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TECHNICAL MEMORANDUM

DATE: January 25, 2019 **PROJECT #**: 605.1604

TO: Victoria Peacey and Greg Ghidotti, Resolution Copper

FROM: Derek Groenendyk and Tim Bayley

PROJECT: Near West Tailings Facility

SUBJECT: Revised Near West TSF Alternatives 2 and 3 Steady-State Modeling Incorporating Additional Seepage Collection Measures

Introduction

The Draft Environmental Impact Statement (DEIS) for the proposed Resolution Copper mine includes the following tailings storage facility alternatives:

- Alternative 2: Near West Modified Proposed Action (Modified Centerline Embankment – “Wet”)
- Alternative 3: Near West Modified Proposed Action (High-density Thickened Non-Pyrite Acid Generating (NPAG) Scavenger Tailings and Segregated Pyrite Acid Generating (PAG) Pyrite Tailings Cell – “Dry”)
- Alternative 4: Silver King Filtered
- Alternative 5: Peg Leg Optimized
- Alternative 6: Skunk Camp

This memorandum was written for the United States Forest Service (USFS) to document construction and results of steady-state groundwater flow modeling (Model) representing the additional engineered seepage control measures for the proposed Near West Tailings Storage Facility (TSF) designs (Alternative 2 and Alternative 3). M&A (2018a) states that the amount of allowable seepage into the aquifer to remain compliant with Arizona water quality standards is 3 acre-feet per year (AF/yr). Previously M&A completed numerical modeling of Alternative 2 and 3 TSF designs that included only seepage control measures required for geotechnical stability (M&A 2018c). The TSF seepage rate determined from this initial modeling indicated that surface water quality at Whitlow Ranch Dam would exceed Arizona Department of Environmental Quality (ADEQ) water quality standards for both Alternatives 2 and 3 (M&A 2018b). The Model developed herein is intended to be a demonstration for the DEIS that additional seepage control measures could be emplaced to reduce TSF seepage rates to levels that would comply with ADEQ water quality standards.

This model is based on the model described in M&A (2018c) but includes added seepage control measures that capture and collect additional seepage. The Model was developed in MODFLOW-USG (Panday and others, 2013) to provide estimates of seepage rates into the three alluvial aquifer subdomains adjacent to the TSF footprint (Potts Canyon, Roblas Canyon and Queen Creek) and travel times from the TSF to these alluvial aquifers in support of GoldSim contaminant transport modeling for Alternatives 2 and 3.

The Model is a simplified representation of both natural hydrogeologic conditions and engineered tailings conditions. While the seepage rates and travel times derived from this Model are considered to be useful tools for TSF alternatives comparison, it is important to recognize that several conservative assumptions are built into the Model. Specifically, the Model represents steady-state conditions assuming operational conditions at full TSF build-out. The hydraulic gradients developed under the modeled conditions are expected to be steeper than would occur during the actual transient build-out of the mine. These steeper gradients would result in shorter travel times and higher flow rates than would likely occur during a more realistic transient mine build-out. Furthermore, the effectiveness of the seepage control measures is likely reduced under steady-state conditions, specifically low-permeability liners and grout curtains. These conservative assumptions likely result in overestimates of seepage rates in the Model.

Model Domain and Boundary Conditions

The site of the proposed Near West TSF is in the Superior Basin, which extends from its headwaters in the Upper Queen Creek watershed to Whitlow Ranch Dam (**Figure 1**). The model domain is shown on **Figure 2** and extends to the Superior Basin boundary in the northwest and northeast, the Queen Creek alluvium in the south and southwest, and the Happy Camp Canyon in the southeast. Model boundaries to the north, west, and northeast are represented as no-flow boundaries. The southeastern model boundary is approximately perpendicular to observed groundwater flow contours (M&A, 2017a) along the Happy Camp Canyon and was simulated as a no-flow boundary. The south/southwestern boundary of the Model is the southern extent of the Queen Creek alluvial deposits. A specified-flux boundary was used to simulate 319 AF/yr of groundwater underflow entering the model domain from the south side of Queen Creek as determined in the Superior Basin Conceptual Model (M&A, 2017a). This specified-flux boundary was implemented using the MODFLOW WEL package.

Model Layering & Geometry

The Model was developed with 14 layers representing the constructed TSF and natural subsurface (**Figure 3**). Layers 1 through 7 represent tailings and are only active where the TSF is present. Layer 7 includes a blanket drain under the proposed extent of the TSF embankment. Model cells in layers 1 through 7 are active based on the vertical and horizontal extent of the TSF at the end of mining operations. Layer 8 is the uppermost layer below the natural ground surface, and represents land surface. Layer 8 also contains finger drains where they are present under the TSF. Layers 9 through 14 represent the remainder of the subsurface to a depth of 650 feet below land surface.

Alluvium in the Model was separated into two units, one representing Queen Creek and the other representing the tributaries of Queen Creek in the basin. Alluvial tributaries within the TSF footprint are assumed to be filled with tailings material where finger drains are not present. The Queen Creek alluvium varies in thickness from 10 to 49 feet and is present in model layers 8 and 9. Tributary alluvium is considered to be 10 feet thick and is present only in layer eight. **Figure 3** provides detailed information on model layering and thickness. Values shown in **Figure 3** represent model cell thickness in feet. Specific details regarding the implementation of low-permeability liners are discussed in the section *TSF Seepage Control Measures*.

Model grid cells in the area of the TSF are 100 x 100 feet; outside the area of the TSF, model cells are 500 x 500 feet (**Figure 2**). Model layering was based on the original, pre-TSF land surface. The land surface elevation for each model cell is calculated as the spatially weighted average of a 22.5 x 22.5 feet Digital Elevation Model of the area.

Hydrogeology

The geologic setting of the proposed TSF site is complex including many rock types and a series faulted and tilted structural features. The principal Hydrogeologic Units (HGUs) identified in the study area include (in order of increasing age): Quaternary alluvial deposits, Tertiary Gila Conglomerate, Tertiary sandstone, younger Tertiary volcanic rocks, Tertiary Apache Leap Tuff, older Tertiary volcanic rocks, Tertiary Whitetail Conglomerate, Tertiary-Cretaceous intrusive igneous rocks, Paleozoic sedimentary rocks, younger Precambrian intrusive igneous rocks, younger Precambrian sedimentary, older Precambrian intrusive igneous rocks, and older Precambrian metamorphic rocks.

Hydrogeologic studies of the Near West tailings site include:

- Near West Tailings Storage Facility: Geotechnical Site Characterization Report, KCB, 2017

- Construction, Development, & Testing of Hydrologic Test Wells at the Near West Tailings Site: Resolution Copper, M&A, 2017b
- Near West TSF Geotechnical Field Investigation Summary Report, Golder Associates, 2017
- Conceptual Hydrogeologic Model for Proposed Near West Tailings Storage Facility, M&A, 2017a

Hydraulic Properties

Hydraulic tests were conducted to determine the hydraulic properties of the geologic units.

Testing conducted at the TSF site and documented by M&A (2017a) includes:

- Packer tests and falling head tests in 38 open boreholes
- Constant-rate pumping tests in eight (8) hydrologic test wells
- Short-duration pumping tests in four (4) geotechnical piezometers and one (1) hydrologic test well
- Slug tests in eight (8) hydrologic test wells and four (4) piezometers
- Downhole nuclear magnetic resonance (NMR) geophysical logging.

Measured hydraulic conductivity values near the TSF range from 4.0×10^{-5} feet per day (ft/d) in the Diabase to over 1,000 ft/d in the Queen Creek alluvium. However, for the purpose of this modeling study, a single homogenous isotropic material was used to represent the bedrock units. Homogeneous isotropic materials with differing hydraulic conductivities were also used to represent the tributary and Queen Creek alluvium, drain, and tailing units (**Table 1**).

The representative hydraulic conductivity of the bedrock was determined to be 1.32×10^{-2} ft/d, by calculating the volume-weighted geometric mean of the HGUs present in the subsurface (M&A, 2017c). Aquifer testing indicated that the hydraulic conductivity of the Queen Creek alluvium was much higher than the surrounding bedrock; the Model uses a value of 1,000 ft/d (M&A, 2017a). The tributary alluvium has a hydraulic conductivity of 500 ft/d in the Model.

Tailings material is represented as a homogeneous, isotropic material with a hydraulic conductivity of 2.83×10^{-2} ft/d which is the expected composite hydraulic conductivity of the scavenger beach. The blanket drain is represented with a homogeneous isotropic highly conductive gravel material, with a hydraulic conductivity of 142 ft/d. Finger drains are also represented by a homogeneous isotropic highly conductive gravel material, with a hydraulic conductivity of 283 ft/d (KCB, 2018a, b).

TSF Seepage Control Measures

The initial model for Alternative 2 and 3 included only the Level 1 seepage control measures provided by KCB (2018a, b), which are required for geotechnical stability (M&A, 2018c). The Level 1 seepage control measures included a blanket drain beneath the embankment, a network of finger drains, and shallow seepage collection dams with pump back wells. Alternative 3 also included a liner for the segregated PAG tailings. Seepage rates from the initial Model for Alternative 2 and Alternative 3 were above the rate allowable in order to meet ADEQ water quality standards. In the model described in this memo, low permeability liners, grout curtains, and additional pump back wells were added to the Model with the goal of reducing uncollected seepage rates to allowable levels. The location of the TSF seepage control measures implemented are shown in **Figure 4** for Alternative 2 and **Figure 5** for Alternative 3.

The blanket drain is designed to be a 3-foot thick, highly conductive layer consisting of coarse gravel that drains the embankment of the TSF. The blanket drain is located in model layer 7 (a 3-foot thick layer) beneath the complete extent of embankment and is represented by a high hydraulic conductivity (142 ft/d). Discharge from the blanket drain to the perimeter of the embankment reports to a MODFLOW Drain Cell (DRN), and exits the simulated flow system. In reality, discharge from the blanket drain would emerge at land surface and flow through lined channels along the embankment toe to the finger drains before reaching the seepage collection dams; however, this surface flow is not being simulated. The stage of the DRNs at the perimeter of the embankment are equal to the elevation of the bottom of layer seven, with a drain conductance of 1×10^6 square feet per day (ft^2/d).

Finger drains are designed as 10 feet thick by 30 feet wide channels filled with highly conductive coarse gravel excavated into existing alluvial tributaries under the TSF. Finger drains are located in model layer eight beneath the blanket drain and extend to the perimeter of the embankment in the model. Flow in the finger drains reports to simulated DRNs at the downstream end, and exits the simulated flow system. As is the case with the blanket drains, in reality, discharge from the finger drains would result in surface flow that reports to the seepage collection dams through lined channels but is not explicitly simulated. The stage of the DRNs at the end of the finger drains is equal to the elevation of the bottom of the layer eight, with a drain conductance of 1×10^6 ft^2/d.

The primary seepage collection dams are designed as general fill dams covered on the upstream side with a geomembrane placed in excavated alluvium downstream of the TSF to capture seepage from the finger drains. Within each drainage downgradient of the TSF, seepage collection dams with cut-off walls are incorporated into the design and model. The seepage collection dams and grouted cut-off wall extend into the subsurface below and a well on the upstream side to pump seepage back onto the TSF. The cut-off walls beneath each seepage collection dam are simulated using MODFLOW's Horizontal Flow Barrier (HFB) package. The cut-off walls are in alluvium cells in model layer eight through eleven; pump back wells extend to the same depth. The cut-off walls have a thickness of 3 feet, a depth of 100 feet, a width of 100 feet (covering the entire downstream cross-sectional area of the cell), and a hydraulic conductivity of 2.83×10^{-3} ft/d. The pump back wells are represented with DRN cells located upgradient from the cut-off walls in each layer. The DRNs have a stage equal to the bottom elevation of the cell, with a drain conductance of 1×10^{6} ft^2/d. Water that enters these drain cells exits the simulated system.

Within the footprint of the TSF, low permeability liners were designed to overlay geologic units with relatively higher hydraulic conductivities than surrounding units. The units to be overlain by liners include Tertiary Perlite, Tertiary Tuff, and Pre-Cambrian Apache Group. The liners are represented using the HFB package and Quasi-3D confining layers. Quasi-3D confining layers exist at the bottom of layer 7 and layer 8. These layers have a thickness of 0.05 feet and hydraulic conductivity of 2.834×10^{-3} ft/d. The confining layers in layer 7 are active only for geologic units where finger drains are absent or tributary alluvium has not been removed. Where finger drains are present or where the tributary alluvium has been removed and replaced by tailings, confining layers are active in layer 8. Vertical liners are represented using HFBs and are present in finger drains for lined areas of layer 8. Alternative 3 contains additional vertical and horizontal liners within the TSF that separate a cell filled with potentially acid generating (PAG) tailings material from non-potentially acid generating (NPAG) tailings material. The HFB walls have a thickness of 0.005 feet and hydraulic conductivity of 2.834×10^{-3} ft/d.

A 7.5 mile grout curtain surrounds the downgradient perimeter of the TSF and extends 100 feet below land surface. In the Model the grout curtain is represented using the HFB package. The HFB walls have a thickness of 5 feet and a hydraulic conductivity of 2.834×10^{-3} ft/d. The performance of the Quasi-3D confining layers representing liners and HFB walls representing the grout curtain is limited because the model is steady-state.

A reasonable number of additional pump back wells (21) were added to both Alternative 2 and Alternative 3 for comparative purposes in locations around the perimeter of the TSF to reduce the uncollected seepage rate. Wells were represented as DRN cells and were placed in layers 8 through 12 down to 200 feet, the approximate depth of bedrock with a higher permeability based on field testing data. The DRN cells have a conductance of 1×10^{6} ft^2/d. Water that enters the DRN cells exits the simulated system and is assumed to be reintroduced in the mine circuit.

Model Water Balance

A complete water balance of the model domain is provided in M&A (2017a). A summary of the model domain water balance and description of its translation into the steady-state numerical model can be found in M&A 2018c. In the Model for Alternative 2 and Alternative 3 ADWR well 55-627523 goes dry, a loss of 5 AF/yr in withdrawals.
A complete water balance of the Model for Alternative 2 and Alternative 3 is provided in **Table 2**.

TSF Recharge

For Alternative 2, recharge in the TSF was added through MODFLOW's well (WEL) package. The wells have an injection rate equal to the rate of applied water (ft/d) multiplied by the cell area (ft^2). For Alternative 3, recharge was added through the recharge (RCH) package, with rates equal to the net rate of water applied to the TSF.

Recharge on the TSF during active deposition for the scavenger beach tailings was estimated by KCB using one-dimensional unsaturated numerical water flow model (**Table 3**) (KCB, 2018a, b). The rate of recharge applied to the scavenger beach tailings at maximum build-out was 2.29×10^{-3} ft/d (5.2×10^{-1} gallons per minute) for Alternative 2 and 6.17×10^{-4} ft/d (1.4×10^{-1} gallons per minute) for Alternative 3. These rates represent the net rate of water applied to the TSF during build-out taking into account precipitation, evaporation, and runoff. The total recharge per year for the scavenger beach tailings is 1,909.7 AF for Alternative 2 and 628.4 AF per year for Alternative 3 (**Table 3**).

The PAG tailings recharge was assumed to be under unit gradient conditions and was limited to the hydraulic conductivity of the consolidated PAG tailings that is equal to 7.08×10^{-4} ft/d (1.6×10^{-1} gallons per minute) for Alternative 2 and Alternative 3. Total recharge per year for the PAG tailings is 223.1 AF for Alternative 2 and 131.9 AF for Alternative 3 (**Table 3**). The location and extent of the ponded PAG tailings in Alternative 2 change throughout the duration of TSF construction, but the PAG tailings cells in the Model are static. The cells used to represent the area of ponded recharge for Alternatives 2 are based on the tailings build-out from the KCB design for Alternative 2 (2018a). The representative cells cover an area near the maximum extent of the ponded area and are located near the center of the TSF footprint, which occurs approximately 25 years after the start of mining operations in Alternative 2 and has an area of 865 acres (**Figure 4**). In the KCB design for Alternative 3 (2018b) the PAG tailings are contained within a lined cell located in the middle of the TSF throughout build-out (**Figure 5**).
The cell has an area of 511 acres and is lined on all sides.

Solute Transport Parameters

The MODFLOW-USG transport package was used as a tool to determine the portion of water that originates from the TSF (seepage) and enters Potts Canyon, Roblas Canyon, and Queen Creek. The seepage that enters these three alluvial aquifer subdomains is provided as the seepage inflow for GoldSim (GoldSim, 2017) simulations used to estimate total seepage.

The Model used solute transport to determine how much TSF seepage water enters each of the alluvial aquifer subdomains surrounding the TSF (Potts Canyon, Roblas Canyon, and Queen Creek) by adding water to the TSF with a unit (1) concentration. The evapotranspiration (ETS) package was used to remove flow but not solute mass. Transport is simulated using the steady-state flow field until concentrations were constant through transport model time.

Porosity values were estimated from specific yield results from pumping tests and NMR logs (M&A, 2017a), or were taken from the literature. Porosities assigned to HGUs are listed in **Table 1**.

Longitudinal dispersivity of 30 feet was used based on Ayra (1986) having a field scale on the order of 2,300 feet (the shortest distance between the toe of the TSF and Queen Creek). This is consistent with the value provided by the Xu and Eckstein (1995) equation and is also in the lower half of the range of dispersivities in Gelhar and others (1992). The transverse dispersivity was 3 feet, one order-of-magnitude smaller than the longitudinal dispersivity.

Results

Seepage Rates

The results from this Model are used to provide estimates of TSF seepage rates for the GoldSim (GoldSim, 2017) contaminant transport modeling for Alternatives 2 and 3. The major pathways for seepage to leave the TSF and travel downstream to Whitlow Ranch Dam via Queen Creek are through Roblas Canyon, Potts Canyon, and a portion of Queen Creek adjacent to the TSF. Potts and Roblas Canyons are southeast and northwest of the TSF, respectively, and flow into Queen Creek.

Total seepage represents the total contribution of flow to Queen Creek sourced from the TSF and is equal to total TSF recharge less the seepage captured by all of the seepage control measures (finger drains, embankment blanket drains, low permeability layers/liners/grouting, primary seepage collection dams with grout curtains, and auxiliary pump back wells).

The total seepage collected by all seepage control measures is equal to 2,112.1 AF/yr for Alternative 2 and 757.6 AF/yr for Alternative 3. The seepage control measures capture 99% of the seepage for Alternative 2 and Alternative 3, resulting in 20.7 AF/yr of uncollected seepage reaching Whitlow Ranch Dam for Alternative 2 and 2.7 AF/yr of uncollected seepage for Alternative 3 (**Table 4**).

The seepage entering the alluvial aquifer subdomains for Alternative 2 and Alternative 3, which is provided to the GoldSim models, is calculated as the uncollected seepage reaching Whitlow Ranch Dam partitioned based on the concentrations in the alluvial aquifer subdomains of Potts Canyon, Roblas Canyon, and Queen Creek. The spatial extents of the aquifer subdomains used to determine flow and concentration are shown on **Figure 6** and **Figure 7**. The amount of seepage originating from the TSF and entering Potts Canyon, Roblas Canyon, and Queen Creek immediately adjacent to the TSF for Alternatives 2 and 3 is presented in **Table 4**.

Travel Times

The GoldSim (GoldSim, 2017) contaminant transport models being developed for Alternatives 2 and 3 only model flow through the alluvium. However, some portion of seepage likely travels from the TSF foundation through the bedrock units before entering the alluvium. Because of the irregular geometry and the fact that the driving hydraulic gradient is based on hydraulic head differences between the TSF and the surrounding rock, this calculation requires outputs from this model.

Transit time for seepage to enter the alluvial aquifer was calculated using the modeled groundwater gradient and hydraulic properties of the subsurface between the crest of the embankment on the TSF and respective alluvial aquifer. The calculation was done for full TSF build-out conditions under steady-state conditions and should be considered conservative with the potential for underestimating travel times under transient build-out conditions. The alluvial aquifers are represented by the domains on **Figures 6 and 7**, for Alternatives 2 and 3 respectively.

The equation used to calculate transit time, t, is as follows:

$$t = \frac{D}{v}$$

Where D is the distance from the crest of the water table in the TSF to the alluvial aquifer and v the flow velocity which is calculated as:

$$v = \frac{K}{n}\frac{dh}{dl}$$

Where *K* is the hydraulic conductivity, *n* the porosity, *dh* difference in head between the embankment of the TSF and alluvial aquifer, *dl* the distance between the locations of head values used (here, equal to *D*) (Freeze & Cherry, 1979).

Contours of groundwater elevations for Alternative 2 used to calculate transit time are shown on **Figure 6** and the contours for Alternative 3 are shown on **Figure 7**. The hydraulic conductivity and porosity values used for each alluvial aquifer were estimated to be the spatially weighted average of the geologic units in the uppermost 100 feet of the area between the TSF and the alluvial aquifer. The average gradient along each alluvial aquifer was used to calculate the transit time for seepage leaving the TSF and entering the alluvial aquifer. The specific values used for all quantities including the calculated transit times are listed in **Table 5** for Alternatives 2 and 3, respectively.

References

Arya, A, 1986, Dispersion and Reservoir Heterogeneity, Ph.D. dissertation, University of Texas, Austin.

Freeze, R. A., J. A. Cherry, 1979, *Groundwater*. Englewood Cliffs, NJ: Prentice-Hall, Inc.

Gelhar, L.W., A. Mantologu, C. Welty, and K.R. Rehfeldt, 1992, A Critical Review of Data on Field-Scale Dispersion in Aquifers: Water Resources Research, Vol. 28, No. 7, pp 1955-1974.

Golder Associates, 2017, Near West TSF Geotechnical Field Investigation Summary Report, October, 2017.

GoldSim Technology Group LLC, 2017, User's Guide: GoldSim Contaminant Transport Module, Version 12.0, February 2017.

Klohn Crippen Berger Ltd. (KCB), 2018a, Resolution Project - DEIS Design for Alternative 3A - Near West Modified Proposed Action (Modified Centerline Embankment - "wet") - Doc. # CCC.03-26000-EX-REP-00002, June 2018.

______, 2018b, Resolution Project - DEIS Design for Alternative 3B - Near West Modified Proposed Action (High-density thickened NPAG Scavenger and Segregated PAG Pyrite Cell) - Doc. # CCC.03-26000-EX-REP-00005, June 2018.

______, 2017, Near West Tailings Storage Facility: Geotechnical Site Characterization Report, October 2017.

Montgomery & Associates, 2018a, Estimated Preliminary Allowable Seepage from TSF Alternative Sites for Comparative Analysis, December 21, 2018.

______, 2018b, TSF Alternatives 2 and 3 – Near West: Life of Mine and Post-Closure Seepage Transport Modeling, December 21, 2018.

______, 2018c, Alternatives 2 and 3 Steady-State Modeling, December 17, 2018.

______, 2017a, Conceptual Hydrogeologic Model for Proposed Near West Tailings Storage Facility, Resolution Copper Mining LLC, Pinal County, Arizona: Final report prepared for Resolution Copper Mining LLC, November 25, 2017.

______, 2017b, Construction, Development, & Testing of Hydrologic Test Wells at the Near West Tailings Site: Resolution Copper, October 2017.

______, 2017c, Datasets and Assumptions for the Near West Leapfrog Geologic Model: Technical Memorandum prepared for Resolution Copper Mining LLC, July 18, 2017.

Panday, Sorab, Langevin, C.D., Niswonger, R.G., Ibaraki, Motomu, and Hughes, J.D., 2013, MODFLOW–USG version 1: An unstructured grid version of MODFLOW for simulating groundwater flow and tightly coupled processes using a control volume finite-difference formulation: U.S. Geological Survey Techniques and Methods, book 6, chap. A45, 66 p.

Xu, Moujin and Eckstein, Yoram, 1995, Use of Weighted Least-Squared Method in Evaluation of the Relationship between Dispersivity and Field Scale: Ground Water, Vol. 33, No. 6, pp 905-908.

Table 1. Hydraulic Properties

Material Type	K_h (ft/d)	*n*
Bedrock	1.32×10^{-2}	0.042
Non-Potentially Acid Generating (NPAG) Tailings	2.83×10^{-2}	0.35
Finger Drain	283	0.15
Blanket Drain	142	0.15
Queen Creek Alluvium	1,000	0.16
Tributary Alluvium	500	0.16

Table 2. Model Water Balance

	Alternative 2 acre-feet	Alternative 3 acre-feet
ANNUAL INFLOWS	**3,107.5**	**1,736.3**
TSF Recharge	2132.8	760.3
Natural Recharge	613.4	616.1
Underflow into Model Domain	319.3	318.8
Queen Creek Subflow	42.0	41.1
ANNUAL OUTFLOWS	**3,107.4**	**1,736.4**
Embankment Drains	809.6	399.2
Finger Drains	1,071.5	238.4
Seepage Collection Dams	0.6	15.3
Auxiliary Pump Back Wells	593.9	483.7
Groundwater ET	213.9	214.7
Whitlow Ranch Dam Flow	417.9	385.1
Error	0.1	-0.1

Table 3. Recharge Applied to TSF

	Alternative 2		Alternative 3	
	NPAG Tailings	**PAG Tailings**	**NPAG Tailings**	**PAG Tailings**
Recharge (gpm/acre)	0.52	0.16	0.14	0.16
Recharge (AF/yr)	1909.7	223.1	628.4	131.9

gpm = gallons per minute

NPAG = Non-Potentially Acid Generating

PAG = Potentially Acid Generating

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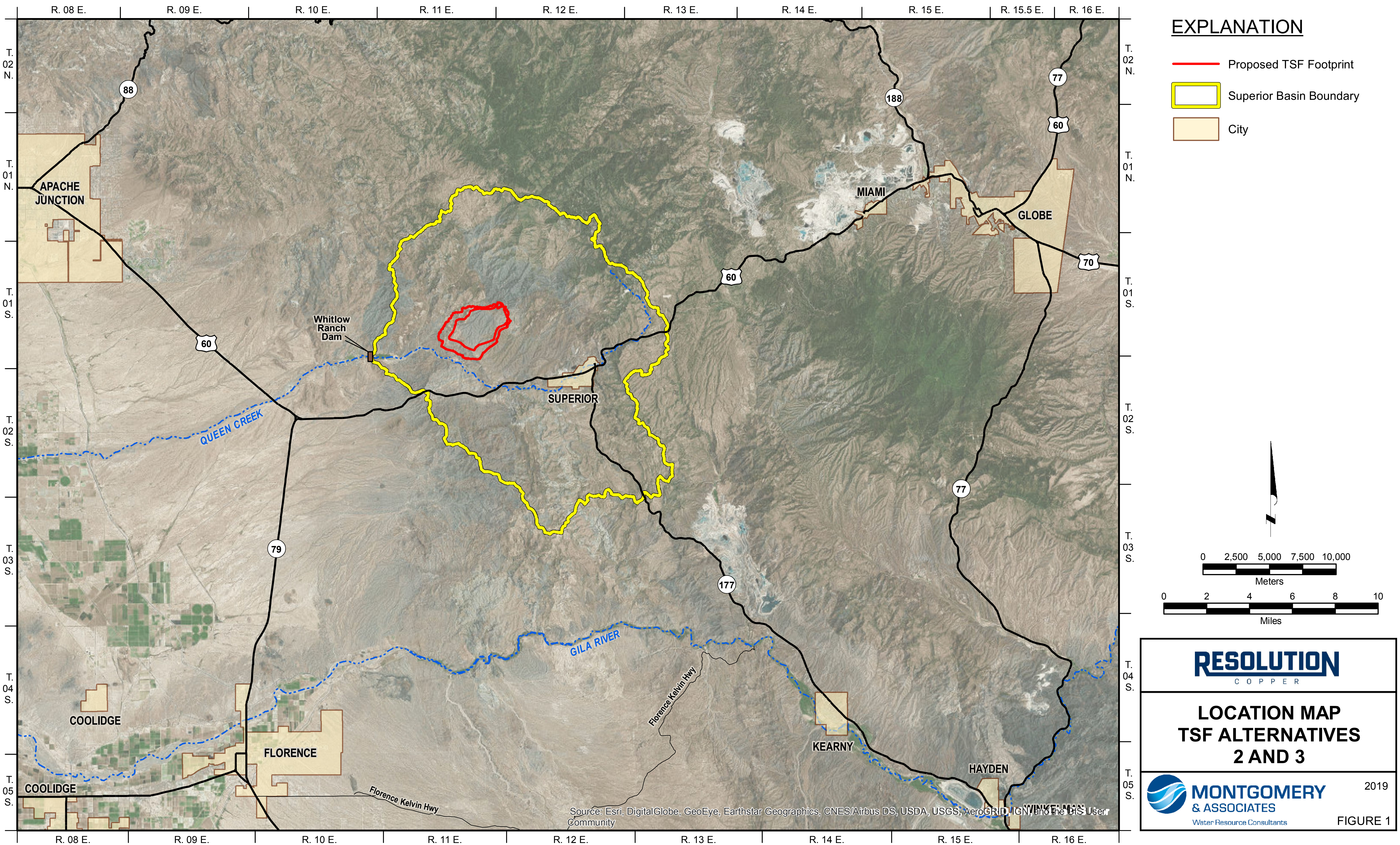
Table 4. Seepage into Alluvium

Aquifer subdomain	Alternative 2 AF/yr	Alternative 2 gpm	Alternative 3 AF/yr	Alternative 3 gpm
Roblas Canyon	9.3	5.8	1.8	1.12
Potts Canyon	8.5	5.3	0.4	0.25
Queen Creek	2.9	1.8	0.5	0.31
Total Seepage	20.7	12.9	2.7	1.68

gpm = gallons per minute

Table 5. Transit Times

Aquifer Subdomain	*K (ft/d)*	*n*	*dl (ft)*	Alternative 2 *dh (ft)*	Alternative 2 *dh/dl*	Alternative 2 *t (yr)*	Alternative 3 *dh (ft)*	Alternative 3 *dh/dl*	Alternative 3 *t (yr)*
Roblas Canyon	0.0354	0.0450	3,609	362.0	0.111	113	166.4	0.0461	273
Potts Canyon	0.0304	0.0176	2,830	401.9	0.128	35	150.9	0.0533	84
Queen Creek	0.0750	0.0482	4,250	599.8	0.141	53	260.6	0.0613	122



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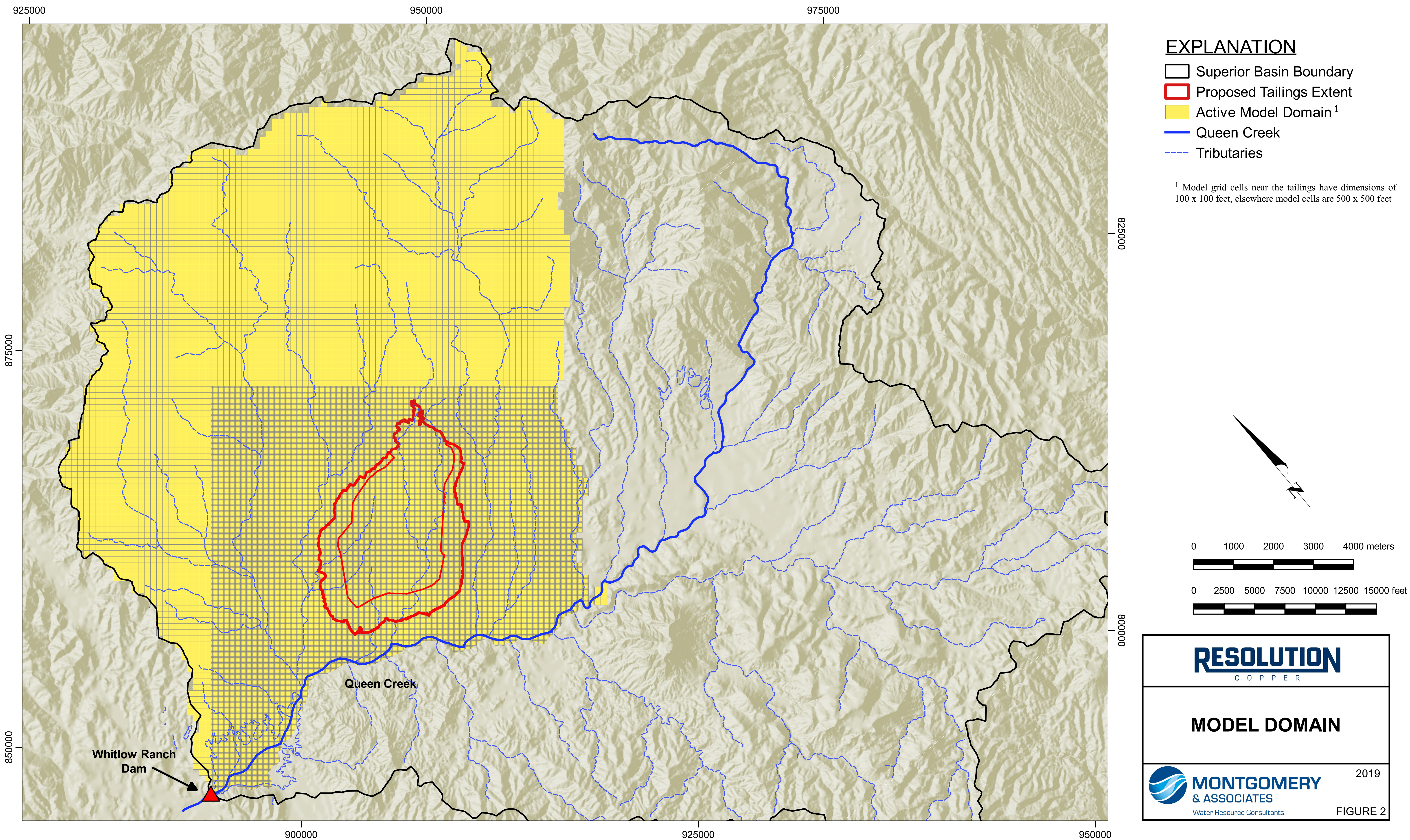

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MODEL DOMAIN

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FIGURE 2

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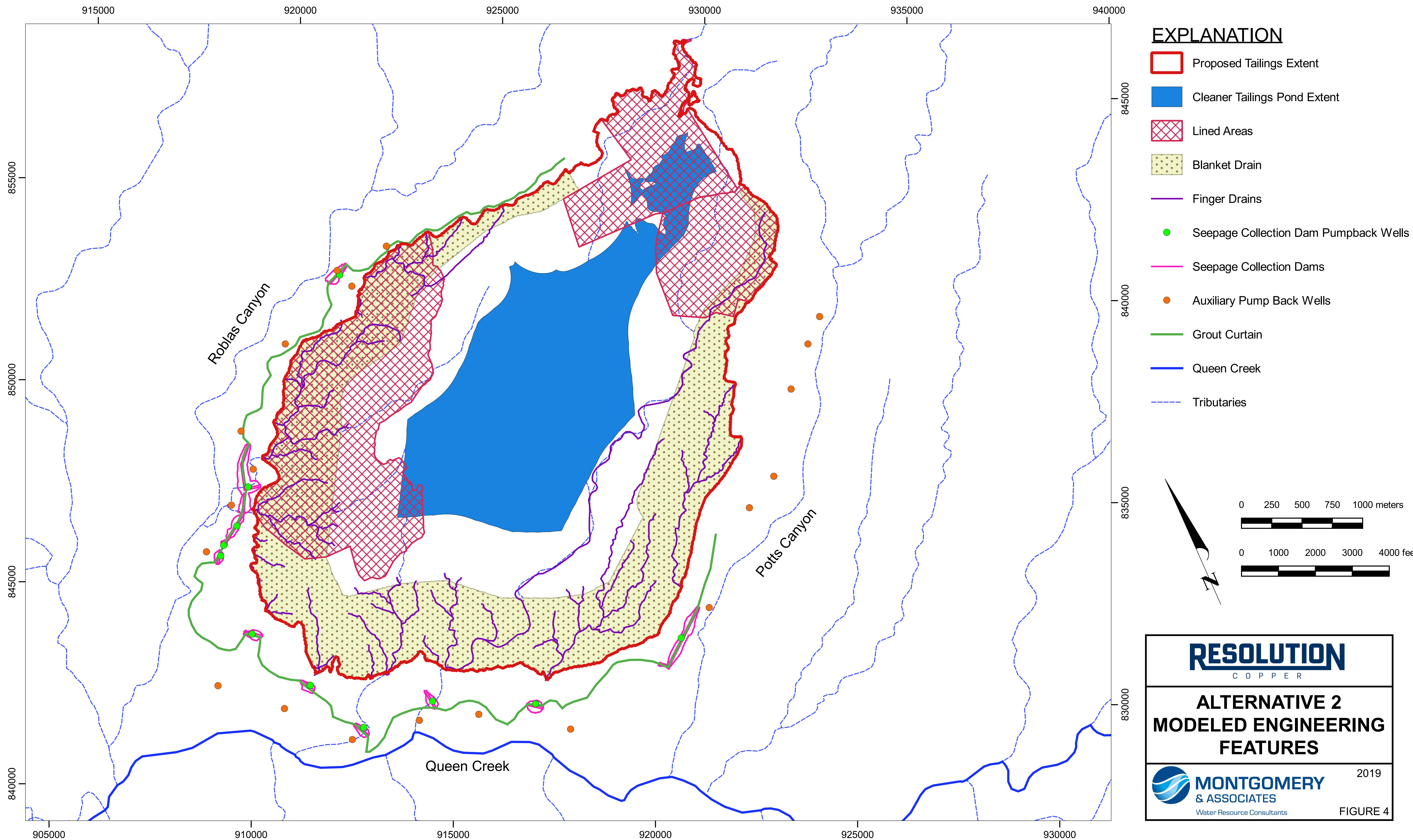
Figure 3. Model Layering

Model Layer	Represents	Outside TSF			Tailings Storage Facility							
					Unlined Area				Lined Area			
					No Finger Drains		Finger Drains		Finger Drains*		No Finger Drains	
		General	Tributary	Queen Creek Alluvium	Bedrock	Excavated Tributary Alluvium	Bedrock	Excavated Tributary Alluvium	Bedrock	Excavated Tributary Alluvium	Bedrock	Excavated Tributary Alluvium*
1	Outside TSF: inactive Inside TSF: tailings				100	100	100	100	100	100	100	100
2					100	100	100	100	100	100	100	100
3					100	100	100	100	100	100	100	100
4					100	100	100	100	100	100	100	100
5					100	100	100	100	100	100	100	100
6					97	97	97	97	97	97	97	97
7	Outside TSF: inactive Inside TSF: blanket drain or tailings				3	3	3	3	3	3	3	3
8	Outside TSF: 10 feet bedrock or 10 to 49 feet alluvium Inside TSF: finger drains, tailings, or bedrock	10	10	10 to 49	10	10	10	10	10	10	10	10
9	Outside TSF: 30 feet bedrock or 30 to 1 feet alluvium Inside TSF: bedrock	30	30	30 to 1	30	30	30	30	30	30	30	30
10	Bedrock	30	30	30 to 20	30	30	30	30	30	30	30	30
11	Bedrock	30	30	30	30	30	30	30	30	30	30	30
12	Bedrock	150	150	150	150	150	150	150	150	150	150	150
13	Bedrock	200	200	200	200	200	200	200	200	200	200	200
14	Bedrock	200	200	200	200	200	200	200	200	200	200	200

Inactive
Alluvium
Blanket drain; tailings where no blanket drain is present
Tailings
Finger drains
Native bedrock
Value in cell indicates layer thickness in feet

Land surface
Low-permeability liner

*vertical liners are only present on the sides of the cell parallel to the downslope direction



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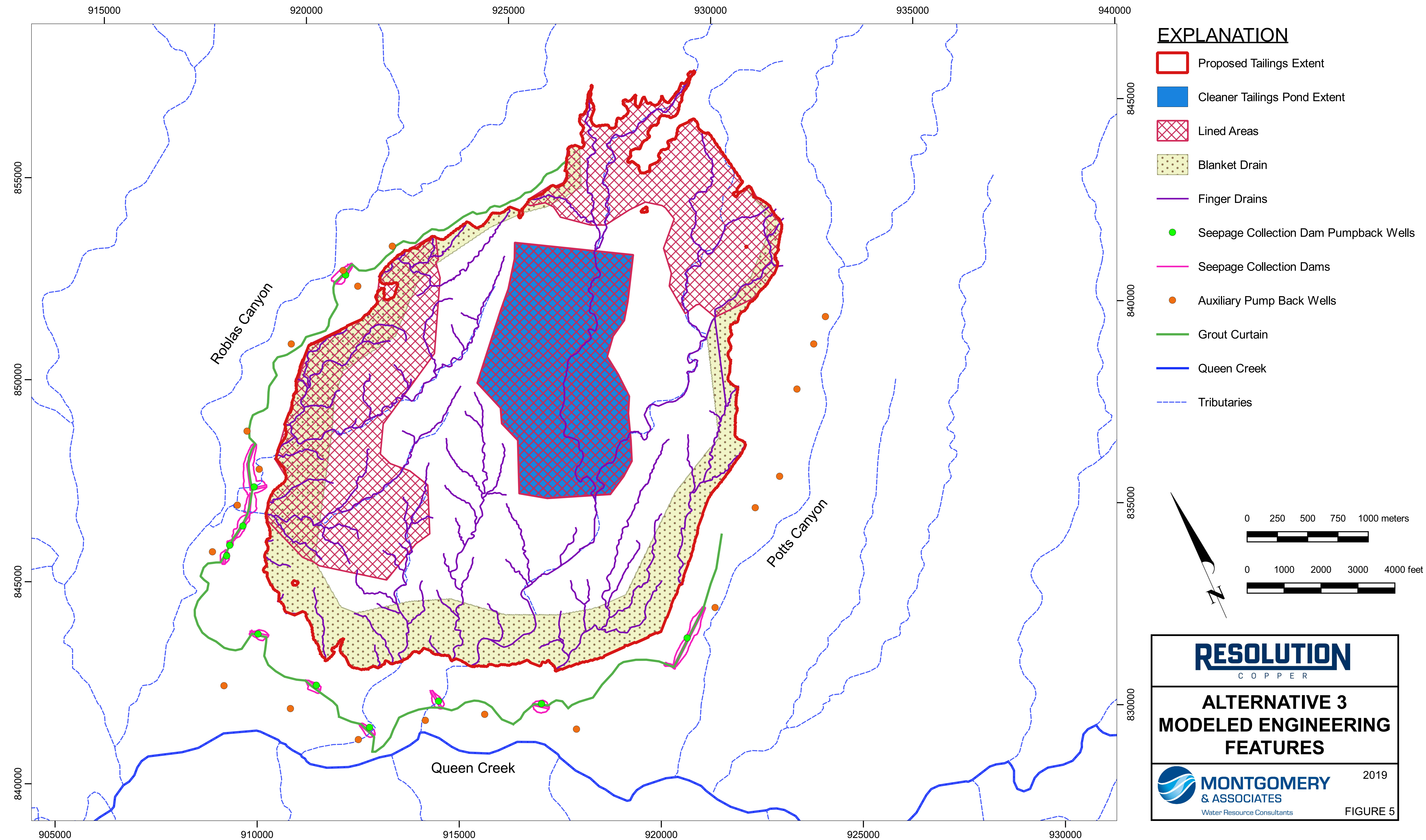

RESOLUTION COPPER

ALTERNATIVE 3 MODELED ENGINEERING FEATURES

MONTGOMERY & ASSOCIATES Water Resource Consultants

2019

FIGURE 5

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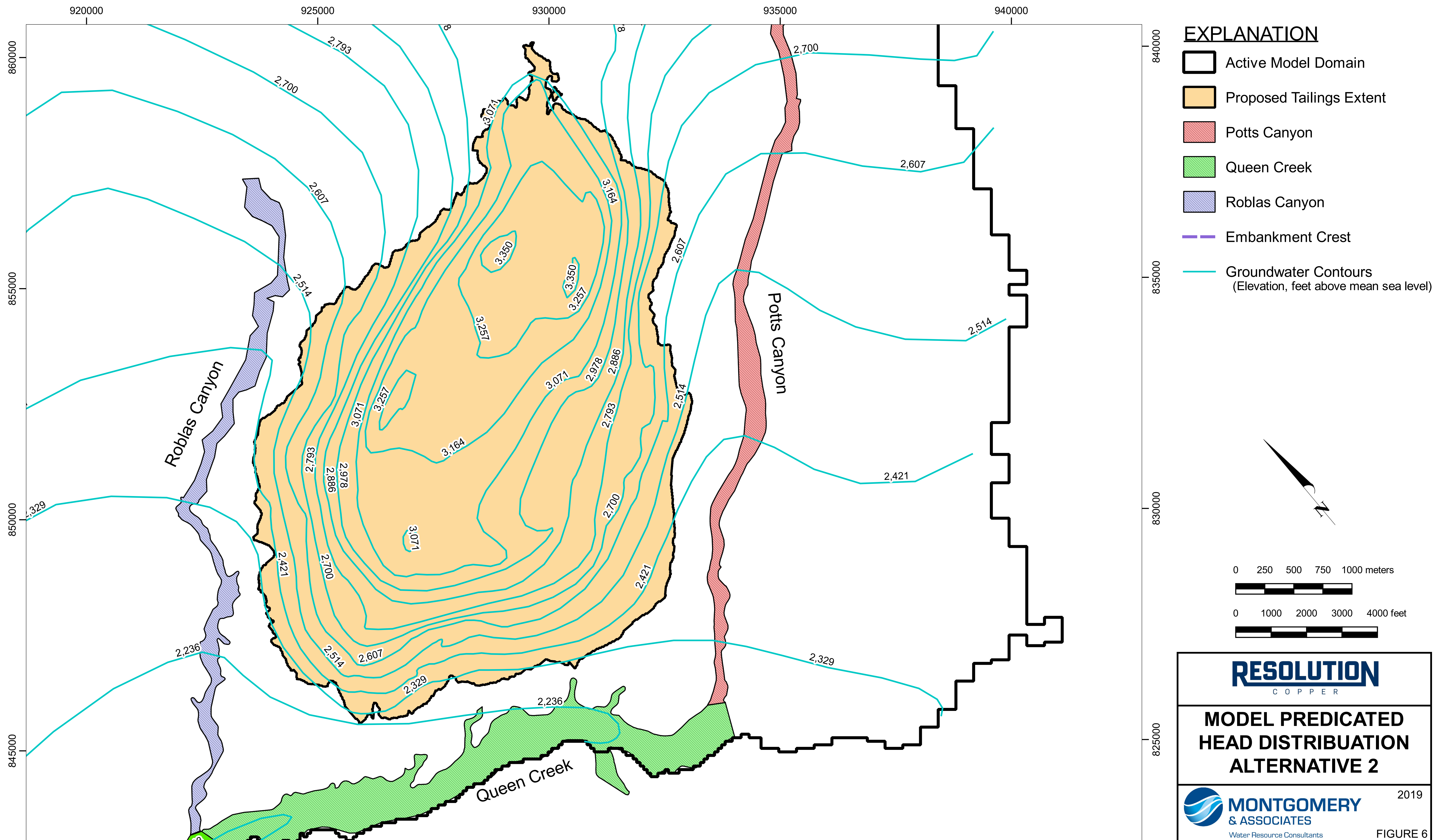

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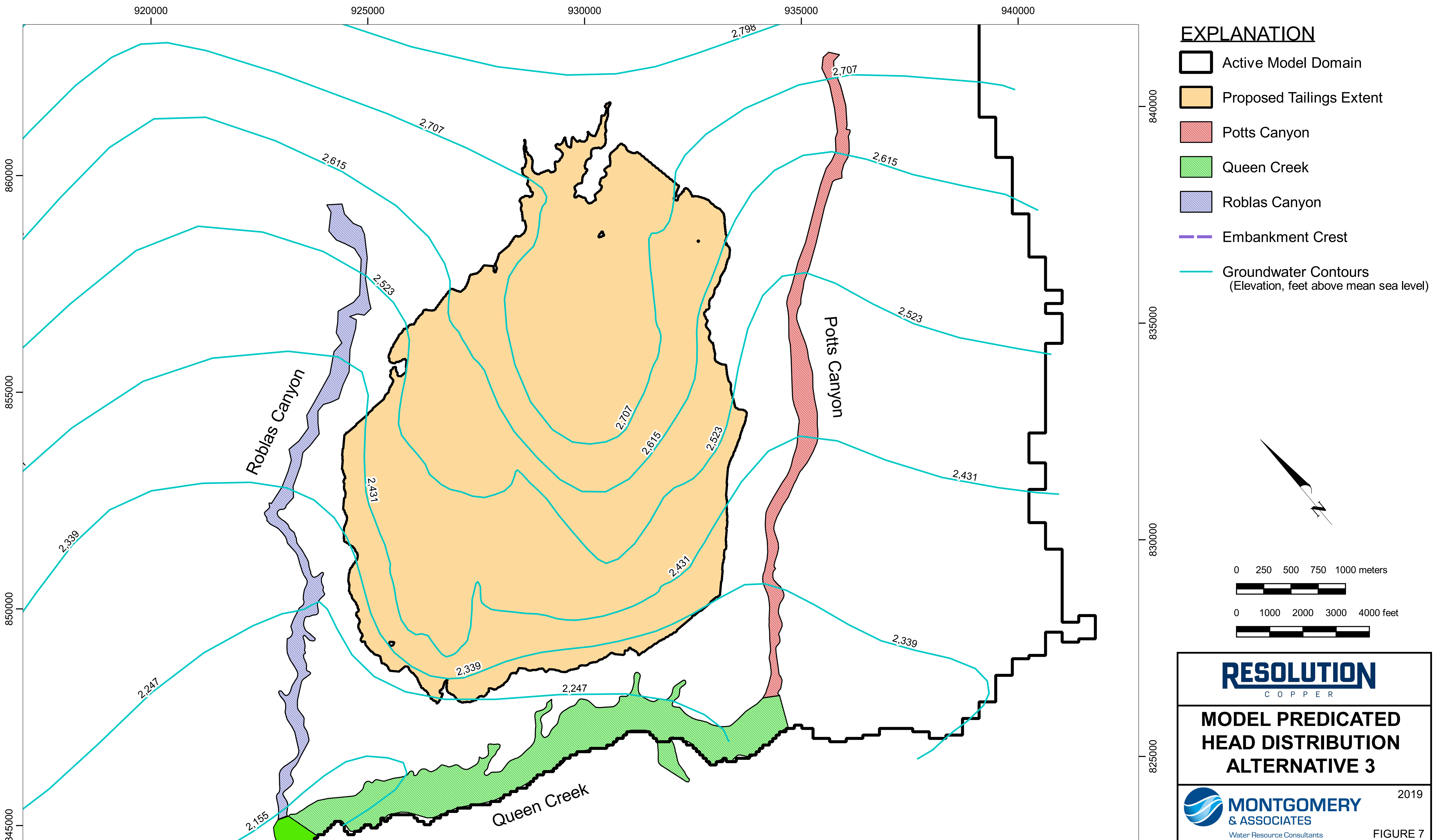

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