmium	0.005	0.00004	0.0000	0.0003	0.0004	0.0051	0.00005[‡]	0.00005[‡]	0.00016[‡]	0.00023[‡]
Chromium, Total	0.1	0.0019	0.0019	0.0026	0.0030	1	0.0015	0.0015	0.0019	0.0021
Copper	–	0.00076	0.003	0.004	0.006	0.0234	0.00230[‡]	0.0035[‡]	0.0038[‡]	0.0049[‡]
Fluoride	4	0.529	0.53	0.56	0.58	140	0.4	0.41	0.42	0.43
Iron	–	0.045	0.0450	0.0450	0.0450	1	0.048	0.048	0.048	0.048
Lead	0.05	0.000065	0.00007	0.00012	0.00015	0.0083	0.00008[‡]	0.00008[‡]	0.00010[‡]	0.00012[‡]
Manganese	–	0.0049	0.010	0.060	0.088	10	0.150	0.153	0.178	0.194
Mercury	0.002	N/A	N/A	N/A	N/A	0.00001	N/A	N/A	N/A	N/A
Nickel	0.1	0.0027	0.004	0.007	0.009	0.1343	0.0027[‡]	0.0031[‡]	0.0047[‡]	0.0060[‡]
Nitrate	10	0.38[†]	0.40	0.40	0.42	3,733.333	1.90	1.91	1.91	1.92
Nitrite	1	N/A	N/A	N/A	N/A	233.333	N/A	N/A	N/A	N/A
Selenium	0.05	0.0009	0.001	0.006	0.008	0.002	0.0007	0.0007	**0.0031**	**0.0046**
Silver	–	0.000036	0.0000	0.0009	0.0014	0.0221	0.000036	0.00004	0.0005	0.00074
Thallium	0.002	0.00003	0.00003	0.00009	0.00012	0.0072	0.000030	0.00003	0.00006	0.00008
Uranium	–	N/A	N/A	N/A	N/A	2.8	N/A	N/A	N/A	N/A
Zinc	–	0.005	0.006	0.053	0.081	0.3031	0.0030[‡]	0.0036[‡]	0.0281[‡]	0.0428[‡]
pH	–	N/A	N/A	N/A	N/A	6.5–9.0	N/A	N/A	N/A	N/A

continued

Table 3.7.2-16. Seepage water quality modeling results for Alternative 4 (mg/L) *(cont'd)*

	Aquifer Water Quality Standard	Baseline Groundwater Quality (Well DS17-17*)	QC-3 Model Cell Year 41	QC-3 Model Cell Year 100	QC-3 Model Cell Year 245	Surface Water Standard for Most Restrictive Use	Baseline Surface Water Quality (Whitlow Ranch Dam*)	Queen Creek at Whitlow Ranch Dam Modeled Surface Water Year 41	Queen Creek at Whitlow Ranch Dam Modeled Surface Water Year 100	Queen Creek at Whitlow Ranch Dam Modeled Surface Water Year 245
Constituents without Numeric Standards										
Sulfate	–	173	175	212	241	–	136	137	156	172
Total Dissolved Solids	–	589	592	647	688	–	546	547	576	598

Notes: N/A= not analyzed in seepage modeling

Shaded cell and bolded text indicate concentrations above water quality standard.

Model data are not specific to total or dissolved fractions; for the purposes of comparison to surface water standards it can be assumed to apply to both.

* Results shown represent median values from water quality measurements.

† No available data for well DS17-17. NO_3-N value calculated as median of three samples collected from Bear Tank and Benson Springs between November 2014 and March 2015.

‡ Standards are hardness dependent and were calculated using lowest (most stringent) hardness value recorded for Whitlow Ranch Dam (307 mg/L $CaCO_3$ on 8/25/2017); see appendix N, table N-5, for details on how these standards were selected.

- Sulfate and total dissolved solids are significant constituents in tailings seepage and can alter the potential use of downstream water resources, but do not have numeric standards. Over time, sulfate concentrations in groundwater closest to the tailings storage facility are expected to rise slightly above the 250 mg/L secondary standard, to 284 mg/L (see appendix M, figure M-15).
- Most constituents increase in concentration in groundwater and surface water above existing baseline conditions.
- Of all the alternatives, Alternative 4 is the only one where seepage control effectiveness was not able to be modeled; instead this alternative relies on professional engineering judgment for the effectiveness of the seepage controls. Additional controls could be needed; the practicability of this is described in the following section.

Practicability for Additional Seepage Controls

The amount of seepage without engineered controls is considerably less for Alternative 4, compared with the other alternatives, with only 79 acre-feet per year. The estimated loss through a full liner is about 550 acre-feet per year for a 2,300-acre facility. This estimate is specifically for a geomembrane as specified under Arizona BADCT; composite liners are able to reach better performance, but there are substantial logistical concerns about the ability to successfully install a full liner of any kind, and the terrain at Alternative 4 was specifically considered for feasibility (see Newell and Garrett (2018d) for a summary of concerns).

Unlike Alternatives 2 and 3, Alternative 4 has more ability to add further layers of seepage control during operations. For instance, there is room to install additional downstream seepage collection ponds with cut-off walls and pumpback wells, in Silver King Wash and Happy Camp Wash. The greater distance downstream to Queen Creek allows more flexibility during operations for this location, compared with Alternatives 2 and 3.

RAMIFICATIONS FOR LONG-TERM CLOSURE

Post-closure Water Quality, Seepage Rates, and Closure Timing

Modeling indicates that the concentrations of constituents of concern continue to increase over time, post-closure. Post-closure seepage rates are estimated as 15.2 to 31.9 acre-feet per year (Wickham 2018).

In the alternative design, Klohn Crippen Berger Ltd. (2018c) estimated that active closure would be required for 5 years after the end of operations. During this time, reclamation of the exposed tailings would be in progress, and the need to retain stormwater in the collection ponds requires more capacity than the collection ponds can passively evaporate and may require active treatment. Once stormwater can again be released downstream, after the tailings surface has been reclaimed with a stable closure cover, the collection ponds would be able to passively evaporate collected water. The sludge of concentrated metals and salts from evaporation would likely eventually require cleanup and handling as solid or hazardous waste.

Financial Assurance for Closure and Post-closure Activities

The regulatory framework to require financial assurance to ensure closure and post-closure activities are conducted is the same as for Alternatives 2 and 3.

POTENTIAL IMPACTS ON IMPAIRED WATERS

As noted, in the project area Queen Creek is currently considered impaired for copper. The overall estimated current loading on this reach of Queen Creek is 0.101 kg/day. The draft TMDL for dissolved copper estimated for this reach of Queen Creek is 0.080 kg/day; this represents the total allowable amount of dissolved copper that would not result in surface water quality standards being exceeded. Note that these calculations include Resolution Copper's current permits for the West Plant Site and East Plant Site, but no discharges from a tailings facility.

ADEQ has identified the need for more than a 20 percent reduction in dissolved copper loading in order for this reach of Queen Creek to not be impaired (Arizona Department of Environmental Quality 2017).

Seepage from Alternative 4 would represent an additional dissolved copper load to Queen Creek of 0.0116 kg/day during operations and 0.0217 kg/day post-closure (see Newell and Garrett (2018d) for calculations of pollutant loading from each alternative). Alternative 4 would increase the dissolved copper load in Queen Creek by 11 to 21 percent and would interfere with efforts to reduce dissolved copper loads to Queen Creek.

PREDICTED REDUCTIONS IN ASSIMILATIVE CAPACITY

The calculated reductions in assimilative capacity are shown in Table 3.7.2-12. For Alternative 4, since concentrations for selenium were already predicted to be above the surface water quality standards, by definition no assimilative capacity remains for this pollutant.

Alternative 5 – Peg Leg

POTENTIAL WATER QUALITY IMPACTS FROM TAILINGS STORAGE FACILITY

Seepage Controls Incorporated into Design

Alternative 5 includes the following seepage controls, similar in nature to those described for Alternative 2. A conceptual diagram of the seepage controls is shown in figure 3.7.2-8. Table 3.7.2-17 summarizes how these are expected to be applied:

- Blanket drains beneath the embankment (Level 0)
- Lined collection ditches and six seepage collection ponds (Level 1)
- A geomembrane (HDPE) over 300 acres where the initial recycled water pond would be, in order to maintain operational control of tailings deposition (Level 1)
- An engineered low-permeability layer under the entire separate PAG cell (Level 1); under Level 2 controls this would be upgraded to a full synthetic liner and additional foundation preparation to remove material down to bedrock
- A pumpback well system (Level 1)
- Use of thin-lift deposition in Year 7 once adequate room becomes available (Level 2)

Anticipated Effectiveness of Seepage Controls

For Alternative 5, total seepage estimates are based on an “Order of Magnitude” water balance estimated using a two-dimensional finite element model (SLIDE V7.0) (Golder Associates Inc. 2018a).

The amount of lost seepage for Alternative 5 is calculated in a different manner than other alternatives. Much of the foundation consists of a deep alluvial aquifer associated with Donnelly Wash, which results in substantial seepage losses even with engineered seepage controls built into the facility. Therefore, a downstream pumpback system is a key component of the engineered seepage controls. The amount of flow the alluvial aquifer is able to handle was estimated and a downstream pumpback well system is expected to remove enough water to maintain the aquifer at equilibrium.

During operations, total seepage created by the tailings was estimated at 3,930 acre-feet per year (2,660 and 1,270 acre-feet per year of NPAG and PAG seepage, respectively) and lost seepage was modeled to be 1,317 acre-feet per year with Level 1 seepage controls, and 261 acre-feet per year with all enhanced engineered seepage controls (Level 2).

Modeling indicates the Level 2 seepage controls would reach a seepage capture efficiency of 84 percent of the seepage. It is important to note that the pumpback well system is adjusted under Level 2 and pumpage is reduced to only what is needed to control water quality; substantial additional pumping could be undertaken if needed at this location.

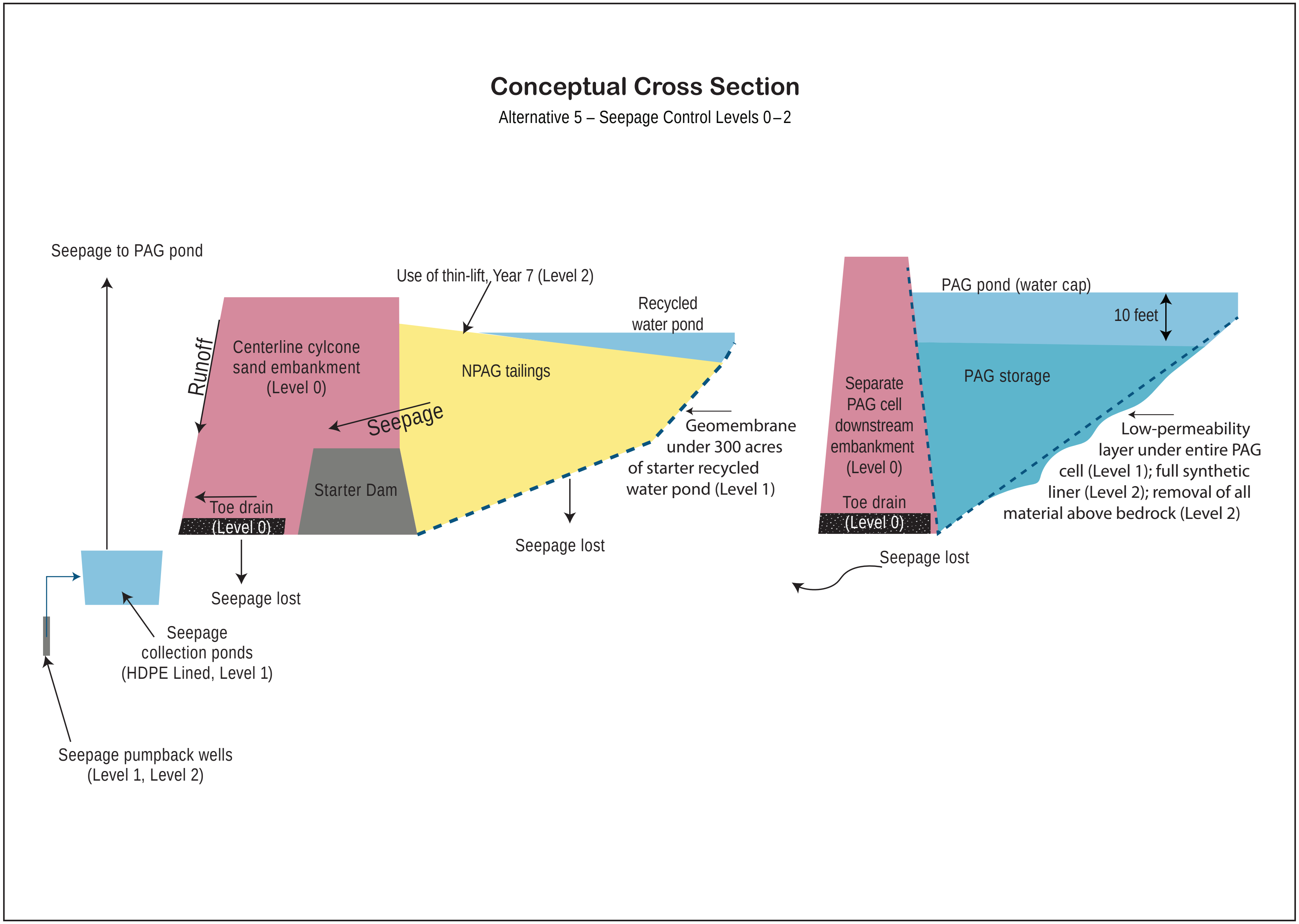


Figure 3.7.2-8. Alternative 5 seepage controls

Table 3.7.2-17. Effectiveness of Alternative 5 engineered seepage controls

Seepage Control Levels and Components	Uncaptured Seepage from Facility	Source
Uncontrolled seepage from tailings facility	3,930 acre-feet/year	Klohn Crippen Berger Ltd. (2019d)
Level 0 (seepage controls for geotechnical stability)		
- Centerline cyclone sand embankment - Blanket drain under embankment - Separate PAG and NPAG cells	Not explicitly modeled; incorporated into Level 1 modeling	N/A
Level 1		
- Lined seepage collection ditches and ponds - Finger drains under facility along natural drainages - 300 acres of geomembrane (HDPE) underneath recycled water pond - Engineered low-permeability layer under entire PAG cell - Pumpback well system to control downgradient flow	1,317 acre-feet per year	Klohn Crippen Berger Ltd. (2019d)
Level 2		
- Full synthetic liner below entire PAG cell - Removal of all material above bedrock below PAG cell - Thin-lift deposition to start in year 7 (requires sufficient room) - Adjustment to pumpback well system, reducing pumping to just amount necessary to control water quality	261 acre-feet per year	Kidner and Pilz (2019) and Klohn Crippen Berger Ltd. (2019d)

Table 3.7.2-18. Seepage water quality modeling results for Alternative 5 (mg/L)

	Aquifer Water Quality Standard	Baseline Groundwater Quality (Tea Cup Well*)	DW-2 Model Cell Year 41	DW-2 Model Cell Year 100	DW-2 Model Cell Year 245	Surface Water Standard for Most Restrictive Use	Baseline Surface Water Quality (Gila River below Donnelly Wash**)	Gila River below Donnelly Wash Modeled Surface Water Year 41	Gila River below Donnelly Wash Modeled Surface Water Year 100	Gila River below Donnelly Wash Modeled Surface Water Year 245
Constituents with Numeric Standards										
Antimony	0.006	0.00003	0.00003	0.00044	0.00214	0.030	0.00023	0.00023	0.00023	0.00025
Arsenic	0.05	0.0021	0.0021	0.0022	0.0032	0.030	0.00889	0.0089	0.0089	0.0089
Barium	2	0.0428	0.0428	0.0442	0.0483	98	0.0826	0.083	0.083	0.083
Beryllium	0.004	0.0010	0.00100	0.00104	0.00202	0.0053	0.0017	0.0017	0.0017	0.0017
Boron	–	0.082	0.082	0.112	0.205	1	0.190	0.190	0.190	0.191
Cadmium	0.005	0.00004	0.0000	0.0006	0.0026	0.0049	0.00006[‡]	0.00006[‡]	0.00006[‡]	0.00009[‡]
Chromium, Total	0.1	0.0019	0.0019	0.0050	0.0137	1	0.0020	0.0020	0.0020	0.0021
Copper	–	0.00330	0.003	0.034	1.035	0.0222	0.00408[‡]	0.0041[‡]	0.0041[‡]	0.0099[‡]
Fluoride	4	0.68	0.68	0.90	1.71	140	0.987	0.99	0.99	1.00
Iron	–	0.045	0.0450	0.0452	0.0470	1	0.056	0.056	0.056	0.056
Lead	0.05	0.002630	0.00263	0.00274	0.00321	0.0078	0.00015[‡]	0.00015[‡]	0.00015[‡]	0.00016[‡]
Manganese	–	0.0049	0.005	0.075	0.580	10	0.028	0.028	0.028	0.033
Mercury	0.002	N/A	N/A	N/A	N/A	0.00001	N/A	N/A	N/A	N/A
Nickel	0.1	0.0027	0.003	0.012	0.085	0.1280	0.0023[‡]	0.0023[‡]	0.0023[‡]	0.0030[‡]
Nitrate	10	**15.20**[†]	**15.26**	**15.53**	**16.34**	3,733.333	0.091	0.09	0.09	0.11
Nitrite	1	N/A	N/A	N/A	N/A	233.333	N/A	N/A	N/A	N/A
Selenium	0.05	0.0011	0.001	0.013	0.050	0.002	0.0004	0.0004	0.0004	0.0010
Silver	–	0.000036	0.0000	0.0026	0.0100	0.0201	0.000061	0.00006	0.00006	0.00018
Thallium	0.002	0.00003	0.00003	0.00024	0.00073	0.0072	0.000080	0.00008	0.00008	0.00009
Uranium	–	N/A	N/A	N/A	N/A	2.8	N/A	N/A	N/A	N/A
Zinc	–	0.016	0.016	0.132	0.560	0.2888	0.0050[‡]	0.0050[‡]	0.0050[‡]	0.0109[‡]
pH	–	N/A	N/A	N/A	N/A	6.5–9.0	N/A	N/A	N/A	N/A

continued

Table 3.7.2-18. Seepage water quality modeling results for Alternative 5 (mg/L) *(cont'd)*

	Aquifer Water Quality Standard	Baseline Groundwater Quality (Tea Cup Well*)	DW-2 Model Cell Year 41	DW-2 Model Cell Year 100	DW-2 Model Cell Year 245	Surface Water Standard for Most Restrictive Use	Baseline Surface Water Quality (Gila River below Donnelly Wash**)	Gila River below Donnelly Wash Modeled Surface Water Year 41	Gila River below Donnelly Wash Modeled Surface Water Year 100	Gila River below Donnelly Wash Modeled Surface Water Year 245
Constituents without Numeric Standards										
Sulfate	–	59	59	138	594	–	159	159	159	164
Total Dissolved Solids	–	523	523	648	1,338	–	776	776	776	783

Notes: N/A= not analyzed in seepage modeling

Shaded cell and bolded text indicate concentrations above water quality standard.

Model data are not specific to total or dissolved fractions; for the purposes of comparison to surface water standards it can be assumed to apply to both.

* Assumed concentrations are based on single sample collected on 27 September 2017 and are therefore approximate.

** Assumed concentrations are based on single sample collected on 13 November 2018 and are therefore approximate.

† NO_3-N concentration shown is above its standard; additional water quality monitoring is required to determine if value is representative of aquifer water quality or due to localized contamination

‡ Standards are hardness dependent and were calculated using a hardness value of 290 mg/L $CaCO_3$ (from sample collected on 13 November 2018); see appendix N, table N-5 for details on how these standards were selected

Risk of Seepage Impacting Groundwater or Surface Water Quality

Modeled results for groundwater and surface water impacts are reported by Gregory and Bayley (2019). The detailed results of the bypass seepage mixing/loading model were supplied as an Excel spreadsheet, and can be found in Garrett (2019c). Table 3.7.2-18 presents model results for all modeled chemical constituents for cells in the first groundwater cell along Donnelly Wash (cell DW-2) and the ultimate surface water cell (Gila River below Donnelly Wash), for model years 41, 100, and 245. This provides perspective on trends and expected conditions at the end of mining and in the long term. Table 3.7.2-18 also presents Arizona water quality standards and baseline chemistry for added perspective.

Figures M-22 through M-28 in appendix M illustrate model results for the seven constituents of concern.

Modeling results for Alternative 5 indicate the following:

- Modeling estimates that engineered seepage controls can recover 84 percent of total seepage. All levels of control (Levels 0 through 2) have been applied to Alternative 5 for the purposes of estimating the effects of tailings seepage on water quality.
- For all constituents, concentrations decrease with distance from the tailings storage facility, but increase over time.
- No chemical constituent are anticipated in concentrations above groundwater or surface water standards. Nitrate is present in concentrations above aquifer water quality standards, but this is due to background nitrate concentrations and not seepage from the facility. Note also that in year 245, selenium just reaches the aquifer water quality standard but is not above it.
- Sulfate and total dissolved solids are significant constituents in tailings seepage and can alter the potential use of downstream water resources, but do not have numeric standards. Over time, sulfate concentrations in groundwater closest to the tailings storage facility are expected to rise substantially above the 250 mg/L secondary standard to 594 mg/L (see appendix M, figure M-22).
- Most constituents increase in concentration in groundwater and surface water above existing baseline conditions.
- The practicability of adding seepage controls during operations is assessed in the following section.

Practicability for Additional Seepage Controls

The site-specific suite of engineered seepage controls designed for Alternative 5 is substantially more effective at controlling seepage than a fully lined facility with no other controls. The estimated loss through a full liner is about 1,400 acre-feet per year for a 5,900-acre facility (see Rowe (2012) and Newell and Garrett (2018d) for details of this estimate). This estimate is specifically for an engineered low-permeability liner as specified under Arizona BADCT; composite liners are able to reach better performance, but there are substantial logistical concerns about the ability to successfully install a full liner of any kind (see Newell and Garrett (2018d) for a summary of concerns).

Under the suite of engineered seepage controls considered (Levels 0 through 2), the entire PAG cell and about 300 acres of the NPAG facility would already use low-permeability layers which have similar permeabilities to the Arizona BADCT specifications. The comparison with a full liner illustrates the need for layered seepage controls, particularly downstream seepage collection dams and pumpback wells, to control seepage that would be generated from within the facility regardless of the foundation treatment.

Alternative 5 has substantial flexibility for adding other layers of seepage controls during operation as needed. The pumpback system for Level 2 seepage controls is not assumed to be operating at full capacity, and this would be an efficient way of increasing seepage capture as needed. The distance downstream to the Gila River offers opportunities for modified or expanded pumpback systems or physical barriers (grout curtains).

RAMIFICATIONS FOR LONG-TERM CLOSURE

Post-closure Water Quality, Seepage Rates, and Closure Timing

Modeling indicates that the concentrations of constituents of concern continue to increase over time, post-closure. Post-closure seepage rates are estimated to be 261 acre-feet per year (Kidner and Pilz 2019).

In the alternative design, Kidner and Pilz (2019) estimated during closure the facility would gradually drain down. The seepage collection ponds would remain in place and passively evaporate seepage, and the seepage extraction wells downstream would remain in place to control seepage as long as necessary. This time frame is estimated from 100 to 150 years (Kidner and Pilz 2019). Once the collection ponds can be closed, the closure plans call for encapsulating the accumulated sludge in the geomembrane and backfilling with soil to grade.

Financial Assurance for Closure and Post-closure Activities

The regulatory framework under the State of Arizona to require financial assurance for long-term closure activities is the same as described for Alternative 2. However, for the tailings facility, financial assurance requirements would be required by BLM, not the Forest Service.

Like the Forest Service, BLM also has regulatory authority to require financial assurance for closure activities, contained in their surface management regulations (43 CFR Subpart 3809). BLM considers that the financial assurance must cover the estimated cost as if BLM were hiring a third-party contractor to perform reclamation of an operation after the mine has been abandoned. The financial assurance must include construction and maintenance costs for any treatment facilities necessary to meet Federal and State environmental standards.

POTENTIAL IMPACTS ON IMPAIRED WATERS

Any discharges from Alternative 5 are downstream of any impaired waters.

PREDICTED REDUCTIONS IN ASSIMILATIVE CAPACITY

The calculated reductions in assimilative capacity are shown in table 3.7.2-12. For Alternative 5, the discharge of seepage into the Gila River uses more than 20 percent of the assimilative capacity for copper and selenium.

Alternative 6 – Skunk Camp

POTENTIAL WATER QUALITY IMPACTS FROM TAILINGS STORAGE FACILITY

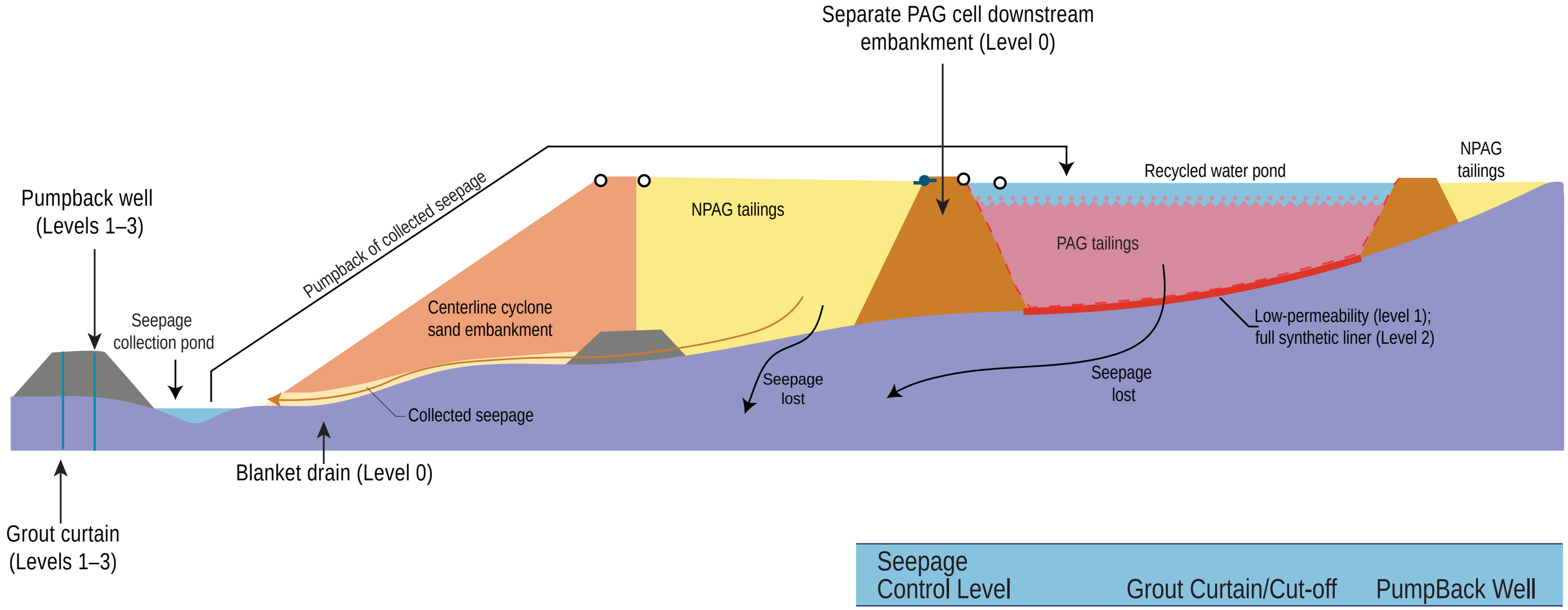
Seepage Controls Incorporated into Design

Alternative 6 includes the following seepage controls, similar in nature to those described for Alternative 2. A conceptual diagram of the seepage controls is shown in figure 3.7.2-9. Table 3.7.2-19 summarizes how these are expected to be applied:

- Blanket drains beneath the embankment (Level 0), extending farther under the facility under Level 1 controls.
- A low-permeability layer under the entire separate PAG cell (Level 1).
- A single downstream seepage collection pond with grout curtains and a pumpback well system (Level 1). Under Level 2 the grout curtain and wells are deepened, and then under Level 3 they are deepened again.

Anticipated Effectiveness of Seepage Controls

For Alternative 6, total seepage estimates are based on two-dimensional steady-state finite element model (SEEP/W) (Klohn Crippen Berger Ltd. 2019c). The amount of lost seepage for Alternative 6 is estimated in two ways, both derived from the two-dimensional model. One estimate of lost seepage is the difference between the modeled seepage from the NPAG and PAG facilities, minus the amount of seepage modeled to be collected in the downstream seepage collection pond. A second estimate



Conceptual Cross Section of Entire Facility

Alternative 6 – Seepage Control Levels 0–3

Seepage Control Level	Grout Curtain/Cut-off	PumpBack Well
1	Depth of 70 feet	Depth of 20 feet
2	Depth of 100 feet	Depth of 70 feet
3	Depth of 100 feet	Depth of 100 feet

Figure 3.7.2-9. Alternative 6 seepage controls

Table 3.7.2-19. Effectiveness of Alternative 6 engineered seepage controls

Seepage Control Levels and Components	Uncaptured Seepage from Facility	Source
Uncontrolled seepage from tailings facility	1,870 acre-feet/year	Klohn Crippen Berger Ltd. (2019c)
Level 0 (seepage controls for geotechnical stability)		
- Centerline cyclone sand embankment - Blanket drain under embankment - Separate PAG and NPAG cells	Not explicitly modeled; incorporated into Level 1 modeling	N/A
Level 1		
- Blanket drain extends 100–200 feet underneath impoundment - Engineered low-permeability layer under entire PAG cell - Seepage collection ponds, with cut-offs, grout curtains, and pumpback wells; grout curtains extend to 70 feet (estimated base of alluvium); pumpback wells extend to 20 feet	580 to 660 acre-feet per year	Klohn Crippen Berger Ltd. (2019c)
Level 2		
- Grout curtains extended to 100 feet (estimated base of Gila Conglomerate); pumpback wells extend to 70 feet	270 to 370 acre-feet per year	Klohn Crippen Berger Ltd. (2019c)
Level 3		
- Pumpback wells extend to 100 feet	70 to 180 acre-feet per year	Klohn Crippen Berger Ltd. (2019c)

is derived directly from the modeled flux of water downstream of the seepage collection pond.

During operations, total seepage created by the tailings was estimated at 1,870 acre-feet per year (1,820 and 50 acre-feet per year of NPAG and PAG seepage, respectively) and lost seepage was modeled to be 580 to 660 acre-feet per year with Level 1 seepage controls, 270 to 370 acre-feet per year with Level 2 enhancements to the grout curtains and wells, and 200 to 260 acre-feet per year with all Level 3 enhancements.

Risk of Seepage Impacting Groundwater or Surface Water Quality

Modeled results for groundwater and surface water impacts are reported by Gregory and Bayley (2019). The detailed results of the bypass seepage mixing/loading model were supplied as an Excel spreadsheet and can be found in Garrett (2019c). Table 3.7.2-20 presents model results for all modeled chemical constituents in the first groundwater cell (cell DS-1) and the ultimate surface water cell (Gila River below Dripping Spring Wash), for model years 41, 100, and 245. This provides perspective on trends and expected conditions at the end of mining and in the long term. Table 3.7.2-20 also presents Arizona water quality standards and baseline chemistry for added perspective.

Figures M-29 through M-35 in appendix M illustrate model results for the seven constituents of concern.

Modeling results for Alternative 6 indicate the following:

- Modeling estimates that engineered seepage controls can recover 90 percent of total seepage. All levels of control (Levels 0 through 3) have been applied to Alternative 6 for the purposes of estimating the effects of tailings seepage on water quality.
- For all constituents, concentrations decrease with distance from the tailings storage facility, but increase over time.
- No chemical constituents are anticipated in concentrations above groundwater or surface water standards.
- Sulfate and total dissolved solids are significant constituents in tailings seepage and can alter the potential use of downstream water resources, but do not have numeric standards. Over time, sulfate concentrations in groundwater closest to the tailings storage facility are expected to rise slightly above the 250 mg/L secondary standard, to 385 mg/L (see appendix M, figure M-29).
- Most constituents increase in concentration in groundwater and surface water above existing baseline conditions.
- The practicability of adding seepage controls during operations is assessed in the following section. Resolution Copper is currently conducting further investigation at the site; this would inform the design of further controls. This investigation currently includes 17 test pits or drill holes, with an additional 15 possible locations within the tailings footprint.

Practicability for Additional Seepage Controls

The site-specific suite of engineered seepage controls designed for Alternative 6 is substantially more effective at controlling seepage than a fully lined facility with no other controls. The estimated loss through a full liner is about 960 acre-feet per year for a 4,000-acre facility (see Rowe (2012) and Newell and Garrett (2018d) for details of this estimate). This estimate is specifically for an engineered low-permeability liner as specified under Arizona BADCT; composite liners are able to reach better performance, but there are substantial logistical concerns about the ability to successfully install a full liner of any kind (see Newell and Garrett (2018d) for a summary of concerns).

Under the suite of engineered seepage controls considered (Levels 0 through 2), the entire PAG cell would already use low-permeability layers which have similar permeabilities to the Arizona BADCT specifications. The comparison to a full liner illustrates the need for layered seepage controls, particularly downstream seepage collection dams and pumpback wells, to control seepage that would be generated from within the facility, regardless of the foundation treatment.

Table 3.7.2-20. Seepage water quality modeling results for Alternative 6 (mg/L)

	Aquifer Water Quality Standard	**Baseline Groundwater Quality (Skunk Camp Well*)**	**DS-1 Model Cell Year 41**	**DS-1 Model Cell Year 100**	**DS-1 Model Cell Year 245**	**Surface Water Standard for Most Restrictive Use**	**Baseline Surface Water Quality (Gila River below Dripping Spring Wash*)**	**Gila River below Dripping Spring Wash Modeled Surface Water Year 41**	**Gila River below Dripping Spring Wash Modeled Surface Water Year 100**	**Gila River below Dripping Spring Wash Modeled Surface Water Year 245**
Constituents with Numeric Standards										
Antimony	0.006	0.00023	0.00091	0.00128	0.00162	0.030	0.00023	0.00024	0.00025	0.00025
Arsenic	0.05	0.0003	0.0003	0.0005	0.0011	0.030	0.00861	0.0086	0.0086	0.0086
Barium	2	0.0038	0.0073	0.0081	0.0078	98	0.0749	0.075	0.075	0.075
Beryllium	0.004	0.0017	0.00171	0.00171	0.00171	0.0053	0.0017	0.0017	0.0017	0.0017
Boron	–	0.026	0.076	0.100	0.109	1	0.196	0.197	0.197	0.197
Cadmium	0.005	0.00006	0.0011	0.0015	0.0014	0.0043	0.00006[†]	0.00008[†]	0.00009[†]	0.00009[†]
Chromium, Total	0.1	0.0020	0.0077	0.0098	0.0087	1	0.0020	0.0021	0.0021	0.0021
Copper	–	0.00165	0.038	0.051	0.044	0.0191	0.00207[†]	0.0026[†]	0.00291	0.0028[†]
Fluoride	4	0.232	0.78	0.96	0.87	140	1.0	1.04	1.04	1.04
Iron	–	0.056	0.0563	0.0564	0.0564	1	0.071	0.071	0.071	0.071
Lead	0.05	0.000140	0.00031	0.00040	0.00045	0.0065	0.00014[†]	0.00014[†]	0.00014[†]	0.00015[†]
Manganese	–	0.0034	0.122	0.170	0.156	10	0.029	0.031	0.032	0.032
Mercury	0.002	N/A	N/A	N/A	N/A	0.00001	N/A	N/A	N/A	N/A
Nickel	0.1	0.0023	0.015	0.020	0.022	0.1098	0.0023[†]	0.0025[†]	0.0026[†]	0.0026[†]
Nitrate	10	1.34	1.82	1.95	1.91	3,733.333	0.305	0.31	0.32	0.31
Nitrite	1	N/A	N/A	N/A	N/A	233.333	N/A	N/A	N/A	N/A
Selenium	0.05	0.0004	0.022	0.030	0.028	0.002	0.0004	0.0007	0.0009	0.0009
Silver	–	0.000061	0.0050	0.0069	0.0059	0.0147	0.000061	0.00014	0.00018	0.00016
Thallium	0.002	0.00008	0.00042	0.00053	0.00047	0.0072	0.000080	0.00009	0.00009	0.00009
Uranium	–	N/A	N/A	N/A	N/A	2.8	N/A	N/A	N/A	N/A
Zinc	–	0.224	0.445	0.538	0.518	0.2477	0.0050[†]	0.0085[†]	0.0103[†]	0.0099[†]
pH	–	N/A	N/A	N/A	N/A	6.5–9.0	N/A	N/A	N/A	N/A

continued

Table 3.7.2-20. Seepage water quality modeling results for Alternative 6 (mg/L) *(cont'd)*

	Aquifer Water Quality Standard	Baseline Groundwater Quality (Skunk Camp Well*)	DS-1 Model Cell Year 41	DS-1 Model Cell Year 100	DS-1 Model Cell Year 245	Surface Water Standard for Most Restrictive Use	Baseline Surface Water Quality (Gila River below Dripping Spring Wash*)	Gila River below Dripping Spring Wash Modeled Surface Water Year 41	Gila River below Dripping Spring Wash Modeled Surface Water Year 100	Gila River below Dripping Spring Wash Modeled Surface Water Year 245
Constituents without Numeric Standards										
Sulfate	–	54	196	365	385	–	100	102	105	105
Total Dissolved Solids	–	327	575	830	846	–	702	706	710	711

Notes: N/A = not analyzed in seepage modeling

Model data are not specific to total or dissolved fractions; for the purposes of comparison to surface water standards it can be assumed to apply to both.

* Assumed concentrations are based on single sample collected on 9 November 2018 and are therefore approximate.

† Standards are hardness dependent and were calculated using a hardness value of 242 mg/L $CaCO_3$ (from sample collected on 9 November 2018); see appendix N, table N-5, for details on how these standards were selected

Like Alternative 5, Alternative 6 has substantial flexibility for adding other layers of seepage controls during operations as needed. The distance downstream to the Gila River offers opportunities for modified or expanded pumpback systems or physical barriers (grout curtains).

RAMIFICATIONS FOR LONG-TERM CLOSURE

Post-closure Water Quality, Seepage Rates, and Closure Timing

Modeling indicates that the concentrations of constituents of concern continues to increase over time, post-closure. Post-closure seepage rates are estimated to be 200 to 260 acre-feet per year (Klohn Crippen Berger Ltd. 2019c). In the alternative design, Klohn Crippen Berger Ltd. (2018d) estimated that active closure would be required up to 20 years after the end of operations. Up to 5 years after closure, the recycled water pond still is present and therefore all engineered seepage controls could remain operational, with seepage pumped back to the tailings storage facility. After 5 years, the recycled water pond is no longer present. At this time the seepage collection ponds would be expanded to maximize evaporation, and then active water management (either enhanced evaporation or treatment for release) would take place until the ponds could passively evaporate all incoming seepage (estimated at 20 years). The sludge of concentrated metals and salts from evaporation would likely eventually require cleanup and handling as solid or hazardous waste.

Financial Assurance for Closure and Post-closure Activities

The regulatory framework under the State of Arizona to require financial assurance for long-term closure activities is the same as described for Alternative 2. However, Alternative 6 differs from the other alternatives because the tailings facility would not be located on lands managed by the Forest Service (Alternatives 2, 3, and 4) or BLM (Alternative 5). For Alternative 6, the Federal financial assurance mechanisms would not be applicable.

POTENTIAL IMPACTS ON IMPAIRED WATERS

As noted, the Gila River between the San Pedro River and Mineral Creek is currently considered impaired for suspended sediment concentrations. Given the stormwater controls put in place during operation and the long-term reclamation after closure, it is unlikely that Alternative 6 would contribute to suspended sediment in the Gila River.

PREDICTED REDUCTIONS IN ASSIMILATIVE CAPACITY

The calculated reductions in assimilative capacity are shown in table 3.7.2-12. For Alternative 6, the discharge of seepage into the Gila River uses more than 20 percent of the assimilative capacity for selenium.

Other Water Quality Concerns

PERSISTENCE OF PROCESSING CHEMICALS IN TAILINGS

In order to extract concentrated copper and molybdenum using flotation, Resolution Copper would add a series of substances or reagents during processing. If these substances were to persist in the processing water, they have the potential to be released to the environment along with seepage from the tailings storage facilities. Six reagents expected to be used in the processing facility were analyzed (Hudson 2018):

- AERO 8989. This substance renders the copper minerals hydrophobic, causing them to attach to air bubbles blown into the flotation tank. The copper-molybdenum concentrate froth then floats to the top of the tank and is skimmed off. The majority of the AERO 8989 exits the process with the copper-molybdenum concentrate. This concentrate gets thickened and separated into copper concentrate and molybdenum concentrate and sent off-site for additional processing. Water recovered from the concentrate thickeners is recycled back to the processing plant. While some small amounts may persist in the tailings stream, there is no pathway for a substantial release of AERO 8989 to the environment.

- Diesel. Diesel acts similarly to AERO 8989 but for molybdenum minerals. Water recovered from the concentrate thickeners is recycled back to the processing plant. As with AERO 8989, while some small amounts may persist in the tailings stream, there is no pathway for a substantial release of diesel to the environment.
- Sodium isopropyl xanthate (SIPX) acts similarly to AERO 8989 and diesel but attaches to pyrite and sulfide minerals and renders them hydrophobic. SIPX is used later in the process, after copper and molybdenum concentrates have been removed, in order to separate the PAG and NPAG tailings streams. The majority of this reagent would enter the tailings storage facility with the PAG tailings stream. Any water recovered in the recycled water pond would potentially contain SIPX and would be recycled back to the processing plant. Some SIPX remains entrained with the PAG tailings and therefore has the potential to contribute to seepage water quality. The breakdown of SIPX yields xanthate and carbon disulfide as two major byproducts. Xanthate decomposes as well as adsorbs; depending on the temperature the half-life can range from less than 1 hour to almost 4 months (Eary 2018h). At the concentrations being considered and the likely temperatures, xanthate is unlikely to survive long enough to be detectable in any lost seepage. Most of the carbon disulfide generated is expected to be volatilized as tailings pass through the spigots and are deposited in the facility; in the atmosphere carbon disulfide decomposes to carbonyl sulfide, carbon monoxide, and sulfur dioxide. The carbon disulfide that remains decomposes with a half-life ranging from roughly 6 months to 1 year. Given that the transit times for seepage to reach aquifers is estimated in the range of decades (Groenendyk and Bayley 2018a), carbon disulfide is unlikely to survive long enough to be detectable in any lost seepage.
- Methyl isobutyl carbinol (MIBC). MIBC is used to lower the surface tension of the water, thus strengthening the air bubbles in the flotation tank. MIBC is used during concentration of copper and molybdenum and during separation of the PAG and NPAG tailings streams. Most MIBC would volatize, and the MIBC that remains degrades relatively quickly, at about 14 percent per day (Hudson 2018). MIBC is unlikely to survive long enough to be detectable in any lost seepage.
- Sodium hydrogen sulfide. This substance is used to separate copper from molybdenum concentrate by causing copper minerals to sink, while molybdenum concentrate remains in flotation. Water recovered from the concentrate thickeners is recycled back to the processing plant. There is no pathway for a substantial release of sodium hydrogen sulfide to the environment.
- Magnafloc 155. This substance is a flocculant, used to cause particles to combine into large groups and therefore settle more readily. This substance would be present in the PAG and NPAG tailings streams and in the copper and molybdenum concentrates. Specific information on the degradation of Magnafloc 155 is lacking. Some evidence exists that exposure to sunlight and physical processing are both likely to cause degradation. The potential for Magnafloc 155 to persist in tailings seepage is unclear, but as the purpose of using Magnafloc is to bind with solid particles it would not be expected to have substantial mobility.

TECHNOLOGICALLY ENHANCED NATURALLY OCCURRING RADIOACTIVE MATERIALS (TENORM)

The potential for the occurrence of natural radioactive materials in the ore deposit, the potential to concentrate those materials during processing, and the potential for these materials to affect tailings seepage were raised as potential concerns for the project. This topic was investigated by Resolution Copper (Duke 2019b), and further analyzed by the Forest Service for the EIS. Full details of the analysis are contained in Newell and Garrett (2018d) and are summarized here.

Radioactive materials such as uranium, thorium, and radium occur naturally in the earth's crust and soil. In some cases, these materials can be concentrated by mining processes, leading to a concern that technologically enhanced naturally occurring radioactive materials (TENORM) could result in water quality concerns in seepage from the tailings storage facility.

The potential for this problem to occur was assessed based on analysis conducted on 5,987 samples of Resolution copper ore from 137 exploration boreholes, master ore composites, laboratory-simulated tailings samples, and background groundwater quality samples. When compared with common background levels, review of existing information at the site does not suggest the strong presence of naturally occurring radioactive materials above typical concentrations, although a small percentage (2 to 6 percent) of samples have exhibited concentrations above thresholds of concern.

Several past examples of TENORM have been documented in the vicinity of the project, including at the Magma Mine, Pinto Valley, and the Ray Mine. However, all of these were associated with acidic leaching and electrowinning. The Resolution Copper Project does not include any heap leaching, solvent extraction-electrowinning, or recycling of raffinate. The processes that historically have been documented with problems would not occur as part of this project.

With respect to the processing (flotation) that would be used during the Resolution Copper Project, site-specific locked cycle testing has simulated the effect of processing to potentially concentrate radioactive materials, and no concentrations are above any thresholds of concern for uranium, radium, and gross alpha activity.

PRESENCE OF ASBESTIFORM MINERALS

Similar to radioactive materials, the potential for asbestiform minerals to occur in the Resolution ore deposit and eventually end up in the tailings facility was raised as a possible concern. Resolution Copper investigated the overall occurrence of these minerals (Duke 2019a).

Asbestos is present in trace to minor amounts in the Resolution ore and development rock as fibrous forms of the amphibole minerals tremolite and actinolite, primarily tremolite. The general threshold for asbestos-containing material is more than 1 percent asbestos as determined by polarized light microscopy (40 CFR 61.141).

Abundances of tremolite and actinolite in the ore body were assessed from 992 samples from 110 exploration boreholes. Tremolite is consistently present (90 percent of samples), with the highest concentrations generally associated with skarn rock units. Abundance ranged from less than 0.01 to 24.24 percent by weight, with a mean of 0.27 percent by weight.

Resolution Copper has conducted two additional targeted studies. In 2006, 34 samples of development rock were submitted for bulk asbestos analysis. Of these, 85 percent of the samples did not contain detectable asbestiform minerals. All samples with detectable asbestiform minerals were associated with skarn rock units. In 2007, 53 samples specific to skarn rock units were submitted for bulk asbestos analysis. Of these, 66 percent of the samples did not contain detectable asbestiform minerals; the remaining abundances ranged from 0.5 to 4.0 percent by weight.

These analyses indicate that asbestiform minerals are present in the ore deposit, but on average the percentage is below the threshold for concern. However, the block caving is not conducted on the ore deposit as a whole, but panel by panel. When viewed on a panel-by-panel basis, overall asbestiform minerals are not anticipated to exceed 0.1 percent by weight.

Cumulative Effects

The Tonto National Forest identified the following reasonably foreseeable future actions as likely, in conjunction with development of the Resolution Copper Mine, to contribute to cumulative impacts on groundwater or surface water quality. As noted in section 3.1, past and present actions are assessed as part of the affected environment; this section analyzes the effects of any RFFAs, to be considered cumulatively along with the affected environment and Resolution Copper Project effects.

- *Ripsey Wash Tailings Project.* Mining company ASARCO is planning to construct a new tailings storage facility to support its Ray Mine operations. The environmental effects of the project were analyzed in an EIS conducted by the USACE and approved in a ROD issued in December 2018. As approved, the proposed tailings storage facility project would occupy an estimated 2,574 acres and be situated in the Ripsey Wash watershed just south of the Gila River approximately 5 miles west-northwest of Kearny, Arizona, and would contain up to approximately 750 million tons of material (tailings and embankment material). ASARCO estimates a construction period of 3 years and approximately 50 years of expansion of the footprint of the tailings storage facility as slurry tailings are added to the facility, followed by a 7- to 10-year period for reclamation and final closure. Results of geochemistry characterization and testing on the proposed tailings and borrow materials reveal a low potential to impact groundwater or surface water with the design and operational safeguards proposed for the facility. Kinetic testing revealed a low potential for any acid generation from tailings materials and confirmed that alluvium materials to be used for construction activities are not acid-generating. The meteoric water mobility testing on both tailings and alluvium material also revealed that possible dissolution and mobilization of minerals from these materials are low. The facility is located close to the Gila River, downstream of Dripping Spring Wash (where Alternative 6 discharges would occur) and upstream of Donnelly Wash (where Alternative 5 discharges would occur). Any pollutant load to the Gila River from the facility, even if within permit limits, would cumulatively affect water quality in the Gila River in combination with Resolution Copper Project impacts for Alternative 5 or 6.
- *Ray Land Exchange and Proposed Plan Amendment.* ASARCO is also seeking to complete a land exchange with the BLM by which the mining company would gain title to approximately 10,976 acres of public lands and federally owned mineral estate located near ASARCO's Ray Mine in exchange for transferring to the BLM approximately 7,304 acres of private lands, primarily in northwestern Arizona. It is known that at some point ASARCO wishes to develop a copper mining operation in the "Copper Butte" area west of the Ray Mine. Specific pollutant discharges are not yet known, but given the location of this future mining activity, any impacts on water quality could potentially be cumulative with Resolution Copper Project–related impacts on the Gila River for Alternatives 5 and 6.
- *Pinto Valley Mine Expansion.* The Pinto Valley Mine is an existing open-pit copper and molybdenum mine located approximately 8 miles west of Miami, Arizona, in Gila County. Pinto Valley Mining Corporation is proposing to expand mining activities onto an estimated 1,011 acres of new disturbance (245 acres on Tonto National Forest land and 766 acres on private land owned by Pinto Valley Mining Corporation) and extend the life of the mine to 2039. The primary concern with regard to water quality centers around the potential for geochemical seepage or runoff from tailings or other mine facilities into groundwater and surface waters within the Pinto Creek watershed. This is in a different watershed from any Resolution Copper Project–related impacts and would not cumulatively affect this resource.

Mitigation Effectiveness

The Forest Service is in the process of developing a robust mitigation plan to avoid, minimize, rectify, reduce, or compensate for resource impacts that have been identified during the process of preparing this EIS. Appendix J contains descriptions of mitigation concepts being considered and known to be effective, as of publication of the DEIS. Appendix J also contains descriptions of monitoring that would be needed to identify potential impacts and mitigation effectiveness. As noted in chapter 2 (section 2.3), the full suite of mitigation would be contained in the FEIS, required by the ROD, and ultimately included in the final GPO approved by the Forest Service. Public comment on the DEIS, and in particular appendix J, will inform the final suite of mitigations.

At this time, no mitigation measures have been identified that would be pertinent to groundwater and surface water quality. Applicant-committed environmental protection measures have already been detailed elsewhere in this section, will be a requirement for the project, and have already been incorporated into the analysis of impacts.

UNAVOIDABLE ADVERSE EFFECTS

The applicant-committed environmental protection measures for stormwater control would effectively eliminate any runoff in contact with ore or tailings. There are no anticipated unavoidable adverse effects associated with the quality of stormwater runoff.

Seepage from the tailings storage facilities has a number of unavoidable adverse effects. In all cases, the tailings seepage adds a pollutant load to the downstream environment, including downstream aquifers and downstream surface waters where groundwater eventually daylights. The overall impact of this seepage varies by alternative. Alternatives 2, 3, and 4 all either have anticipated impacts on water quality or have a high risk to water quality because of the extreme seepage control measures that must be implemented, and the relative inflexibility of adding more measures as needed, given the proximity to Queen Creek.

Alternatives 5 and 6 are located at the head of larger alluvial aquifers with some distance downstream before the first perennial water (the Gila River). Adverse effects are not anticipated from these alternatives, and in addition these locations offer more flexibility in responding to potential problems with additional seepage controls.

Other Required Disclosures

SHORT-TERM USES AND LONG-TERM PRODUCTIVITY

The use of the alternative sites for tailings storage represents a short-term use, with disposal happening over the operational life of the mine. However, the seepage from the tailings facilities would continue for much longer, with potential management anticipated being required over 100 years in some cases. While seepage persists, the long-term productivity of the downstream aquifers and surface waters could be impaired for some alternatives.

Irreversible and Irretrievable Commitment of Resources

The potential impacts on water quality from tailings seepage would cause an irretrievable commitment of water resources downstream of the tailings storage facility, lasting as long as seepage continued. Eventually the seepage amount and pollutant load would decline, and water quality conditions would return to a natural state. This may take over 100 years to achieve in some instances.

While long lived, the impacts on water quality would not be irreversible, and would eventually end as the seepage and pollutant load declined.

3.7.3 Surface Water Quantity

3.7.3.1 Introduction

Perennial streams and springs are relatively rare in the area but do exist (see discussion in Section 3.7.1, Groundwater Quantity and Groundwater-Dependent Ecosystems). For the most part, surface waters in the area consist of dry washes or ephemeral channels that flow only in response to moderate- to high-intensity rainfall events. Water that flows in these washes and streams due to runoff from rainfall events reflects conditions in the upstream watershed—the geographic area that contributes to flow in the stream—and these flows could change if the upstream watershed changes.

The project would cause two major changes to these watersheds. Once the subsidence area develops at the surface, precipitation falling within this area would no longer report to the downstream stream network, potentially reducing runoff reaching both Devil’s Canyon and Queen Creek.

In addition to the loss of runoff from the subsidence area, precipitation falling on or within the tailings storage facility would also be unavailable to downstream washes. All the tailings alternatives are designed to allow any runoff from upstream in the watershed to flow around the facility and continue flowing downstream. However, for the slurry tailings facilities (Alternatives 2, 3, 5, and 6), the top of the tailings facility is managed as a pond to allow process water to be recycled. Any rain falling within the bounds of a slurry facility, including the seepage recovery ponds at the downstream toe of the tailings embankment, is retained and recycled.

Alternative 4 – Silver King is the sole filtered tailings alternative and is different from the slurry alternatives. Filtered tailings must be managed to shed, not retain, water. However, because rain that sheds off the filtered tailings has contacted tailings, it must be collected downstream and not released to the environment during operations. The overall result for the filtered tailings alternative is the same as for the slurry alternatives—less surface water reporting downstream.

This section analyzes the reduction in streamflow caused by each of the alternatives, in terms of both total volume and peak flows during flood events. This section also analyzes the impacts that would be expected on sediment yields and stream geomorphology, impacts on water quality from sediment changes, impacts on jurisdictional waters of the U.S. (related to the CWA Section 404 program), impacts on floodplains, and impacts on wetlands (related to Executive Order 11990). Some aspects of the analysis are briefly summarized in this section. Additional details not included are captured in the project record (Newell and Garrett 2018d).

3.7.3.2 Analysis Methodology, Assumptions, and Uncertain and Unknown Information

Analysis Area

The analysis area for surface water quantity includes the Queen Creek, Devil’s Canyon, Dripping Spring Wash, and Donnelley Wash drainages: all of these watercourses are tributaries of the Gila River. The primary focus of the analysis is on waters downstream of areas that would be directly impacted by the mine, including by the subsidence area. Since the entire watershed affects flow in these areas, the analysis area also includes the larger watershed of these channels, as shown on figure 3.7.3-1. Specific analysis locations used to assess changes in streamflow are also shown on figure 3.7.3-1.

Approach

Two separate modeling approaches were used to assess how the subsidence area and tailings storage facilities would affect runoff. Flood flows are often characterized by the “return period,” i.e., a 2-year or 20-year flood event, which is just another way of expressing the probability of an event occurring. For example, a 2-year event has a 50 percent chance of occurring for any given storm, and a 20-year event has a 5 percent chance of occurring for any given storm. An approach developed by the USGS was used to analyze how reduced watershed

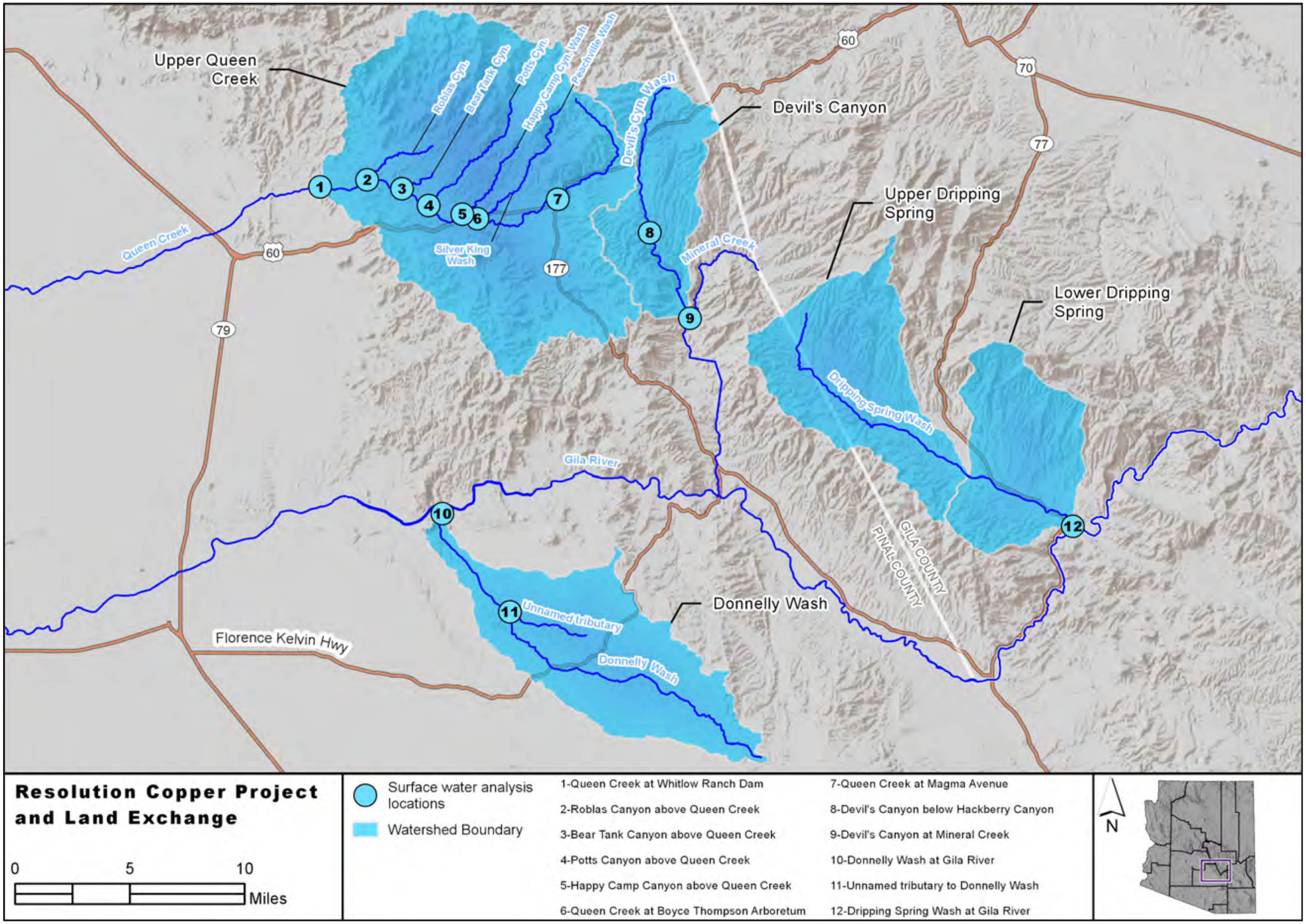


Figure 3.7.3-1. Surface water quantity analysis area

area would affect peak flood flows with different return periods (Lehman 2017, 2018).

In addition to changes to individual flood events, the loss of watershed area also would affect the overall volume of water flowing through a wash and available to wildlife, vegetation, and surface water users. A "monthly water balance" modeling approach was used to assess reductions in the overall volumes of water available to the natural system due to the subsidence area and the tailings storage facilities (BGC Engineering USA Inc. 2018c). Prior to use, the monthly water balance model was first calibrated using data from Pinto Creek. The modelers found Devil's Canyon, Queen Creek, and Dripping Spring Wash watersheds to be similar in nature to Pinto Creek, but note that Donnelly Wash is substantially different (less-steep gradient), which may introduce some uncertainty into the modeling (BGC Engineering USA Inc. 2018c). For a further overview of these two modeling approaches, and for additional citations for further information, see Newell and Garrett (2018d).

For much of the project area, 100-year floodplains have not been mapped, but have been estimated based on available geological mapping (Newell and Garrett 2018d).

3.7.3.3 Affected Environment

Relevant Laws, Regulations, Policies, and Plans

A number of laws, regulations, and policies are pertinent to surface water quantity and are summarized in Newell and Garrett (2018d). Two of these are worth noting here.

As discussed in section 1.5.3, the USACE would rely on this EIS to support issuance of a permit under Section 404 of the CWA, which regulates dredge and fill within waters of the U.S. Part of the USACE permitting responsibility would be to identify jurisdictional waters of the U.S., identify which alternative represents the least environmentally damaging practicable alternative, and to require adequate mitigation to compensate for impacts on waters of the U.S. This section summarizes the potentially jurisdictional waters associated with each alternative, and considers the mitigation proposed to compensate for impacts on waters of the U.S.

Primary Legal Authorities Relevant to the Surface Water Quantity Analysis

- Clean Water Act (Section 404)
- Executive Order 11988—Occupancy and modification of floodplains; Executive Order 11990—Destruction, loss, or degradation of wetlands
- Pinal County Floodplain Management Ordinance

In Arizona, jurisdictional waters of the U.S. often include both ephemeral washes and wetlands areas. Both types of jurisdictional waters are defined by specific technical guidance from the USACE. The Forest Service also considers wetlands under Executive Order 11990, which directs Federal agencies to minimize the destruction, loss, or degradation of wetlands and to preserve and enhance the natural and beneficial value of wetlands in carrying out programs that affect land use. Wetlands considered under Executive Order 11990 are not strictly defined and differ from the jurisdictional waters considered for a 404 permit. This section separately considers wetlands under Executive Order 11990, relying on the National Wetlands Inventory as a data source.

DOCUMENTATION SPECIFIC TO CLEAN WATER ACT SECTION 404 PERMIT ISSUANCE

Issuance of a permit under Section 404 of the CWA requires submittal of a permit application and supporting documentation to the USACE. Fundamental to those regulations is the principle that dredged or fill material cannot be discharged into the aquatic ecosystem unless it can be demonstrated that there is no less environmentally damaging practicable alternative that achieves an applicant's project purpose. In other words, only the least environmentally damaging practicable alternative can be permitted (40 CFR 230.10(a)).

The 404 permitting process includes submittal of a document called a "404(b)1 alternatives analysis." The purpose of the 404(b)1 alternatives analysis is to identify the least environmentally damaging practicable alternative. To determine the least environmentally damaging practicable alternative, each practicable alternative for the proposed mine must be fully analyzed in the 404(b)1 alternatives analysis to assess the relative magnitude of project impacts, including direct, secondary, and cumulative impacts.

Most of the impacts considered under the USACE process are identical to those considered in this EIS, describing physical effects on the environment caused by the mine. However, some impacts considered under the USACE process are specific only to that permitting process, which may have a different scope of analysis. For example, the analysis in sections 3.7.1 and 3.7.3 of this EIS considers the overall physical impacts on streams and the riparian ecosystems associated with streams, but in doing so does not look at acreage as a measure of impact. In contrast, the calculation of the exact acreage of impacts on jurisdictional waters (both direct and indirect) is a very specific requirement of the 404(b)1 alternatives analysis.

Because of these differences, the 404(b)1 alternatives analysis is a document strongly related to the EIS, but also separate. The 404(b)1 alternatives analysis submitted to the USACE by Resolution Copper for the preferred alternative is attached to the EIS as appendix C.

An additional requirement of the USACE process is for compensatory mitigation to offset the impacts on jurisdictional waters. Similar to the 404(b)1 alternatives analysis, this mitigation is pertinent to both the EIS and the USACE process but is handled differently in each. In the EIS, the focus is on whether mitigation would be effective at addressing impacts of any resources, and if so, what residual impacts would remain. This is often a qualitative assessment. For the USACE process, the calculations of the amount of mitigation required are quantitative and formulaic with specific acreage multipliers used for different types of impacts. The conceptual compensatory mitigation plan submitted to the USACE by Resolution Copper for the preferred alternative is attached to the EIS as appendix D.

Table 3.7.3-1. Watershed characteristics

Watershed	Minimum Elevation (feet amsl)	Maximum Elevation (feet amsl)	Mean Elevation (feet amsl)	Average Slope (percent)	Area (square miles)
Devil's Canyon	2,240	5,610	4,240	36	36
Dripping Spring Wash	2,025	7,645	3,670	33	117
Queen Creek	2,135	5,610	3,225	31	143
Donnelly Wash	1,615	3,900	2,900	7	60

Note: Watershed characteristics derived from USGS StreamStats application (U.S. Geological Survey 2018d)

The effectiveness of the conceptual mitigation is assessed in this section of the EIS in a manner similar to other resources and does not reflect USACE calculations or analysis.

Existing Conditions and Ongoing Trends

REGIONAL HYDROLOGIC SETTING

The analysis area includes the Queen Creek, Devil's Canyon, Dripping Spring Wash, and Donnelly Wash drainages: all of these watercourses are tributaries of the Gila River, as shown in figure 3.7.3-1. Watershed characteristics of these drainages are summarized in table 3.7.3-1.

QUEEN CREEK AND DEVIL'S CANYON WATERSHEDS (SUBSIDENCE AREA AND ALTERNATIVES 2, 3, AND 4)

The western part of the analysis area is drained by Queen Creek, which arises in the highlands around the Pinal Mountains and flows past Oak Flat and through the town of Superior. Queen Creek ultimately flows to Whitlow Ranch Dam, about 11 miles west of Superior. The dam is an ungated flood risk–management structure that was constructed in 1960 to reduce the risk of downstream flood damage to farmland and the communities of Chandler, Gilbert, Queen Creek, and Florence Junction. The dam includes a diversion structure to satisfy local water rights.

As discussed in Section 3.7.1, Groundwater Quantity and Groundwater-Dependent Ecosystems, Queen Creek is primarily ephemeral but exhibits perennial flow downstream of the town of Superior wastewater treatment plant, both from effluent and groundwater discharges from a nearby mine pit.

The ore body is located approximately 4,500–7,000 feet beneath Oak Flat in the upper Queen Creek basin. Devil's Canyon is located to the immediate east of Oak Flat with its headwaters located north of U.S. 60. Devil's Canyon cuts through the Apache Leap Tuff, forming a steep-sided canyon that flows in a southerly direction for approximately 9 miles. Devil's Canyon discharges into the reservoir of Big Box Dam. Mineral Creek, to the immediate east of Devil's Canyon, also discharges into the reservoir. Big Box Dam was constructed to divert flows from Devil's Canyon and Mineral Creek around the Ray Mine and into the Gila River. As discussed in section 3.7.1, much of upper Devil's Canyon is ephemeral, where runoff is driven by rainfall events. However, there are several perennial reaches that are sustained either by shallow, recharged groundwater systems or a regional groundwater system that discharges to the surface via seeps and springs.

The subsidence area would affect portions of the watershed for Queen Creek and Devil's Canyon, and the tailings storage facilities for Alternatives 2, 3, and 4 would affect tributaries to Queen Creek.

GILA RIVER WATERSHED (ALTERNATIVES 5 AND 6)

Alternative 5 – Peg Leg would impact Donnelly Wash, which flows north to join the Gila River downstream of Mineral Creek. Donnelly Wash flows through an alluvial valley and has more gentle slope gradients, compared with the other watersheds. The main stem channel of Donnelly Wash is entirely ephemeral, with no known perennial reaches.

Alternative 6 – Skunk Camp would impact Dripping Spring Wash. Dripping Spring Wash is located in the eastern part of the analysis area. Dripping Spring Wash flows to the southeast for approximately 18 miles before discharging into the Gila River downstream of the Coolidge Dam. The main stem channel of Dripping Spring Wash is entirely ephemeral, with no known perennial reaches.

Both Alternatives 5 and 6 would also affect flow to the Gila River itself, which is perennial between Coolidge Dam and Florence.

CLIMATE CONDITIONS

The climate of the project area is generally arid to semi-arid. Topography influences the spatial distribution of precipitation, being lowest in the valley bottoms (average annual totals of approximately 13 inches in the vicinity of Whitlow Ranch Dam), and greatest in the upper elevations of the Queen Creek watershed (26 inches). There are two separate rainfall seasons. The first occurs during the winter from November through March, when the area is subjected to occasional storms from the Pacific Ocean. The second rainfall period occurs during the July and August "monsoon" period when Arizona is subjected to widespread thunderstorm activity whose moisture supply originates in the Gulf of Mexico and Pacific Ocean.

Precipitation typically occurs as high-intensity, short-duration storms during the summer monsoon, and longer term storms of more moderate intensity that occur during the winter months. Summer storms, coupled with relatively impervious land surfaces, sparse vegetation, and steep topographic gradients, result in rapid increases in streamflow. Winter rains tend to produce runoff events of longer duration and with higher maximum flows than summer rains. This is a result of higher rainfall totals and wetter antecedent moisture conditions that tend to prevail in the winter months due to a significantly lower evapotranspiration demand. These wetter conditions result in less near-surface storage capacity in the winter and a larger proportion of any given rain event runs off rather than infiltrating. Regional gaging stations indicate that a majority of runoff occurs during the winter months (December to March) when evaporation rates are at a minimum.

Climate trends suggest that runoff could decrease in the future due to increased temperatures and reduced precipitation. Average temperatures in Arizona have increased about 2°F in the last century (U.S. Environmental Protection Agency 2016). In the Lower Colorado River basin, the annual mean and minimum temperature have increased 1.8°F–3.6°F for the time period 1900–2002, and data suggest that spring minimum temperatures for the same time period have increased 3.6°F–7.2°F (Dugan 2018). Annual average temperatures are projected to rise by 5.5°F to 9.5°F by 2070–2099, with continued growth in global emissions (Melillo et al. 2014).

While future projected temperature increases are anticipated to change mean annual precipitation to a small degree, the majority of changes to annual flow in the Lower Colorado River basin are related to changes in runoff timing. Increased temperatures are expected to diminish the accumulation of snow and the availability of snowmelt, with the most substantial decreases in accumulation occurring in lower elevation portions of the basin where cool season temperatures are most sensitive to warming (Dugan 2018).

Most precipitation falling within the watershed either evaporates or is transpired by vegetation, either from shallow surface soils (approximately 96 percent of precipitation) or along stream drainages and areas where the groundwater is relatively close to the surface and directly available to trees and shrubs (approximately 1 percent of precipitation). The remainder recharges to groundwater or leaves the basin as surface runoff (Montgomery and Associates Inc. 2018).[55]

3.7.3.4 Environmental Consequences of Implementation of the Proposed Mine Plan and Alternatives

Alternative 1 – No Action

Under the no action alternative, impacts on surface water runoff from the Resolution Copper Project and associated activities would not occur. However, impacts on a number of springs because of groundwater drawdown would occur under the no action alternative, as analyzed and discussed in section 3.7.1.

Impacts Common to All Action Alternatives

Table 3.7.3-2 summarizes locations where changes in average monthly and annual streamflow quantity were quantified for each the identified alternatives (BGC Engineering USA Inc. 2018c). Potential changes in streamflow have also been quantified for peak instantaneous flood flows and flows with durations of 1, 3, 7, 15, and 30 days (Lehman 2017, 2018). These changes in streamflow discharge-duration-frequency were assessed for annual exceedance probability (AEP) at 50, 20, 10, 4, 2, 1, 0.5, and 0.2 percent levels.

Streamflow discharge-duration-frequency analysis provides a detailed look at the dynamics of a stream under many conditions, and the full comparison is available for review (Newell and Garrett 2018d). For purposes of comparison in the EIS, two values from the discharge-duration-frequency analysis were selected to represent impacts at each location. The values selected are those that represent the peak instantaneous and the 30-day streamflows, each with a 50 percent probability of exceedance. The return period was selected because it represents flows that happen with relative frequency. The short duration (peak instantaneous streamflow) was selected to represent short, intense ephemeral flows that occur, typical of monsoon events. The long duration (30-day streamflow) was selected to represent streamflow

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[55] These percentages were calculated specifically for the Queen Creek watershed but in general would expect to be similar to the other watersheds in the analysis area, which are at similar elevations, with similar climate, and similar topography.

Table 3.7.3-2. Watershed locations where changes in streamflow for the project EIS action alternatives were analyzed

Location	**Drainage Area (square miles)**	**Action Alternative**
Devil's Canyon – downstream of confluence with Hackberry Canyon, roughly DC-8.1C.	19.0	All
Devil's Canyon – *confluence with Mineral Creek*	35.8	All
Queen Creek – *at Magma Avenue Bridge*	10.4	All
Queen Creek – at Boyce Thompson Arboretum	27.9	All
Queen Creek – *Upstream of Whitlow Ranch Dam*	143.0	All
Potts Canyon* – confluence with Queen Creek	18.1	Alternative 4
Happy Canyon* – confluence with Queen Creek	4.2	Alternative 4
Silver King Wash* – confluence with Queen Creek	6.7	Alternative 4
Roblas Canyon† – confluence with Queen Creek	10.2	Alternative 2, Alternative 3
Bear Tank Canyon† – confluence with Queen Creek	4.9	Alternative 2, Alternative 3
Unnamed Wash – *confluence with Gila River*	7.1	Alternative 5
Donnelly Wash – *confluence with Gila River*	59.9	Alternative 5
Gila River at Donnelly Wash	18,011	Alternative 5
Dripping Spring Wash – confluence with Gila River	117	Alternative 6
Gila River at Dripping Spring Wash	12,866	Alternative 6

Note: See process memorandum for more information on differences between analysis points (Newell and Garrett 2018d).
* Northern tributary impacted by Alternative 4 tailings storage facility.
† Northern tributary impacted by Alternative 2 and Alternative 3 tailings storage facility.

occurring over longer periods but at lesser volume, more typical of conditions affected by baseflow.

The locations analyzed by BGC Engineering USA Inc. (2018c) and Lehman (2017, 2018) differ slightly—coincident analysis locations are identified in italic font in table 3.7.3-2.

The total area of watershed removed from the system of each of the alternatives is summarized in table 3.7.3-3. These footprints reference the total watershed area where water losses would occur, either due to contact water being collected (tailings storage facilities or West Plant Site) or from the subsidence area.

Table 3.7.3-3. Watershed area lost for each mine component

Mine Component	**Area of Watershed Lost (square miles)**
Subsidence area – Queen Creek	1.76
Subsidence area – Devil’s Canyon	0.94
West Plant Site	1.40
Near West tailings storage facility – Alternatives 2 and 3	6.90
Silver King tailings storage facility – Alternative 4	6.32
Peg Leg tailings storage facility – Alternative 5	11.88
Skunk Camp tailings storage facility – Alternative 6	12.15

EFFECTS OF THE LAND EXCHANGE

The land exchange would have effects on surface water quantity.

The Oak Flat Federal Parcel would leave Forest Service jurisdiction. Several surface waters are located on the Oak Flat Federal Parcel, including Rancho Rio Canyon, Oak Flat Wash, and Number 9 Wash, and the parcel also is a portion of the watershed feeding both Queen Creek and Devil’s Canyon. The role of the Tonto National Forest under its primary authorities in the Organic Administration Act, Locatable Regulations (36 CFR 228 Subpart A), and Multiple-Use Mining Act is to ensure that mining activities minimize adverse environmental effects on NFS surface resources; this includes these surface waters. The removal of the Oak Flat Federal Parcel from Forest Service jurisdiction negates the ability of the Tonto National Forest to regulate effects on these resources.

The offered lands parcels would enter either Forest Service or BLM jurisdiction. A number of ephemeral washes and perennial water features are located on these lands:

- Tangle Creek. Tangle Creek is an intermittent or perennial tributary to the Verde River and bisects the parcel. It includes associated riparian habitat with mature hackberry, mesquite, ash, and sycamore trees.
- Turkey Creek. Features of the Turkey Creek Parcel include Turkey Creek, which is an intermittent or perennial tributary to Tonto Creek and eventually to the Salt River at Roosevelt Lake. Riparian vegetation occurs along Turkey Creek with cottonwood, locus, sycamore, and oak trees.
- Cave Creek. Features of the Cave Creek Parcel include Cave Creek, an ephemeral to intermittent tributary to the Agua Fria River, with some perennial reaches in the vicinity of the parcel.
- East Clear Creek. Features of the East Clear Creek Parcel include East Clear Creek, a substantial perennial tributary to the Little Colorado River. Riparian vegetation occurs along East Clear Creek, including boxelder, cottonwood, willow, and alder trees.
- Lower San Pedro River. Features of the Lower San Pedro River Parcel include the San Pedro River and several large ephemeral tributaries (Cooper, Mammoth, and Turtle Washes). The San Pedro River itself is ephemeral to intermittent along the 10-mile reach that runs through the parcel; some perennial surface water is supported by an uncapped artesian well. The San Pedro is one of the few remaining free-flowing rivers in the Southwest and it is recognized as one of the more important riparian habitats in the Sonoran and Chihuahuan Deserts. The riparian corridor in

the parcel includes more than 800 acres of mesquite woodlands that also features a spring-fed wetland.

- Appleton Ranch. The Appleton Ranch Parcels are located along ephemeral tributaries to the Babocomari River (Post, Vaughn, and O'Donnell Canyons). Woody vegetation is present along watercourses as mesquite bosques, with very limited stands of cottonwood and desert willow.
- Small ephemeral washes and unnamed drainages are associated with the Apache Leap South Parcel or the Dripping Springs Parcel.

Specific management of surface water resources on the offered lands would be determined by the agencies, but in general when the offered lands enter Federal jurisdiction, these surface waters would be afforded a level of protection they currently do not have under private ownership.

EFFECTS OF FOREST PLAN AMENDMENT

The Tonto National Forest Land and Resource Management Plan (1985b) provides guidance for management of lands and activities within the Tonto National Forest. It accomplishes this by establishing a mission, goals, objectives, and standards and guidelines. Missions, goals, and objectives are applicable on a forest-wide basis. Standards and guidelines are either applicable on a forest-wide basis or by specific management area.

A review of all components of the 1985 Forest Plan was conducted to identify the need for amendment due to the effects of the project, including both the land exchange and the proposed mine plan (Shin 2019). A number of standards and guidelines (22) were identified applicable to management of surface water resources. None of these standards and guidelines were found to require amendment because of the proposed project, on either a forest-wide or management area–specific basis. For additional details on specific rationale, see Shin (2019).

SUMMARY OF APPLICANT-COMMITTED ENVIRONMENTAL PROTECTION MEASURES

A number of environmental protection measures are incorporated into the design of the project that would act to reduce potential impacts on surface water quantity. These are non-discretionary measures and their effects are accounted for in the analysis of environmental consequences.

In the GPO, Resolution Copper has committed to various measures to reduce impacts on surface water quantity:

- To the extent practicable, stormwater flows upgradient of the facilities would be diverted around the disturbed areas and returned to the natural drainage system;
- As much water as possible would be recycled for reuse;
- Permanent diversion channels would be designed for operations and closure; and
- Runoff from roads, buildings, and other structures would be handled through best management practices, including sediment traps, settling ponds, berms, sediment filter fabric, wattles, etc.

IMPACTS ON SURFACE RUNOFF AND STREAMFLOW

The proposed block-cave mining operation would result in the formation of a subsidence area at the surface. This subsidence area is estimated to cover an area of 2.7 square miles within the Queen Creek and Devil's Canyon watersheds. Once fully formed, precipitation within the subsidence area footprint would not be expected to report as runoff to either Queen Creek or Devil's Canyon, resulting in a decrease in streamflow in both drainages. Tables 3.7.3-4 and 3.7.3-5 summarize expected changes in average monthly streamflow at two locations on Devil's Canyon and three locations on Queen Creek. These tables also show the peak instantaneous and 30-day (50 percent exceedance) streamflows for Queen Creek at Magma Avenue and for Devil's Canyon at Mineral Creek. Note that tables 3.7.3-4 and 3.7.3-5 only reflect streamflow losses from mine components common to all action

Table 3.7.3-4. Estimated changes in average monthly streamflow and peak flood flows common to all action alternatives – Devil’s Canyon

	DC-8.1C			Mineral Creek Confluence		
Month	**Existing (cfs)**	**Proposed (cfs)**	**Decrease (%)**	**Existing (cfs)**	**Proposed (cfs)**	**Decrease (%)**
January	13.73	13.01	−5.3	21.97	21.25	−3.3
February	11.23	10.61	−5.6	17.33	16.71	−3.6
March	6.60	6.25	−5.3	10.38	10.04	−3.4
April	1.64	1.56	−5.1	2.47	2.38	−3.4
May	0.48	0.45	−5.4	0.73	0.71	−3.5
June	0.17	0.17	−5.3	0.27	0.26	−3.4
July	0.53	0.48	−8.2	0.84	0.79	−5.2
August	1.36	1.27	−7.2	2.18	2.09	−4.5
September	1.18	1.09	−7.5	1.98	1.89	−4.5
October	1.04	0.97	−6.5	1.75	1.68	−3.9
November	1.96	1.84	−5.9	3.22	3.11	−3.6
December	5.32	5.04	−5.4	8.48	8.19	−3.4
Average	**3.74**	**3.53**	**−5.6**	**5.92**	**5.71**	**−3.5**
Peak instantaneous streamflow (50% exceedance)	–	–	–	666	657	−1.4
30-day streamflow (50% exceedance)	–	–	–	13.9	13.6	−2.2

Sources: BGC Engineering (2018c); Lehman (2018)

Notes: Numbers have been rounded for presentation.

cfs = cubic feet per second

Table 3.7.3-5. Estimated changes in average monthly streamflow and peak flood flows common to all action alternatives – Queen Creek

Month	Queen Creek at Magma Avenue			Queen Creek at Boyce Thompson Arboretum			Queen Creek above Whitlow Ranch Dam		
	Existing (cfs)	Proposed (cfs)	Decrease (%)	Existing (cfs)	Proposed (cfs)	Decrease (%)	Existing (cfs)	Proposed (cfs)	Decrease (%)
January	5.63	4.61	−18.2	6.54	5.66	−13.4	23.90	23.02	−3.7
February	4.75	3.86	−18.6	5.50	4.75	−13.7	21.14	20.39	−3.6
March	2.61	2.12	−18.8	3.07	2.66	−13.5	12.11	11.69	−3.4
April	0.68	0.56	−17.8	0.81	0.71	−12.8	2.83	2.73	−3.7
May	0.20	0.16	−18.4	0.24	0.20	−13.4	0.87	0.84	−3.6
June	0.07	0.06	−18.5	0.08	0.07	−13.3	0.32	0.31	−3.5
July	0.31	0.25	−20.2	0.38	0.32	−14.3	1.50	1.44	−3.6
August	0.74	0.59	−19.6	0.98	0.84	−13.5	3.64	3.51	−3.6
September	0.64	0.51	−19.7	0.81	0.70	−13.6	3.27	3.16	−3.4
October	0.49	0.39	−19.5	0.63	0.54	−13.4	2.60	2.52	−3.2
November	0.83	0.67	−19.4	1.12	0.97	−13.0	5.07	4.93	−3.2
December	2.17	1.76	−18.6	2.68	2.33	−13.2	10.94	10.59	−2.9
Average	**1.58**	**1.28**	**−18.6**	**1.89**	**1.63**	**−13.4**	**7.28**	**7.03**	**−3.5**
Peak instantaneous streamflow (50% exceedance)	356	316	−11.2	–	–	–	–	–	–
30-day streamflow (50% exceedance)	4.4	3.9	−20.4	–	–	–	–	–	–

Sources: BGC Engineering (2018c); Lehman (2018)

Notes: Impacts shown are solely for effects from the subsidence area and West Plant Site. Combined impacts from the tailings storage facilities for Alternatives 2 and 3 (affecting Queen Creek above Whitlow Ranch Dam) and Alternative 4 (affecting Queen Creek at Boyce Thompson Arboretum and Queen Creek above Whitlow Ranch Dam) are detailed later in this section.

Numbers have been rounded for presentation.

cfs = cubic feet per second

alternatives, like the subsidence area and the West Plant Site. Additional losses occur under Alternatives 2, 3, and 4, shown later in this section.

IMPACTS ON SEDIMENT YIELDS AND GEOMORPHOLOGY OF STREAMS

Physical changes to watersheds can affect not just runoff, but also the sediment those flows carry downstream. One of the major functions of a stream is to transport sediment. All of the stream systems immediately downstream of project components are ephemeral in nature and only flow in response to precipitation. Ephemeral channels or washes have a cyclical pattern of infill and erosion. In this pattern, sediment movement usually occurs as pulses associated with flood events that push large amounts of coarse sediment through the system (Levick et al. 2008). The long-term stability of the downstream channel is based on the equilibrium between erosion and deposition of sediment delivered to the system. When that delivery system is disrupted or altered, changes to stream aggradation (the rising of the grade of a streambed) and scour (the erosive removal of sediment from a streambed) can occur until the system reaches equilibrium once again.

The beds of the downstream channels consist mostly of unsorted, unconsolidated sands, gravels, and cobbles. On smaller tributary washes higher in the watershed, particularly around the Near West (Alternatives 2 and 3) and Silver King (Alternative 4) sites, these sediments may be relatively shallow. Farther downstream, in Queen Creek (Alternatives 2, 3, and 4), Donnelly Wash (Alternative 5), or Dripping Spring Wash (Alternative 6), channels are often quite wide and sediments quite deep (Hart 2016).

All of these ephemeral washes are sediment transport–limited systems. This means that there is more sediment in the system than stormwater can transport. This is common in ephemeral streams due to the flashy (i.e., short duration) nature of flows. Flashy flows emanating from large precipitation events pick up sediment in a pulse of water and then deposit it quickly as flows recede.

Stormflows are expected to change both in the amount of flow and the magnitude of peak flows. For Queen Creek, a reduction in storm flow volume of roughly 19 percent is anticipated at Magma Avenue Bridge (all alternatives), dropping to 4 to 9 percent at Whitlow Ranch Dam (varies by alternative). These changes may result in both a reduced sediment supply to Queen Creek from impacted tributaries and less bedload transport in Queen Creek due to reduced tractive forces.

The potential reduction in sediment supply is not considered a significant impact because the system is sediment-transport limited. With respect to reduced sediment transport, such a reduction would be well within the natural variability of the system, as is evident from the historical data. The existing system already experiences significant variability in the potential for sediment transport for individual flood events. For example, the 2-year return period (50 percent annual probability) flood in Queen Creek for existing conditions is 1,280 cubic feet per second (cfs), compared with 15,830 cfs during a 100-year return period (1 percent annual probability) flood. That difference in peak flow is greater than an order of magnitude. Where the creek’s banks are composed of alluvium, an expected response to reduced peak flows might be a slight narrowing of the channel width proportional to the magnitude of the predicted flow reduction.

Additionally, these systems do not frequently flow. Therefore, any adjustments to the channel geometry would be very slow to occur and difficult to detect. There are two GDEs present along Queen Creek, between km 17.4 and 15.6, and at Whitlow Ranch Dam.[56] Both of these systems are adapted to heavy sediment loads occurring now in ephemeral systems and their function would not be impacted.

Impacts are slightly greater for Donnelly Wash (Alternative 5), with reduction in storm flow volume of roughly 21 percent at the confluence with the Gila River. Reductions in flows in Dripping Spring Wash

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[56] Kilometers are referenced here because many of the stream descriptions used by Resolution Copper reference the distance upstream of the confluence, measured in kilometers. For instance, spring “DC-8.4W” is located 8.4 km upstream of the mouth of Devil’s Canyon, on the west side of the drainage.

(Alternative 6) are roughly 13 percent at the confluence with the Gila River. These changes may result in both a reduced sediment supply to Donnelly Wash and Dripping Spring Wash from impacted tributaries and less bedload transport due to reduced tractive forces. As with Queen Creek, the potential reduction in sediment supply is not considered a significant impact for a sediment transport–limited system. No GDEs or aquatic habitat have been identified along either Donnelly Wash or Dripping Spring Wash. Tributaries upstream of the main stems of Queen Creek, Donnelly Wash, and Dripping Spring Wash exhibit greater changes; no aquatic habitat or GDEs exist in any of these tributaries.

IMPACTS ON WATER QUALITY FROM SEDIMENT CHANGES

Ground disturbance and removal of vegetation can increase sediment movement into downstream waters and affect water quality and aquatic habitat. Water quality is often characterized by the measurement of the amount of sediment per given amount of water (also known as the sediment concentration). As described in detail in section 3.7.2, during operations, stormwater controls would be in place for all major project components (West Plant Site, East Plant Site, tailings facilities, filter plant and loadout facility) to prevent stormwater that contacts tailings materials or processing areas from being discharged downstream. This prevents stormwater from moving downstream but also prevents any increases in sediment concentration from the disturbed areas. The remaining flows in the undisturbed part of the watershed would continue to move sediment at the concentrations found under normal conditions. The design storm event selected for sizing the stormwater management facilities at the East Plant Site, West Plant Site, and filter plant and loadout facility is the 100-year, 24-hour storm event, which Resolution Copper selected based on recommendations from the ADEQ Arizona Mining Guidance Manual BADCT (Arizona Department of Environmental Quality 2004; Resolution Copper 2016d). Note that tailings storage facilities themselves use much larger events in the design of their embankments, as discussed in section 3.10.1.

After closure and all reclamation has occurred, these stormwater controls would no longer be in place for most project components. Long-term revegetation is expected to be effective, and the reclaimed landforms stable without excessive erosion (see Section 3.3, Soils and Vegetation). Even with successful reclamation and revegetation, these areas would not return to pre-disturbance conditions; however, they would still meet a level of functioning condition as specified by the Forest Service. If desired long-term stability or revegetation conditions are not met, then financial assurance or bonds would not be released, and the Forest Service could maintain stormwater controls until revegetation is successful at stabilizing the disturbed ground surface. The long-term expectation is for most disturbed areas to return to the watershed in a condition without excess erosion or excess delivery of sediment.

Linear features, such as pipeline corridors, roads, and power line corridors, also result in ground disturbance but would not have operational stormwater controls in place to contain all runoff. Instead, stormwater permitting requirements under the AZPDES require that active stormwater controls remain in place until adequate site stabilization has occurred to minimize soil loss. Active stormwater controls typically are temporary measures that are designed and applied in a way specific to each location in order to prevent sediment movement into nearby water courses. Active controls require maintenance and eventually are removed once site stabilization has taken place. Active stormwater controls could include such items as silt fences, straw bales or rolls, dikes, sediment traps, or water bars; stabilization techniques could include such items as reseeding, soil treatment, or hardscaping. Provided adequate stormwater controls and best management practices are used, impacts from linear disturbance are generally minimal, since the amount of disturbance reporting to any one wash is relatively limited.

Stormwater and erosion controls applicable to each alternative are summarized in Newell and Garrett (2018d).

Alternative 2 – Near West Proposed Action

IMPACTS ON SURFACE RUNOFF AND STREAMFLOW

Changes in runoff from the subsidence area and West Plant Site would reduce average flows in Queen Creek at Whitlow Ranch Dam by about 4 percent; these losses in combination with additional changes caused by the tailings facility for Alternative 2 would reduce average flows by about 7 percent. As well as impacting flows in Queen Creek, Alternative 2 would impact flows in Roblas Canyon, Bear Tank Canyon, and Potts Canyon. Estimated changes in average monthly streamflow for these drainages are presented in table 3.7.3-6. All streamflow in Bear Tank Canyon would either be diverted into Potts Canyon or captured within the tailings storage facility footprint, resulting in a total loss of surficial runoff at the canyon's mouth. Surface runoff diverted into Potts Canyon results in a slight increase in streamflow for this watershed.

Table 3.7.3-6 also shows the peak instantaneous and 30-day (50 percent exceedance) streamflows for Queen Creek at Whitlow Ranch Dam. In percentages, changes in peak flows are similar to changes in average streamflow, with reductions from 3 to 7 percent.

IMPACTS ON JURISDICTIONAL WATERS OF THE U.S. (RELATED TO CLEAN WATER ACT SECTION 404 PERMIT)

Section 404 of the CWA requires issuance of a permit for discharge of dredged or fill material within jurisdictional waters of the U.S. Waters of the U.S. generally consist of aquatic features such as streams/washes and wetlands. The determination of what aquatic features are considered jurisdictional is made by the USACE.

In 2012 and 2015, the USACE issued determinations that no jurisdictional waters exist within substantial portions of the Queen Creek watershed upstream of Whitlow Ranch Dam, which includes the footprint of Alternative 2 (U.S. Army Corps of Engineers 2012a, 2015). Therefore, no jurisdictional waters would be impacted by Alternative 2.

IMPACTS ON FLOODPLAINS (RELATED TO EXECUTIVE ORDER 11988)

Mapped floodplains for Alternative 2 total 8.5 acres, where the eastern boundary of the West Plant Site overlaps the floodplain of a tributary to Queen Creek. Further information on floodplain acreages, including mapping coverage, is included in Newell and Garrett (2018d).

IMPACTS ON WETLANDS (RELATED TO EXECUTIVE ORDER 11990)

As previously noted, assessing wetlands under Executive Order 11990 is different from assessing jurisdictional waters under a CWA Section 404 permit. For the analysis in this section, the FWS National Wetlands Inventory is used to identify potential wetlands. Details of the wetlands identified from the National Wetlands Inventory are found in Newell and Garrett (2018d). Wetlands affected include

- xeroriparian vegetation along ephemeral washes (92.5 acres),
- stock tanks (5.1 acres for six separate tanks), and
- wetlands near Benson Spring and in the subsidence area (1 acre).

Alternative 3 – Near West – ultrathickened

Alternatives 2 and 3 have almost identical footprints; therefore, all streamflow impacts are the same as summarized in table 3.7.3-6. Impacts on potentially jurisdictional waters, floodplains, and wetlands would also be identical to Alternative 2.

Alternative 4 – Silver King

IMPACTS ON SURFACE RUNOFF AND STREAMFLOW

Changes in runoff from the subsidence area and West Plant Site would reduce average flows in Queen Creek at Whitlow Ranch Dam by about

Table 3.7.3-6. Estimated changes in average monthly streamflow and peak flood flows for Queen Creek and northern tributaries – Alternative 2

	Queen Creek above Whitlow Ranch Dam*			Roblas Canyon			Bear Tank Canyon			Potts Canyon		
Month	**Existing (cfs)**	**Proposed (cfs)**	**Decrease (%)**	**Existing (cfs)**	**Proposed (cfs)**	**Decrease (%)**	**Existing (cfs)**	**Proposed (cfs)**	**Decrease (%)**	**Existing (cfs)**	**Proposed (cfs)**	**Increase (%)**
January	23.90	22.29	−6.8	2.91	2.70	−7.1	1.20	0.0	−100	8.19	8.55	+4.5
February	21.14	19.80	−6.3	2.38	2.22	−6.7	0.96	0.0	−100	6.81	7.11	+4.4
March	12.11	11.33	−6.4	1.37	1.27	−7.6	0.54	0.0	−100	3.64	3.80	+4.6
April	2.83	2.64	−6.7	0.32	0.30	−7.9	0.13	0.0	−100	1.01	1.05	+3.9
May	0.87	0.81	−6.4	0.10	0.09	−7.4	0.04	0.0	−100	0.29	0.30	+4.2
June	0.32	0.30	−6.5	0.04	0.03	−7.5	0.01	0.0	−100	0.10	0.11	+4.3
July	1.50	1.39	−7.3	0.19	0.17	−9.5	0.08	0.0	−100	0.45	0.48	+4.7
August	3.64	3.40	−6.7	0.40	0.37	−7.7	0.17	0.0	−100	1.19	1.24	+4.5
September	3.27	3.05	−6.5	0.38	0.35	−8.3	0.15	0.0	−100	1.04	1.09	+4.3
October	2.60	2.43	−6.4	0.29	0.26	−8.5	0.12	0.0	−100	0.78	0.81	+4.4
November	5.07	4.76	−6.2	0.58	0.53	−8.7	0.25	0.0	−100	1.41	1.47	+4.7
December	10.94	10.23	−6.5	1.25	1.14	−8.7	0.52	0.0	−100	3.34	3.48	+4.3
Average	**7.28**	**6.81**	**−6.5**	**0.84**	**0.78**	**−7.5**	**0.35**	**0.0**	**−100**	**2.33**	**2.44**	**+4.4**
Peak instantaneous streamflow (50 % exceedance)	1,280	1,238	−3.3	–	–	–	–	–	–	–	–	–
30-day streamflow (50 % exceedance)	34.8	32.4	−6.9	–	–	–	–	–	–	–	–	–

Sources: BGC Engineering (2018c); Lehman (2018)

Note: Numbers have been rounded for presentation.

* Calculations reflect the combined effects of subsidence, West Plant Site, and Alternative 2 tailings storage facility.

4 percent; these losses, combined with additional changes caused by the tailings facility for Alternative 4, would reduce average flows by about 9 percent. Alternative 4 also impacts flows at Boyce Thompson Arboretum, reducing average flows by about 20 percent. Additional flow losses would also occur under Alternative 4, with the proposed tailings storage facility impacting flows in Happy Canyon, Silver King Wash, and Potts Canyon. Estimated changes in average monthly streamflow are presented in table 3.7.3-7 (Queen Creek) and table 3.7.3-8 (northern tributaries). Whereas the tailings storage facility disturbance footprint within Silver King Wash is 0.21 square mile, portions of the Potts Canyon and Happy Canyon watersheds are diverted into Silver King Wash. As a result, the overall impact on streamflow in this wash is only 0.5 percent on average.

Table 3.7.3-7 also shows the peak instantaneous and 30-day (50 percent exceedance) streamflows for Queen Creek at Whitlow Ranch Dam. In percentages, changes in peak flows are similar to changes in average streamflow, with reductions from 3 to 7 percent.

IMPACTS ON JURISDICTIONAL WATERS OF THE U.S. (RELATED TO CLEAN WATER ACT SECTION 404 PERMIT)

As with Alternatives 2 and 3, the USACE issued determinations that no jurisdictional waters exist within substantial portions of the Queen Creek watershed upstream of Whitlow Ranch Dam, which includes the footprints of these alternatives. Therefore, no jurisdictional waters would be impacted by Alternative 4.

IMPACTS ON FLOODPLAINS (RELATED TO EXECUTIVE ORDER 11988)

Floodplain impacts for Alternative 4 are identical to those for Alternatives 2 and 3. Further information on floodplain acreages, including mapping coverage, is included in Newell and Garrett (2018d).

IMPACTS ON WETLANDS (RELATED TO EXECUTIVE ORDER 11990)

As previously noted, assessing wetlands under Executive Order 11990 is different from assessing jurisdictional waters under a CWA Section 404 permit. For the analysis in this section, the FWS National Wetlands Inventory is used to identify potential wetlands. Details of the wetlands identified from the National Wetlands Inventory are found in Newell and Garrett (2018d). Wetlands affected include

- xeroriparian vegetation along ephemeral washes (86.2 acres),
- stock tanks (4.1 acres for five separate tanks), and
- a wetland in the subsidence area (0.2 acre).

Alternative 5 – Peg Leg

IMPACTS ON SURFACE RUNOFF AND STREAMFLOW

Streamflow at the mouth of Donnelly Wash and a smaller tributary to the immediate north (herein called “unnamed wash”) would be impacted by the Alternative 5 tailings storage facility footprint. Estimated changes in average monthly streamflow are presented in table 3.7.3-9.

Average monthly streamflows for the Gila River are based on USGS gage 09474000, “Gila River at Kelvin, AZ.” Streamflow records for this gage extend as far back as 1911. Monthly values reported in table 3.7.3-9 are averages for the 1981–2016 period. This USGS gage is located approximately 15 miles upstream of the Donnelly Wash confluence.

This table also shows the peak instantaneous and 30-day (50 percent exceedance) streamflows for Donnelly Wash. Potential changes in streamflow discharge-duration-frequency for the Gila River have not been estimated for two reasons:

Table 3.7.3-7. Estimated changes in average monthly streamflow and peak flood flows for Queen Creek – Alternative 4

	Queen Creek at Boyce Thompson Arboretum			Queen Creek above Whitlow Ranch Dam		
Month	**Existing (cfs)**	**Proposed (cfs)**	**Decrease (%)**	**Existing (cfs)**	**Proposed (cfs)**	**Decrease (%)**
January	6.54	5.24	−19.8	23.90	21.66	−9.4
February	5.50	4.40	−20.0	21.14	19.25	−8.9
March	3.07	2.46	−19.9	12.11	11.08	−8.5
April	0.81	0.66	−18.8	2.83	2.57	−9.3
May	0.24	0.19	−19.7	0.87	0.79	−9.1
June	0.08	0.07	−19.6	0.32	0.29	−8.9
July	0.38	0.30	−21.3	1.50	1.36	−9.0
August	0.98	0.77	−20.7	3.64	3.29	−9.6
September	0.81	0.64	−20.4	3.27	2.98	−8.8
October	0.63	0.50	−20.2	2.60	2.38	−8.4
November	1.12	0.89	−20.3	5.07	4.68	−7.9
December	2.68	2.15	−19.7	10.94	10.03	−8.4
Average	**1.89**	**1.51**	**−19.9**	**7.28**	**6.64**	**−8.9**
Peak instantaneous streamflow (50% exceedance)	–	–	–	1,280	1,239	−3.2
30-day streamflow (50% exceedance)	–	–	–	34.8	32.4	−6.9

Sources: BGC Engineering (2018c); Lehman (2018)
Notes: Numbers have been rounded for presentation. Calculations reflect the combined effects of subsidence, West Plant Site, and Alternative 4 tailings storage facility.

Table 3.7.3-8. Estimated changes in average monthly streamflow and peak flood flows for Queen Creek tributaries – Alternative 4

	Silver King Wash			Happy Canyon			Potts Canyon		
Month	**Existing (cfs)**	**Proposed (cfs)**	**Change (%)**	**Existing (cfs)**	**Proposed (cfs)**	**Decrease (%)**	**Existing (cfs)**	**Proposed (cfs)**	**Decrease (%)**
January	3.23	3.23	−0.2	0.99	0.44	−55.3	8.19	6.49	−20.7
February	2.68	2.66	−0.6	0.84	0.38	−54.1	6.81	5.39	−20.7
March	1.48	1.48	−0.3	0.52	0.26	−50.6	3.64	2.88	−20.8
April	0.41	0.41	0.7	0.11	0.05	−58.0	1.01	0.82	−19.4
May	0.12	0.12	0.0	0.03	0.01	−57.1	0.29	0.23	−20.3
June	0.04	0.04	−0.1	0.01	0.01	−53.8	0.10	0.08	−20.4
July	0.19	0.19	−0.8	0.07	0.03	−51.5	0.45	0.36	−21.8
August	0.47	0.47	−1.4	0.18	0.09	−49.9	1.19	0.92	−22.6
September	0.41	0.41	−0.5	0.14	0.07	−51.4	1.04	0.83	−21.0
October	0.31	0.31	−0.9	0.11	0.05	−50.1	0.78	0.61	−21.4
November	0.53	0.53	−1.6	0.23	0.13	−45.1	1.41	1.10	−21.9
December	1.31	1.30	−0.7	0.46	0.23	−49.7	3.34	2.64	−20.8
Average	**0.93**	**0.92**	**−0.5**	**0.31**	**0.15**	**−52.5**	**2.33**	**1.85**	**−20.9**

Source: BGC Engineering (2018c)

Note: Numbers have been rounded for presentation.

Table 3.7.3-9. Estimated changes in average monthly streamflow and peak flood flows for Donnelly Wash, Unnamed Wash, and Gila River – Alternative 5

	Donnelly Wash at Mouth			Unnamed Wash at Mouth			Gila River at Donnelly Wash		
Month	**Existing (cfs)**	**Proposed (cfs)**	**Decrease (%)**	**Existing (cfs)**	**Proposed (cfs)**	**Decrease (%)**	**Existing (cfs)**	**Proposed (cfs)**	**Decrease (%)**
January	13.19	10.23	−22.5	1.18	0.87	−26.1	746	743.2	−0.4
February	9.26	7.14	−22.9	0.82	0.60	−26.7	554	551.3	−0.4
March	5.27	4.09	−22.3	0.55	0.43	−22.0	852	850.3	−0.2
April	1.31	1.03	−21.0	0.13	0.10	−22.5	609	608.4	0.0
May	0.34	0.25	−24.8	0.03	0.02	−26.3	536	536.1	0.0
June	0.14	0.11	−22.7	0.01	0.01	−24.1	636	636.3	0.0
July	0.66	0.55	−15.8	0.05	0.04	−21.9	744	743.9	0.0
August	2.32	1.92	−17.2	0.19	0.14	−22.3	720	719.1	−0.1
September	1.49	1.21	−19.3	0.16	0.13	−18.9	345	344.5	−0.1
October	2.10	1.66	−20.9	0.22	0.18	−20.5	252	251.2	−0.2
November	3.13	2.53	−19.3	0.27	0.21	−23.0	61	60.5	−1.1
December	5.30	4.29	−19.1	0.54	0.43	−19.6	245	243.4	−0.5
Average	**3.69**	**2.90**	**−21.3**	**0.34**	**0.26**	**−23.7**	**526**	**525.0**	**−0.2**
Peak instantaneous streamflow (50 % exceedance)	866	784	−9.5	–	–	–	–	–	–
30-day streamflow (50 % exceedance)	10.9	8.9	−18.4	–	–	–	–	–	–

Sources: BGC Engineering (2018c); Lehman (2018)

Notes: Numbers have been rounded for presentation.

Some uncertainty has been noted for the monthly water balance model as used on Donnelly Wash, due to the difference in watershed characteristics, compared with Pinto Creek, which was used to calibrate the model.

- The upstream Coolidge/San Carlos Reservoir regulates flow, making it difficult to conduct a flood frequency analysis (Lehman 2018); and
- The total drainage area reductions are very small (<0.1 percent) for the Peg Leg alternative.

IMPACTS ON JURISDICTIONAL WATERS OF THE U.S. (RELATED TO CLEAN WATER ACT SECTION 404 PERMIT)

Unlike locations within the Queen Creek watershed, the USACE has not made any determination on potentially jurisdictional waters for the Peg Leg location. However, based on discussions between the USACE and the Forest Service, it is believed that washes within the Donnelly Wash watershed would be considered jurisdictional waters of the U.S. and would be subject to permitting under Section 404 of the CWA.

It is estimated that approximately 759,064 linear feet of potentially jurisdictional waters are located within the footprint of the Alternative 5 tailings storage facility, potentially impacting 182.5 acres of waters of the U.S. (WestLand Resources Inc. 2018c). No potentially jurisdictional wetlands were noted within the footprint of Alternative 5 during field surveys. The USACE also considers indirect impacts from the "dewatering" of downgradient reaches through upgradient fills; these have not been estimated. Indirect impacts are generally considered to extend from the point of fill down to the confluence with the next substantial drainage.

IMPACTS ON FLOODPLAINS (RELATED TO EXECUTIVE ORDER 11988)

Impacts on floodplains for Alternative 5 differ slightly by pipeline route, with impacts of 171 acres for the eastern pipeline corridor and tailings storage facility footprint, and 167 acres for the western pipeline corridor and tailings storage facility footprint. This includes 8.5 acres for the West Plant Site, identical to Alternatives 2, 3, and 4.

Floodplains are associated with Donnelly Wash and an unnamed tributary wash. The eastern pipeline corridor alternative crosses mapped floodplains associated with the Gila River and Walnut Canyon. The western pipeline corridor alternative crosses mapped floodplains associated with the Gila River and Cottonwood Creek.

IMPACTS ON WETLANDS (RELATED TO EXECUTIVE ORDER 11990)

As previously noted, assessing wetlands under Executive Order 11990 is different from assessing jurisdictional waters under a CWA Section 404 permit. For the analysis in this section, the FWS National Wetlands Inventory is used to identify potential wetlands. Details of the wetlands identified from the National Wetlands Inventory are found in Newell and Garrett (2018d).

Wetland impacts for the eastern pipeline corridor alternative include

- xeroriparian vegetation along ephemeral washes (200.9 acres),
- the Gila River and Queen Creek crossings,
- stock tanks (8.6 acres for six separate tanks), and
- a wetland in the subsidence area (0.2 acre).

Wetland impacts for the western pipeline corridor alternative include

- xeroriparian vegetation along ephemeral washes (219.6 acres),
- the Gila River crossing,
- stock tanks (8.8 acres for five separate tanks), and
- a wetland in the subsidence area (0.2 acre).

Table 3.7.3-10. Estimated changes in average monthly streamflow and peak flood flows for Dripping Spring Wash and Gila River – Alternative 6

	Dripping Spring Wash at Mouth			Gila River at Dripping Spring Wash Confluence			Gila River at Donnelly Wash Confluence		
Month	**Existing (cfs)**	**Proposed (cfs)**	**Decrease (%)**	**Existing (cfs)**	**Proposed (cfs)**	**Decrease (%)**	**Existing (cfs)**	**Proposed (cfs)**	**Decrease (%)**
January	43.66	35.06	−12.8	436	427.9	−2.0	746	740.9	−0.7
February	31.65	25.08	−13.5	384	377.5	−1.7	554	549.4	−0.8
March	16.89	13.34	−13.6	701	697.7	−0.5	852	849.3	−0.3
April	4.12	3.27	−13.4	562	561.1	−0.2	809	608.1	−0.1
May	1.11	0.87	−13.9	536	535.8	0.0	536	536.0	0.0
June	0.46	0.36	−13.5	642	642.0	0.0	636	636.3	0.0
July	1.44	1.16	−12.4	687	686.4	0.0	744	743.8	0.0
August	3.84	3.10	−12.5	602	601.3	−0.1	720	719.1	−0.1
September	3.27	2.63	−12.6	288	287.7	−0.2	345	344.4	−0.1
October	4.63	3.87	−10.6	153	152.7	−0.5	252	251.2	−0.2
November	7.92	6.44	−12.1	33	32.0	−4.4	61	60.2	−1.6
December	16.17	12.96	−12.9	179	175.5	−1.8	245	242.5	−0.9
Average	**11.18**	**8.94**	**−12.9**	**435**	**432.5**	**−0.5**	**526**	**524.4**	**−0.3**
Peak instantaneous streamflow (50% exceedance)	1,168	1,114	−4.7	–	–	–	–	–	–
30-day streamflow (50% exceedance)	36.2	32.7	−9.7	–	–	–	–	–	–

Sources: BGC Engineering (2018c); Lehman (2018)

Note: Numbers have been rounded for presentation.

Alternative 6 – Skunk Camp

IMPACTS ON SURFACE RUNOFF AND STREAMFLOW

Streamflow at the mouth of Dripping Spring Wash would be impacted both by the Alternative 6 tailings storage facility footprint and the northern diversion channels, which divert water into the Mineral Creek watershed. Estimated changes in average monthly streamflow are presented in table 3.7.3-10.

Average monthly streamflows for the Gila River are based on USGS gage 09469500, “Gila River below Coolidge Dam, AZ.” Streamflow records for this gage extend as far back as 1899. Monthly values reported in table 3.7.3-10 are averages for the 1981–2016 period. This USGS gage is located approximately 20 miles upstream of the Dripping Spring Wash confluence.

Table 3.7.3-10 also shows the peak instantaneous and 30-day (50 percent exceedance) streamflows for Donnelly Wash. As with Alternative 5, potential changes in streamflow discharge-duration-frequency for the Gila River were not estimated.

IMPACTS ON JURISDICTIONAL WATERS OF THE U.S. (RELATED TO CLEAN WATER ACT SECTION 404 PERMIT)

Similar to the Peg Leg location, the USACE has not made any determination on potentially jurisdictional waters for the Skunk Camp location. However, based on discussions between the USACE and the Forest Service, it is believed that washes within the Dripping Spring watershed would be considered jurisdictional waters of the U.S. and would be subject to permitting under Section 404 of the CWA.

It is estimated that approximately 395,215 linear feet of potentially jurisdictional waters are located within the footprint of the Alternative 6 tailings storage facility, potentially impacting 120.0 acres of waters of the U.S. (WestLand Resources Inc. 2018c). No potentially jurisdictional wetlands were noted within the footprint of Alternative 6 during field surveys. The USACE also considers indirect impacts from the “dewatering” of downgradient reaches through upgradient fills; these have not been estimated. Indirect impacts are generally considered to extend from the point of fill down to the confluence with the next substantial drainage.

IMPACTS ON FLOODPLAINS (RELATED TO EXECUTIVE ORDER 11988)

Impacts on floodplains for Alternative 6 total 794 acres. This includes 8.5 acres for the West Plant Site, identical to Alternatives 2, 3, and 4.

Floodplains associated with Dripping Spring Wash and tributaries include Stone Cabin Wash and Skunk Camp Wash. Both pipeline corridor alternatives cross Devil’s Canyon and Mineral Creek but do not impact mapped floodplains. The southern pipeline corridor alternative also crosses Queen Creek west of Superior; floodplains have not been mapped in this area but are likely to exist. The northern pipeline corridor alternative crosses Queen Creek east of Superior; floodplains are not mapped but are unlikely to exist in this area based on existing mapped segments.

IMPACTS ON WETLANDS (RELATED TO EXECUTIVE ORDER 11990)

As previously noted, assessing wetlands under Executive Order 11990 is different from assessing jurisdictional waters under a CWA Section 404 permit. For the analysis in this section, the FWS National Wetlands Inventory is used to identify potential wetlands. Details of the wetlands identified from the National Wetlands Inventory are found in Newell and Garrett (2018d).

Wetland impacts for the southern pipeline corridor alternative include

- xeroriparian vegetation along ephemeral washes (232.9 acres),
- wetlands associated with Queen Creek, Devil’s Canyon, and Mineral Creek (28.2 acres),
- stock tanks (11.9 acres for 15 separate tanks), and

- a wetland in the subsidence area (0.2 acre).

Wetland impacts for the northern pipeline corridor alternative include

- xeroriparian vegetation along ephemeral washes (229.6 acres),
- wetlands associated with Mineral Creek (25.4 acres),
- stock tanks (12.7 acres for 17 separate tanks), and
- a wetland in the subsidence area (0.2 acre).

Cumulative Effects

The Tonto National Forest identified the following reasonably foreseeable future actions as likely, in conjunction with development of the Resolution Copper Mine, to contribute to cumulative impacts on surface water quantity. As noted in section 3.1, past and present actions are assessed as part of the affected environment; this section analyzes the effects of any RFFAs, to be considered cumulatively along with the affected environment and Resolution Copper Project effects.

- *Pinto Valley Mine Expansion.* The Pinto Valley Mine is an existing open-pit copper and molybdenum mine located approximately 8 miles west of Miami, Arizona, in Gila County. Pinto Valley Mining Corporation is proposing to expand mining activities onto an estimated 1,011 acres of new disturbance (245 acres on Tonto National Forest land and 766 acres on private land owned by Pinto Valley Mining Corporation) and extend the life of the mine to 2039. While impacts are foreseen with Pinto Creek, these actions are in an entirely different watershed than could be affected by Resolution Copper Mine–related activities (Pinto Creek ultimately flows to Roosevelt Lake), and there are unlikely to be cumulative effects with the Resolution Copper Project.
- *Ripsey Wash Tailings Project.* Mining company ASARCO is planning to construct a new tailings storage facility to support its Ray Mine operations. The environmental effects of the project were analyzed in an EIS conducted by the USACE and approved in a ROD issued in December 2018. As approved, the proposed tailings storage facility project would occupy an estimated 2,574 acres and be situated in the Ripsey Wash watershed just south of the Gila River approximately 5 miles west-northwest of Kearny, Arizona, and would contain up to approximately 750 million tons of material (tailings and embankment material). ASARCO estimates a construction period of 3 years and approximately 50 years of expansion of the footprint of the tailings storage facility as slurry tailings are added to the facility, followed by a 7- to 10-year period for reclamation and final closure. This project is estimated to result in a reduction of recharge to the Gila River of 0.2 percent. This would be cumulative with losses from either Alternative 5 (estimated reduction in flow in the Gila River at Donnelly Wash of 0.2 percent) or Alternative 6 (estimated reduction in flow in the Gila River at Donnelly Wash of 0.3 percent).
- *Silver Bar Mining Regional Landfill and Cottonwood Canyon Road.* AK Mineral Mountain, LLC, NL Mineral Mountain, LLC, POG Mineral Mountain, LLC, SMT Mineral Mountain, LLC, and Welch Mineral Mountain, LLC are proposing to build a municipal solid waste landfill on private property surrounded by BLM land (Middle Gila Canyons area). Site access would require crossing BLM land. An unnamed ephemeral wash passing through the landfill site would be impacted by the landfill's construction. No proposed landfill may be located within 0.5 mile of a 100-year floodplain with flows in excess of 25,000 cfs; however, the hydrologic analysis generated a 100-year peak flow on Cottonwood Canyon Wash of less than 3,800 cfs. Cottonwood Canyon is tributary to Queen Creek, but much of the flow is lost to overland flow as it exits the mountains east of the Salt River valley, and there are unlikely to be cumulative effects with Resolution Copper Project–related impacts.
- *Ray Land Exchange and Proposed Plan Amendment.* ASARCO is also seeking to complete a land exchange with the BLM by which the mining company would gain title to approximately

10,976 acres of public lands and federally owned mineral estate located near ASARCO's Ray Mine in exchange for transferring to the BLM approximately 7,304 acres of private lands, primarily in northwestern Arizona. It is known that at some point ASARCO wishes to develop a copper mining operation in the "Copper Butte" area west of the Ray Mine; however, no details are currently available as to potential environmental effects, including to surface waters, resulting from this possible future mining operation. Given the location of this activity, impacts on water could potentially be cumulative with Resolution Copper Project–related impacts on the Gila River for Alternatives 5 and 6.

- *LEN Range Improvements.* This range allotment is located near Ray Mine. Under the proposed action, upland perennial sources of water would be provided to supplement the existing upland water infrastructure on the allotment. The supplemental water sources would provide adequate water facilities for existing authorized grazing management activities. While beneficial, these water sources are located in a different geographic area than the GDEs potentially impacted by the Resolution Copper Project.
- *Millsite Range Improvements.* This range allotment is located 20 miles east of Apache Junction, on the southern end of the Mesa Ranger District. The Mesa Ranger District is proposing to add three new 10,000-gallon storage tanks and two 600-gallon troughs to improve range condition through better livestock distribution and to provide additional wildlife waters in three pastures on the allotment. Water developments are proposed within the Cottonwood, Bear Tanks, and Hewitt pastures of the Millsite grazing allotment. These improvements would be beneficial for providing water on the landscape and are within the same geographic area where some water sources could be lost (Alternatives 2 and 3); they may offset some loss of water that would result because of the Resolution Copper Project–related tailings storage facility construction.

Other projects and plans are certain to occur or to be in place during the foreseeable life of the Resolution Copper Mine (50–55 years). These, combined with general population increase and ground-disturbing activities, may cumulatively contribute to future changes to surface water quantity.

Mitigation Effectiveness

The Forest Service is in the process of developing a robust mitigation plan to avoid, minimize, rectify, reduce, or compensate for resource impacts that have been identified during the process of preparing this EIS. Appendix J contains descriptions of mitigation concepts being considered and known to be effective, as of publication of the DEIS. Appendix J also contains descriptions of monitoring that would be needed to identify potential impacts and mitigation effectiveness. As noted in chapter 2 (section 2.3), the full suite of mitigation would be contained in the FEIS, required by the ROD, and ultimately included in the final GPO approved by the Forest Service. Public comment on the EIS, and in particular appendix J, will inform the final suite of mitigations.

This section contains an assessment of the effectiveness of mitigation and monitoring measures found in appendix J that are applicable to surface water quantity.

MITIGATION MEASURES APPLICABLE TO SURFACE WATER QUANTITY

Compensatory mitigation plan (RC-217): One mitigation measure is contained in appendix J that would be applicable to surface water quantity and is contained in full in appendix D. In May 2019, the Forest Service received from Resolution Copper a document titled "Draft Resolution Copper Project, Clean Water Act Section 404, Conceptual Mitigation Plan" (WestLand Resources Inc. 2019). This document outlines the concepts being proposed to the USACE for compensatory mitigation required under Section 404 of the CWA.

The document includes a detailed functional assessment of the types of ephemeral washes and xeroriparian habitat found at the Alternative 6 location, and then identifies six off-site mitigation opportunities to address these losses. No on-site mitigation opportunities were identified.

The six off-site opportunities are as follows:

- *The Gila River Indian Community MAR-5 Recharge Project.* This project involved a 3-year pilot study to discharge water back into the Gila River on the Gila River Indian Community. The pilot project resulted in a five-fold increase in total vegetation volume and a six-fold increase in total herbaceous cover, and at the end of the pilot study the site was populated with desirable riparian species including cattails and willow. Tamarisk density at the site also increased substantially and any ecological lift may be negatively impacted by the presence and density of tamarisk. The project would involve enhancement and continuation of the project.
- *The Lower San Pedro River Wildlife Area In-lieu Fee Project.* In-lieu fee programs allow impacts on surface water features to be mitigated through funds paid to a governmental or non-profit natural resources management entity. The Lower San Pedro River Wildlife Area in-lieu fee project consists of converting over 100 acres of agricultural fields to native pasture grasses to reduce groundwater consumption and help restore base flows and riparian habitat. Additionally, the restoration project will involve substantial exotic species removal and subsequent plantings to establish native woody vegetation within the 2,116-acre site.
- *The Olberg Road Restoration Site Project.* This is a proposed 23-acre restoration site located along the south bank of the Gila River just east of the Olberg Bridge, immediately upstream of the MAR-5 site. Restoration would consist of exotic tree species (principally tamarisk) removal and control, combined with native plant species reseeding.
- *The Queen Creek Project.* This project consists of actions to improve the ecological condition of a stretch of Queen Creek near Superior, Arizona, including the removal of tamarisk to allow riparian vegetation to return to its historic composition and structure and promote more natural stream functions. Additionally, a conservation easement would be established, covering approximately 150 acres along 1.8 miles of Queen Creek to restrict future development of the site and provide protected riparian and wildlife habitat.
- *The Arlington Wildlife Area In-lieu Fee Project.* This is a 1,500-acre wetland and riparian habitat restoration project along the west bank of the Gila River in Maricopa County, southwest of the Phoenix metropolitan area.
- *The Lower San Pedro River BHP Parcel Preservation Project.* This would involve the preservation through a conservation easement (or similar instrument) of land parcels currently owned and managed by BHP that encompass the San Pedro River riparian corridor and adjacent bosque habitat along an approximately 5-mile stretch of the San Pedro River east of San Manuel, Arizona.

MITIGATION EFFECTIVENESS AND IMPACTS

Effectiveness of Mitigation

The exact type and amount of mitigation is not yet quantified, but all of the conceptual mitigations would be effective at enhancing, increasing, or improving the overall riparian habitat within the state of Arizona. How pertinent these improvements would be to the impacts from the Resolution Copper Project is primarily a reflection of their location.

The Queen Creek Project is on the same stream that would be impacted by reduced surface flows, as well as groundwater drawdown. Mitigation at this location would represent a direct offset of any lost riparian function.

The MAR-5 and Olberg Road projects are both on the Gila River, but no loss in riparian function is anticipated on the Gila River, as the reductions in average flow are relatively small (0.3 to 0.5 percent). In addition, the Gila River flow is largely diverted upstream of Florence and any impacts would be unlikely to be noticed on the Gila River Indian Community at the locations of these mitigation projects. These projects would not reflect a direct offset of impacts but would still reflect a replacement of riparian function on the same stream system.

The two Lower San Pedro projects and the Arlington Wildlife Area project both would help replace riparian function, but in different watersheds. Conceptually, the Lower San Pedro projects are upstream of any impacts that would be seen on the Gila River and potentially could be considered direct offsets, although there is a substantial distance between these locations and the Gila River. The Arlington Wildlife Area project is on the Gila River but far downstream and removed from the potential impacts. These projects most likely would not reflect a direct offset of impacts but would still reflect a replacement of riparian function in the greater Gila River watershed.

Impacts from Mitigation Actions

The exact type and amount of improvement is not yet quantified, nor are any additional ground disturbance or physical effects that would result from these actions.

UNAVOIDABLE ADVERSE IMPACTS

The primary impact described in the analysis (in this section, as well as section 3.7.1) is the loss of surface water flow to riparian areas (including xeroriparian vegetation along ephemeral washes) and loss of surface flow to any GDEs that are associated with these drainages. With the possible exception of the Queen Creek project, the conceptual mitigation proposed under the CWA would not be effective at avoiding, minimizing, rectifying, or reducing these impacts. Rather, the proposed conceptual mitigation would be mostly effective at offsetting impacts caused by reduced surface water flows by replacing riparian function far upstream or downstream of project impacts.

As the subsidence area is unavoidable, the loss of runoff to the watershed due to the subsidence area is also unavoidable, as are any effects on GDEs from reduced annual flows. The loss of water to the watershed due to the tailings facility (during operations, prior to successful reclamation) is unavoidable as well, due to water management and water quality requirements. Direct impacts on wetlands, stock tanks, and ephemeral drainages from surface disturbance are also unavoidable.

Other Required Disclosures

SHORT-TERM USES AND LONG-TERM PRODUCTIVITY

Desert washes, stock tanks, and wetland areas in the footprint of the subsidence area and tailings storage facility would be permanently impacted. In the short term, over the operational life of the mine, precipitation would be lost to the watershed. In the long term, most precipitation falling at the tailings facility would return to the watershed after closure and successful reclamation. There would be a permanent reduction in the quantity of surface water entering drainages as a result of capture of runoff by the subsidence area.

IRREVERSIBLE AND IRRETRIEVABLE COMMITMENT OF RESOURCES

With respect to surface water flows from the project area, all action alternatives would result in both irreversible and irretrievable commitment of surface water resources. Irreversible commitment of surface water flows would result from the permanent reduction in stormwater flows into downstream drainages from the subsidence area. Changes to wetlands, stock tanks, and ephemeral drainages caused by surface disturbance would also be irreversible. Irretrievable commitment of surface water resources would be associated with additional temporary diversion, storage, and use of stormwater during active mining, but that would be restored to the watershed after closure and reclamation.