RESOLUTION COPPER, LLC

RESOLUTION COPPER GROUNDWATER FLOW MODEL REPORT

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1 INTRODUCTION

1.1 PURPOSE OF THE MODEL AND STRUCTURE OF REPORT

The regional numerical groundwater model constructed for the Resolution Copper (RC) project is described in detail in this report. The model has been built to address potential environmental impacts associated with the proposed mine in support of an Environmental Impacts Study (EIS) overseen by the United States Forest Service (USFS). The model replicates historic hydrogeologic conditions, including the historical dewatering of the Magma Mine and calibrated to the measured groundwater levels. The calibrated model is used to:

- Support and validate the conceptual understanding of the hydrogeologic system
- Evaluate and predict future hydrogeologic impacts from the proposed Resolution Mine during construction, operation and closure/post closure phases, to specifically address issues raised during public scoping:
  - For the Life of Mine - Issue 6: Impacts to water resources. Specifically Issue *6A Groundwater Availability* and *6C Surface Water Availability*.
  - For the Closure/Post-Closure – Issue 6: Impacts to Water Resources. Specifically issues *6B Groundwater Quality* and *6D Surface Water Quality*, as the potential for a pit lake will be assessed.
- Inform the future hydrogeologic monitoring and mitigation program.

The predictive simulations encompass the mine construction and operation phases when dewatering activities will occur, as well as the post-mining closure and post-closure period, when the dewatering system will be decommissioned and groundwater levels recover.

The purpose of this report is to summarize the construction and calibration of the regional groundwater model, including historical and predictive periods. The specific goals are as follows:

- Provide background on the project, historical mining, the future proposed mining method and dewatering both historical and current (described in Section 1)
- To reference the available data sets from the hydrogeologic characterization of the project area and describe the conceptual hydrogeologic model as the basis underpinning the numerical groundwater flow model (described in Section 2).
- To describe the model construction and how the important hydrogeologic system components are incorporated into the numerical model (described in Section 3).
- To detail the groundwater flow model calibration and its ability to replicate historical data (described in Section 3).
- To describe the proposed life of mine plan and how it is incorporated into the model setup (described in Section 4).
- To describe the setup of the predictive simulations for mine closure and post-closure groundwater system recovery phases (described in Section 4).

Predictive results for the life of mine and closure/post-closure periods are presented in *Resolution Copper Groundwater Flow Model - Predictive Results Memo* (WSP, 2018a).

1.2 PROJECT BACKGROUND

The Resolution Copper project includes a proposed underground mine, ore processing operations, and associated facilities and infrastructure. The proposed mine is located approximately 2-3 miles east of the town of Superior, in Pinal County, Arizona (Figure 1.1). It is in the same area as the historical Magma Mine, and extraction will be generally from a mineral deposit that is adjacent to the Magma orebody, but deeper and to the southeast.

The depth of the RC deposit ranges from about 4,500 to 7,000 feet (ft) below ground surface (bgs), it is massive with a thickness locally greater than 1,600 ft. The deposit is bound on all sides by structure in what is referred to as the Resolution Graben. Existing Shafts 9 and 10 currently extend to depths of 4,882 and 6,943 ft bgs, respectively. Shaft 9 was completed in 1973, and Shaft 10 was constructed by RC and completed in December 2014. The existing Magma Mine workings in the East Plant Site area extend to the 4300 level, which is approximately 4,900 ft bgs at Shaft 9. The proposed RC mine workings would be approximately 2,100 ft deeper.

The proposed mine will use the underground mining method known as panel caving. The footprint area of the RC orebody is a little over one square mile. Caving would be induced by undercutting the ore zone, removing its ability to support the overlying rock material. From the ore extraction level near the bottom of the mine, fractures would extend upward causing the ore to collapse and form a cave zone, which would gradually propagate upward through the geologic sequence and would eventually intersect the ground surface.

1.3 PROJECT SETTING

The RC project area lies within the Basin and Range physiographic province, and includes a combination of basins to the west and rugged mountainous terrain to the north and east and south (Superstition, Pinal, Dripping Spring and Mineral Mountains), see Figure 1.1.

The north-south trending Apache Leap escarpment separates the project into two areas: the West Plant Site and the East Plant Site (Figure 1.2). The Apache Leap escarpment consists of a series of vertical cliffs up to 300 ft high, with a westward drop in topography toward the Superior Basin of over 1,000 ft. The town of Superior lies immediately to the west of the escarpment at an elevation of approximately 2,900 ft above mean sea level (amsl). The East Plant Site and associated Shaft 9 and Shaft 10 (collared at 4,167 ft amsl) lie to the east of the Apache Leap escarpment. The site encompasses the proposed underground mine, associated shafts (existing Shafts 9 and 10 and proposed Shafts 11-14), and surface support facilities. The surface topography is rugged and includes rocky outcrops and steep canyons, with minimal soil coverage in some areas and thick desert vegetation. Topographic elevations at the East Plant Site range from 3,900 to 4,600 ft amsl.

The Resolution deposit and mine area (East Plant Site) is currently overlain by lands administered by the Tonto National Forest, as well as state and RC private land. The area above the deposit is an area of relatively flat topography compared to the extreme topography of the surrounding land scape: Queen Creek to the northwest, Apache Leap to the west, Devils Canyon to the east and highway US 60 to the north. Queen Creek forms a steeply incised canyon through the Apache Leap escarpment that is followed by highway US 60 and exits the canyon at the eastern edge of the town of Superior. Oak Flat, which is an area of relatively flat topography and includes an existing U.S. Forest Service campground, is immediately northeast of the proposed mine. East of the East Plant Site and the RC mine area is Devils Canyon, a north-south canyon that is approximately 300-500 ft deep and forms the east side of Oak Flat. The topography rises to over 5,600 ft amsl on the divide between Queen Creek and Devils Canyon about three miles north-northeast of the East Plant Site, as well as at Hutton Peak near Top of the World, about five miles east-northeast of the East Plant Site. The East Plant Site area is completely uninhabited.

West of the Apache Leap escarpment, the Superior Basin extends south of the Superstition Mountains and is drained by Queen Creek, which drains west from the town of Superior. The West Plant Site is located in the Superior Basin and includes the RC water treatment facility, RC administrative offices and the proposed concentrator. Queen Creek leaves the Superior basin at Whitlow Ranch Dam (USGS Gaging Station 09478500) at an elevation of 2,040 ft amsl.

1.4 HISTORIC MINING AND DEWATERING

Historic mining in the district commenced in 1875, exploiting ore within the Paleozoic and Precambrian Apache Group bedrock. From 1875 to 1910, mining activity centered on the Silver King Mine, north of Superior. Other mines opened during this period, including the Silver Queen Mine (which became the Magma Mine) and the Lake Superior & Arizona (LS&A) Mine (near the mouth of Queen Creek, just south of the Magma Mine). Apart from the Silver King and the LS&A, other mining in the area appears to have occurred in shallow veins and bedding planes above the groundwater level. The

Magma Copper Company was formed in 1910 and the Magma Mine underground workings include an extensive system of shafts, tunnels, drifts, and stopes that cover an area of approximately 1.2 square miles (see Figure 1.2 and 1.3).

1.4.1 EXISTING MINE WORKINGS AND INFRASTRUCTURE

SHAFTS

Nine vertical shafts (Shafts 1 through 9) were installed for the Magma Mine (see Figure 1.3). Shaft 1 (collared at 3,585 ft amsl) was commenced in 1882 and completed to a depth of 800 ft in 1912. The Shaft 1 collar (3,585 ft amsl) is considered to be zero mine level and other Magma mining levels are referenced to this datum. By about 1940, shafts were constructed to depths of 4,000 ft bgs as part of the Magma Mine operation and largely confined to the West Plant Site. In the early 1970's and driven by ore accessibility issues, Shaft 9 was constructed in the location of the current East Plant Site in the early 1970's.

Completed in December 2014, Shaft 10 was installed by RC to a depth of 6,943 ft (2,776 ft below sea level), near the base of the ore and close to the proposed full depth of future mining. Shafts 9 and 10 are approximately 300 ft apart in the East Plant Site area within the Resolution Graben and are collared at 4,167 ft amsl. They are sunk through the Apache Leap Tuff, Whitetail Conglomerate and into the deep bedrock units. Shaft 9 is planned to be deepened to a similar depth as Shaft 10.

Table 1.1: Details of the existing mine shafts

Shaft	Collar elevation (ft amsl)	Bottom elevation (ft amsl)	Depth of Shaft (ft below collar)	Construction began	Construction completed
1	3,585	2,785	800	1882	1912
2	3,385*	-16	3,401	1915	1942
3	3,435	-1,214	4,649	1917	1942
4	3,514	2,087	1,427	1921	1923
5	3,137	-1,457	4,594	1926	1959
6	3,663	-217	3,880	1929	1957
7	3,011	1,033	1,978	1929	1931
8	3,168	-1,214	4,382	1935	1942
9	4,167	-715	4,882	1969	1973
10	4,167	-2,776	6,943	2009	2014

** Shaft 2 collar is underground*

NEVER SWEAT TUNNEL

The Never Sweat Tunnel (NST) was developed as part of the Magma Mine and connects the West Plant Site near Superior to the East Plant Site at Shaft 9. Construction began in 1965 and the tunnel was driven eastwards from the base of the Apache Leap escarpment. The tunnel was driven at a slight upward incline (~1%) and intersects Shaft 9 at 3,077 ft amsl (~1,090 ft bgs).

UNDERGROUND WORKINGS

The Magma Mine workings were driven generally eastwards from the shafts below the Apache Leap escarpment and cover an area of about 1.2 square miles. The workings are divided into zones that include: West, Central, Koerner, East and Far East, as shown on Figure 1.3. They extend to an elevation of approximately -1,315 ft amsl. Prior to the construction of Shaft 10, the deepest part of the mine was Shaft 5, which extends to -1,457 ft amsl. Workings in the East Plant Site area extend to about -715 ft amsl at Shaft 9. There is a high point within the lowest workings between the eastern and western areas that lies at about -15 ft amsl (at the Magma Mine 3600 Level). Note that the levels are not perfectly horizontal, but dip at about 1 percent to the west for drainage (McIntosh Engineering, 2005).

Some of the Magma Mine workings were backfilled, specifically: 1) the majority of stoped areas within the mine were backfilled with a 10:1 ratio of cement and tailings; 2) portions of tunnels and drifts were backfilled; and 3) connections between the east and west sides of the mine at the 3200, 3300 and 3500 levels were backfilled (McIntosh Engineering, 2005).

1.4.2 HISTORIC AND ONGOING DEWATERING

DEWATERING FROM 1910 TO 1998

Large-scale mine dewatering activity began in 1910. The water level in Shaft 1 was reported to be at approximately 3,150 ft amsl in 1910, prior to extensive dewatering (Short, et al., 1943). This is about 50 ft above the bed of the nearest reach of Queen Creek, 0.5 mile to the south (M&A, 2017b). Dewatering of the Magma Mine was roughly continuous from 1910 until 1998, except for the period between 1986 and 1989 when no significant pumping occurred. Although active mining in the Magma Mine ceased on June 30, 1996, the underground mine dewatering system remained in operation until May 6, 1998, when the dewatering pumps in the mine were shut off.

Prior to 1978, pumping from Shaft 3 represented all dewatering from the mine. Water from the eastern areas of the mine were pumped through the 3600 level to the western side of the mine (to Shaft 6), from where it could be stored and subsequently pumped out of Shaft 3. In 1978, the pumping system was installed in Shaft 9 and Shafts 3 and 9 were directly connected through the 3600 level. Thus, dewatering of the entire mine to about -15 ft amsl could be accomplished by pumping either shaft. There are no hydrological connections between the eastern and western areas of the mine below the 3600 level. Dewatering operations were conducted from both Shafts 3 and 9. In May 1986, the mine was shut down and dewatering was discontinued for a three-year period, allowing a partial recovery (1,100 ft) of water levels until pumping resumed in August 1989.

Annual average dewatering rates for the Magma Mine based on pumping from Shaft 3 and/or Shaft 9 (depending on the year) ranged from 387 to 922 gpm (for the period 1963-1997), and usually averaged between 500 and 700 gpm (Figure 1.4). Pumping at that rate caused drawdown of 3,750 ft (1997 water level at -595 ft amsl) and achieved successful dewatering of the workings.

Following the shutdown of the dewatering system on May 6, 1998, the rising water levels were monitored in Shaft 9. At shut down, the water level in Shaft 9 was at -595 ft amsl and the water level in Shaft 3 was at approximately -15 ft amsl. Water level recovery was also monitored in Shaft 3 starting in 2001. Water levels had recovered to approximately 2,200 ft amsl by the time dewatering was resumed on March 17, 2009. The 2009 water levels (2,100 ft amsl) were still below the pre-1910 water levels (about 3,150 ft amsl).

DEWATERING FROM 2009 TO PRESENT

Sinking of Shaft 10 began in February 2009 and dewatering of Shaft 9 was resumed on March 17, 2009. Shaft 10 was completed to a total depth of 6,943 ft in December 2014. Figure 1.4 shows the pumping rate from Shafts 9 and 10 through December 2016 (dewatering is ongoing). Details of the dewatering are as follows:

— By December 2011, the water level in Shaft 9 was down to 4,680 ft bgs (-515 ft amsl), and is maintained at that level. The required pumping rate from Shaft 9 to maintain the water level at 4,680 ft bgs is varies between 550-625 gpm.

— Shaft 10 was deepened below the base of Shaft 9 (4,882 ft bgs, -715 ft amsl) beginning in January 2012.

- Early inflows to Shaft 10 were up to 75 gpm, but typically less than 50 gpm until Shaft 10 sinking reached approximately 6,450 ft bgs.
- In December 2012, Shaft 10 intersected fractures within the Paleozoic limestone near 6,450 ft bgs and the associated inflow required the pumping rate to be increased from about 10 gpm to about 250 gpm to maintain dry working conditions.
- Between January and October 2013, the inflow rate rose steadily to 450 gpm when Shaft 10 reached 6,630 ft bgs and into the diabase, resulting in the inflow rate to Shaft 9 gradually decreasing.
- During early 2014, when the depth of Shaft 10 was reached 6,650 ft bgs, the inflows were 140 gpm from Shaft 9 and 480 gpm from Shaft 10, to give a combined rate of 620 gpm. In the past five years, the combined pumping rate from Shafts 9 and 10 is consistent with the average historic pumping rate from the Magma workings (500-700 gpm in the 1960s through 1990s).

1.5 PROPOSED MINE PLAN

The Resolution ore zone is hosted within the Cretaceous volcaniclastic, Paleozoic, and Precambrian Apache Group rock units. The ore will be removed from a series of vertical, conical shaped draw points (referred to as “drawbells”) on the extraction level near the bottom of the mine. As ore is removed from drawbells, the overlying material will collapse, filling the void space that the extracted ore previously occupied, thus allowing broken ore to be extracted as it moves down from the column above. The collapsed material increases in volume from its in-situ state in a process called bulking (swelling).

The mine plan involves development of infrastructure to a depth of approximately 7,000 ft bgs, approximately 2,100 ft deeper than the existing Magma Mine workings. The mine will require six shafts (Shafts 9 through 14) to be located at the East Plant Site) for a planned production rate of 120,000 tonnes per day mining rate providing access into the mine, removal of ore from the mine, and to move sufficient volumes of conditioned air into and out of the mine. At the planned 120,000 tonnes per day mining rate, the life of mine would be approximately 40 years.

The initial mine excavations and cave zone would experience groundwater inflows into the deep bedrock. As mining proceeds and the ore moves downward towards the extraction level, fracturing and fragmentation in the cave zone propagates upward to the overlying units (Whitetail Conglomerate and Apache Leap Tuff). Eventually, the fracturing and fragmentation within the cave zone would propagate upward to the ground surface, creating a zone of surface subsidence centered over the orebody.

The groundwater inflows to the cave zone would enter the evolving fracture pore spaces as the material fragments. Part of the water would be retained within the cave in the developing pore space, and some would drain down to the extraction level at the base of the cave zone, where it would be pumped to the surface to maintain dry safe working conditions. A scaleable dewatering system will therefore be required to prevent water from adversely affecting efficiency and safety during construction and mine operation.

2 HYDROGEOLOGY

Analysis of available hydrological and hydrogeological data was used to prepare a hydrogeological conceptual site model (CSM) of the RC project area. This chapter summarizes the sources of hydrogeological data and key features of the conceptual model, which form the basis of the numerical groundwater flow model (described in Section 3).

2.1 SOURCES OF DATA

RC has carried out a comprehensive hydrogeologic study to characterize groundwater and surface water. The goal has been to investigate, evaluate and demonstrate current conditions to assess the potential for future changes to the groundwater system as a result of the proposed project development and subsequent impacts on surface water. The investigation quantified the existing effects of historical and ongoing mine dewatering (for protection of mine and shaft infrastructure) and compiled available historic data to help establish baseline conditions. Work was initiated in 2002 for the Order of Magnitude (OoM) Study, and in 2007 for the Pre-feasibility Study (PFS). The studies involved numerous consulting firms and technical specialists. The work has included:

GROUNDWATER

- Installation of groundwater monitoring wells and vibrating wire piezometers (VWPs).
- Establishment of a water level and water quality monitoring network that includes:
  - 87 shallow boreholes at 76 locations, including those installed by RC (HRES series), those installed by BHP-Billiton (BHP), and private wells.
  - 57 VWPs installed in 11 multi-level completions (grouted in place).
  - 12 deep monitoring wells with open well screens in the deep groundwater units (DHRES holes).
  - 4 open boreholes in the shallow Apache Leap Tuff (PHRES holes).
- Short-term aquifer tests, slug tests, and packer tests.
- Long-term aquifer tests (pumped for 23 to 90 days) at 5 wells.
- Monitoring of pumping rates and water levels during shaft dewatering and recovery.

Data are summarized in *Analysis of Groundwater Level Trends Queen Creek / Devils Canyon Study Area* (M&A, 2017a).

SURFACE WATER

- Sampling of surface water at 37 sites for hydrochemistry to understand sources of water and installation of 10 data sondes for the baseline surface water sampling program.
- Inventory of perennial stream flow reaches occurrence surveys, springs and seeps investigations in Devils Canyon, Upper Queen Creek, and a portion of Mineral Creek, and springs emanating from the Apache Leap escarpment and the Superior Basin.

Data are summarized in *Surface Water Baseline Survey: Devils Canyon, Mineral Creek, and Queen Creek Watersheds* (M&A, 2013) and *Surface Water Baseline Addendum: Upper Queen Creek, Devils Canyon, and Mineral Creek Watersheds* (M&A, 2017b).

GEOLOGIC AND HISTORIC MINING CHARACTERIZATION

Detailed descriptions of geologic units and the structural geologic framework for the project area are summarized in:

- *Summary of Geologic Information Relevant to Development of the Porphyry Cu-Mo Resolution Deposit, Arizona* (4DGeo – Applied Structural Geology, 2017)
- *Geology and Exploration Progress at the Resolution Porphyry Cu-Mo Deposit, Arizona* (Hehnke, et al., 2012).

— *Fault Core Review and Guidance for Groundwater Modeling* (Wickham GeoGroup, 2015a)

Historical geological and mining information include:

— *Geology and ore deposits of the Superior mining area, Arizona* (Short, et al., 1943)
— Engineering drawing of Magma Mine workings (McIntosh Engineering, 2005)
— Magma Mine pumping and dewatering data
— Magma Mine annual reports.

Content within all referenced field data reports were analyzed and used for development of the conceptual and numerical models.

2.2 HYDROGEOLOGIC CONCEPTUAL MODEL

2.2.1 GENERAL HYDROGEOLOGIC SETTING

From a general geological and hydrogeological standpoint, the Concentrator Fault zone (Figure 2.1) represents a major domain boundary given the large vertical displacement (westside is downdropped several thousand feet relative to the east side). The geologic units east of the Concentrator Fault, from the base of the Apache Leap escarpment eastward, are significantly different than those west of the Concentrator Fault across the Superior Basin, as summarized below. Furthermore, due to the permeability contrasts of adjacent rock units, large discontinuities appear in groundwater levels across the fault. An east-west cross section representing the principal components of the hydrogeological conceptual model is shown in Figure 2.2.

East of Concentrator Fault (and east of the Apache Leap Escarpment), the principal hydrogeologic units include:

— Quaternary alluvial deposits (Qal), primarily thin and discontinuous units lying along the major surface water features (Devils Canyon, Queen Creek, and Mineral Creek).
— Tertiary Apache Leap Tuff (Tal), forming the shallow groundwater system.
— Tertiary Whitetail Conglomerate (Tw), which is dominated by fine-grained materials and forms a low permeability aquitard.
— The Deep Groundwater System, consisting of undifferentiated Paleozoic sedimentary units (Pz; carbonates and quartzites), Precambrian Apache Group metasediments (pCy; carbonates, sandstones, siltstones, quartzites, and diabase), and, within the Resolution Graben, Cretaceous volcaniclastics (Kvs). All the ore in the existing Magma Mine and the proposed Resolution Copper Project is contained within units of the Deep Groundwater System within the Resolution Graben.
— Precambrian Pinal Schist (pCpi) is underlying the above units.

West of the Concentrator Fault (in the Superior Basin), the principal hydrogeologic units are:

— Quaternary alluvial deposits (Qal), primarily lying along the major surface water features (Queen Creek and tributaries).
— Quaternary–Tertiary upper Gila Conglomerate (QTg).
— The mudstone unit of the Gila Conglomerate, which occurs within the Gila Conglomerate in the West Plant site area, forms a discontinuous semi-confining layer.
— The Deep Groundwater System, consisting of the Gila Conglomerate (QTg) below the mudstone unit, older and younger Tertiary volcanics (Tvo, Tvy), Apache Leap Tuff (Tal), undifferentiated Paleozoic sedimentary units (Pz), and the Precambrian Apache Group (pCy), as in the east system.
— Precambrian Pinal Schist (pCpi) is underlying the above units and in some areas outcrops at the ground surface.

Further detailed descriptions and supporting data of each hydrogeologic unit are presented in Section 2.2.2 below. In addition, hydrogeologic cross sections (Figures 2.3 and 2.4) showing May 2015 water levels are also shown and will be referenced for supporting evidence of the conceptual model.

Numerous fault zones occur, the most prominent of which is the north-south trending Concentrator Fault zone and its associated splays, namely the Main Fault. The Resolution ore deposit occurs within the Deep Groundwater System inside a fault bounded graben formed by the North Boundary, West Boundary, South Boundary, Rancho Rio and Conley Springs faults, referred to as the Resolution Graben (Figure 2.1).

2.2.2 HYDROGEOLOGIC UNITS

To simplify the geology for use in the hydrogeological conceptual model and numerical groundwater flow model, geologic units were combined into a simplified set of Hydrogeologic Units (HGUs) based on hydrogeologic characteristics. There are 10 basic HGUs defined in the project area, not including the faults. These HGUs are described below.

ALLUVIUM

There are isolated pockets of alluvial material (Qal) deposited on the surface of the underlying bedrock, generally along streambeds. The alluvium has hydraulic conductivity and porosity that is generally much greater than the underlying bedrock. The minor alluvial groundwater contained within these pockets is isolated from any regional flow and is hydraulically decoupled (perched) from the groundwater system in some cases, but in others is connected to the underlying bedrock groundwater system.

Where saturated alluvial deposits occur along the bases of the main drainages, the deposits may be more continuous, and may be elongated along the channel floor. These deposits may receive recharge due to occasional runoff from the surrounding area or along the drainage itself, or, in the lower lying areas where the bedrock water levels are near-surface, they may receive groundwater recharge from the bedrock hydrogeologic units. Where there is bedrock groundwater discharge into the alluvium, the alluvium and bedrock may locally be in continuity, including the continuously saturated reaches of Devils Canyon and Mineral Creek (M&A, 2017b).

Where the water table in the bedrock is below the base of the alluvium in the creek bed (throughout much of Queen Creek and tributaries as well as localized areas along Devils Canyon and Mineral Creek), the alluvium may locally collect and store surface water runoff, which then either discharges to the surface, is lost to evapotranspiration, or contributes to bedrock groundwater recharge along the drainages.

GILA CONGLOMERATE

West of the Concentrator Fault, the Quaternary-Tertiary Gila Conglomerate (QTg) is the main geologic unit; it is over 3,000 ft thick in the West Plant Site area. Due to offset from the Concentrator Fault zone, the Gila, Paleozoic and Precambrian rock are juxtaposed together (Figure 2.2 and 2.3). In the study area, it is a fluvial basin fill deposit formed during a period of down-faulting of the Superior Basin and occurs west of the Concentrator Fault. This unit includes unconsolidated to weakly consolidated Pleistocene and older Quaternary alluvial deposits, and moderately to well consolidated Tertiary sandstone and conglomerate consisting of pebble to boulder-sized, angular to sub-rounded fragments of older rocks in a poorly-sorted, arkosic sandstone matrix.

At the West Plant Site, there is a mudstone unit within the Gila Conglomerate that varies in thickness and depth, but thins and grades to silt to the north before ultimately pinching out. It is generally encountered between 20 and 200 ft bgs and ranges in thickness from 0 to 630 ft. The Gila Conglomerate is shown to have relatively low permeability in the project area. The combination of its low permeability and the presence of the Concentrator Fault zone represent a major hydrogeologic domain boundary to the west of the Magma Mine and RC mine area.

APACHE LEAP TUFF

The most significant unit in the East Plant Site and mine area is the Tertiary (early Miocene) Apache Leap Tuff (Tal), which is a crystal-rich, quartz latite, ashflow deposit, about 1,000 to 1,600 ft thick. It forms the surface outcrop geology throughout the East Plant Site area and extends east across Devils Canyon. It is also present at depth in some areas of the West Plant Site. The unit includes both welded and non-welded zones and, although it is largely considered to consist of a single cooling unit, it is seen to be fairly well stratified. Massive layers of unsorted ejecta with fresh, coarse fragments occur within some of the stratified zones. It is variably fractured, of low to moderate permeability and contributes to minor base-flow (downstream of the proposed RC mine) along some reaches of Devils Canyon and Mineral Creek.

YOUNGER TERTIARY VOLCANIC ROCKS

The younger Tertiary volcanic rocks (Tvy) occur in the central to southern portion of the study area in the Superior Basin, and include middle to early Miocene age felsic lavas and tuffs and basaltic lavas. Geologic units that are classified as Younger Volcanics include units Tb, Tt, Tfp, Tftp, and Tfpi (Spencer and Richard, 1995). These units are part of the Gila Group volcanic rocks of the Superstition Volcanic Field (Ferguson and Skotnicki, 2001) and include basaltic lavas (Tb) and felsic tuff (Tt) interbedded with the Tcg, and Picketpost Mountain Formation felsic lavas, tuffs, and hypabyssal intrusives (Tfp, Tfpt, and Tfpi, respectively). This unit is expected to behave hydraulically similarly to the Apache Leap Tuff. These units are found interbedded in the Gila Conglomerate at the West Plant Site.

OLDER TERTIARY VOLCANIC ROCKS

Older Tertiary volcanic rocks (Tvo) occur chiefly in the northwestern and northeastern parts of the study area and include early Miocene age volcanic rocks that predate the Apache Leap Tuff. These include felsic lavas and associated tuffs (Trdu and Trdt), rhyodacite lava (Trw), intermediate to mafic lavas (Tdm) in the northwestern part of the study area, and undifferentiated volcanic rocks (Tev) in the northeastern part of the study area. The formations form part of the Superstition Group volcanic rocks. These units are approximately 650 ft thick in the Roblas Canyon area (Spencer and Richard, 1995). This unit is expected to behave hydraulically similarly to the Apache Leap Tuff.

WHITETAIL CONGLOMERATE

The Tertiary Whitetail Conglomerate (Tw), which is dominated by fine-grained materials, occurs immediately below the Apache Leap Tuff and forms a low to extremely low permeability aquitard with a wedge-shaped geometry that thickens to the east (see Figure 2.2). The thickness of the Whitetail increases from less than 300 ft beneath the Apache Leap escarpment to almost 6,000 ft east of the mine beneath Devils Canyon. Based on water level data, the Whitetail is shown to separate the groundwater flow system in the Apache Leap Tuff from the underlying Deep Groundwater System.

CRETACEOUS VOLCANICLASTIC SEDIMENTS

The Cretaceous rocks consists of a sequence of volcaniclastic sedimentary rocks (Kvs; graywacke, conglomerate, lava flows and tuff, andesitic, rhyodacitic and dacitic) and quartzose sediments (Kqs; sandstone and siltstone). These rocks are found only within the graben area underneath the Whitetail Conglomerate. They are not exposed at the surface. Within the area of the proposed mine, the sequence is approximately 2,800 ft thick. The ore body is hosted in the lower half of the Cretaceous rocks. Groundwater movement is primarily through fractures. Groundwater present within the Kvs was under confined conditions, but dewatering of Shafts 9 and 10 has led to unsaturated conditions beneath the Whitetail Conglomerate resulting in an unconfined aquifer in the Kvs.

PALEOZOIC ROCKS

Paleozoic sedimentary rocks (Pz) overlie the Precambrian units. The main units within the sequence are the Cambrian Bolsa Quartzite (Cb), Devonian Martin Formation (Dm; chiefly dolomite and dolomitic limestone), Mississippian Escabrosa Limestone (Me) and Pennsylvanian-Permian Naco Limestone (Pn). Within the area of the Resolution Graben, the Paleozoic section has been significantly eroded and in some parts has been completely removed. The Naco Group has been completely eroded within the graben area, but is present immediately outside the graben. The Martin Formation and eroded remnants of the Escabrosa Limestone have been altered to skarn in the mine area. The thickness of the sequence within the project area is strongly controlled by faulting and ranges from less than 600 ft to over 1,500 ft within the planned area of the mine.

The Paleozoic rocks outcrop in a long narrow belt along the Apache Leap escarpment, where the beds maintain a fairly uniform 30 to 45° eastward dip, with localized fault blocks that contain west-dipping strata. The Paleozoic assemblage of rocks composes a portion of the lower half of the proposed block cave zone. Groundwater movement is primarily through fractures in the Paleozoic units. The Paleozoic unit generally has a confined aquifer, but pumping of Shafts 9 and 10 may have caused it to become unconfined in some areas, as with the Kvs. The Graben Faults impede lateral groundwater flow, so strong inward gradients into the Resolution Graben have developed. The current recharge is derived from a combination of downward flow through the Whitetail and potentially some recharge where Paleozoic rocks are exposed in Queen Creek Canyon, particularly during and following periods when Queen Creek is flowing.

APACHE GROUP

The Precambrian Apache Group, Troy Quartzite, and diabase are collectively referred to as pCy. The Precambrian Apache Group is a conformable sequence of sedimentary and volcanic rocks that include (from oldest to youngest) the Pioneer Formation (thinly-bedded tuffaceous mudstone or siltstone that has a basal conglomeratic to coarsely arkosic member), the Dripping Spring Quartzite (conglomerate, arkosic sandstones or orthoquartzites, and thinly bedded, silty, fine-grained, feldspar-rich rock) and the Mescal Limestone (primarily dolomite) and unnamed basalt flows that locally overlie the Mescal Limestone. Regionally, the Troy Quartzite (arkose, sandstone and quartzite) unconformably overlies the Apache Group, but it is absent in the mine area. Diabase sills and dikes intrude all of the Precambrian sedimentary units. A thick (> 600 ft) diabase sill (the lower sill) intrudes between the Pioneer Formation and the Dripping Spring Quartzite, and an upper diabase sill commonly intrudes above the Mescal Limestone where it is up to 300 ft thick.

The pCy sequence is generally continuous within the study area and is more than 3,000 ft thick below the RC orebody (Figure 2.4). Much of the mine development below the bottom of the cave zone will be developed in rocks belonging to the pCy. Groundwater movement is primarily through fractures in the Apache Group units. The Graben faults impede lateral groundwater flow, so strong inward gradients into the Resolution Graben have developed. The current recharge is derived from a combination of downward flow through the Whitetail and potentially some recharge where the Precambrian Apache Group where it is exposed in Queen Creek Canyon, particularly during and following periods when Queen Creek is flowing.

PINAL SCHIST

The Precambrian Pinal Schist (pCpi) is the oldest geologic unit and forms the basement rock across the entire project area. The Pinal Schist is unconformably overlain by the younger Precambrian Apache Group. The Pinal schist is a fine-grained rock with well-developed foliation. It outcrops in the northeast part of the study area between the mine and Top of the World (area on the north-eastern edge of the Devils Canyon watershed), to the northwest of Superior, and also southwest of Superior in the Gonzales Pass area (Figure 1.3). In the RC mine area, the Pinal schist lies stratigraphically below the level of mining within the graben block. Groundwater movement is primarily through fractures in the Pinal Schist. However, the Pinal Schist has low hydraulic conductivity and has limited groundwater flow.

FAULT ZONES

Numerous fault zones occur within the project area, the most prominent of which is the north-south trending Concentrator Fault zone, which divides the project area into two distinct hydrogeologic domains. The Resolution ore deposit occurs within the deep bedrock inside a fault bounded graben formed by the North Boundary, West Boundary, South Boundary, Rancho Rio and Conley Springs faults, referred to as the Resolution Graben (Figure 2.1). The North Boundary, West Boundary, and South Boundary faults only offset the deep bedrock units. To the east of the Resolution Graben, the north-south trending Devils Canyon and JI Ranch faults form continuous structural features (and/or hydrogeologic discontinuities) across the study area and penetrate the full geologic sequence (Figure 2.3). The north-south trending Mineral Creek fault occurs further to the east and is coincident with the Mineral Creek drainage. Other faults of significance to groundwater flow include the north-south Anxiety Fault and generally east-west pre-Laramide faults.

Further details on the hydraulic behavior of each of the faults is detailed in Section 2.2.6 below.

2.2.3 HYDRAULIC PROPERTIES OF HYDROGEOLOGIC UNITS

The hydraulic properties of the HGUs have been characterized through a series of aquifer tests and are summarized in Tables 2.1, 2.2, 2.3 and 2.4. For purposes of this discussion, the testing results have been divided into three different areas, East of the Concentrator Fault – Shallow Groundwater System (Tal and Tw), East of the Concentrator Fault – Deep Groundwater System (Kvs, Pz and pCy) and West of the Concentrator Fault (QTg, Tal, Tvy). Surficial alluvial units were not included in the groundwater model, hence this section will not discuss their hydraulic properties. More details for each of the tests are provided in Appendix A.

Additionally, Figure 2.5 summarizes the general statistics of the hydraulic conductivity for the HGUs with sufficient data in a box and whisker plot, to allow better visualization of the ranges of values, median values, and geometric means for comparison between units.

EAST OF THE CONCENTRATOR FAULT – SHALLOW GROUNDWATER SYSTEM

Hydraulic properties of the Apache Leap Tuff were characterized through a series of single-well aquifer tests and multiple-well aquifer tests (one well is pumped while water levels are monitored at multiple wells and VWPs) conducted in the HRES series and other wells (A-06, MJ-11 etc.). Twenty-two wells were tested in total (see Table 2.1). Hydraulic conductivity values calculated from the tests range from 4E-04 to 1E+01 ft/d. These values are in line with the ranges reported in the literature for fractured igneous rocks (Freeze and Cherry, 1979).

Four long-term aquifer tests were conducted in the Apache Leap Tuff – HRES-04, HRES-07, HRES-09 and HRES-20. These tests are more representative of larger areas and allow for better assessment of any preferential direction of flow. Hydraulic conductivity values for the four long-term tests (pumping ranged from 23 to 90 days in duration) ranged from 0.2 to 5 ft/d. Specific yield values reported for these four tests ranged between 2E-03 and 7E-02. Specific storage values for these four tests were between 3E-09 and 7E-07 (ft^{-1}). Drawdown caused by the long-term aquifer test in HRES-20 indicated that the Apache Leap Tuff has some horizontal anisotropy, with higher hydraulic conductivity in the north-south direction than in the east-west direction (following the pattern of faulting along Devils Canyon) (M&A, 2014). In terms of vertical hydraulic conductivity, some testing indicated that hydraulic conductivity decreased with depth. The final zone distribution of hydraulic conductivity presented in Section 3.1.8 in the next chapter reflects the results of this fieldwork.

All available hydraulic testing data indicate that the Whitetail Conglomerate is a low permeability unit (Table 2.2). There was one slug test completed in the Tw in HRES-08D, which yielded a hydraulic conductivity of 1E-04 ft/d, and the hydraulic conductivities for the 70-day aquifer test at DHRES-15 were calculated at 1E-05 to 1E-03 ft/day for the lower Whitetail (subunits Tw3 [conglomerate] and Tw4 [ferricrete]) and 2E-07 to 2E-05 ft/day for the Tw4 subunit alone. As such, this supports the hypothesis that the unit acts as an aquitard unit between the shallow and deep system. Due to these low values, it is infeasible to economically exploit the water resource, and there are no drinking water supply wells in the Whitetail Conglomerate.

Table 2.1: Hydraulic Properties - East of the Concentrator Fault – Shallow System

Well tested	Test type	HGUs tested	Hydraulic Conductivity Range (ft/day)[1]	Specific Yield Range	Specific Storage Range (/ft)
HRES-01	Constant-rate tests in multiple zones	Tal	1E-02 - 2E-01	N/D	N/D
HRES-02	Constant-rate tests in multiple zones	Tal	5E-02 - 9E+00	N/D	N/D
HRES-03	Constant-rate tests in multiple zones	Tal	2E-02	N/D	N/D
HRES-03D	Slug test in deep perforated zone	Tal	7E-04	N/D	N/D
HRES-04	Constant-rate tests in multiple zones	Tal	1E+00 - 9E+00	N/D	N/D
HRES-04	Long-term constant rate pumping test (25 days)	Tal	1E+00 - 5E+00	N/D	8E-08 - 7E-07
HRES-05	Constant-rate tests in multiple zones	Tal	1E+00 - 1E+01	N/D	N/D
HRES-06	Constant-rate pumping test (12 hours)	Tal	6E-02 - 2E-01	N/D	N/D
HRES-07	Constant-rate pumping test (8 hours)	Tal	3E+00	N/D	N/D
HRES-07	Long-term constant rate pumping test (25 days)	Tal	1E+00 - 2E+00	2E-02 – 7E-02	N/D
HRES-07D	Slug test in deep perforated zone	Tal	6E-02	N/D	N/D
HRES-09	Constant-rate pumping test (24 hours)	Tal	5E-02 - 6E-02	N/D	N/D
HRES-09	Long-term constant rate pumping test (23 days)	Tal	2E-01	4E-02	3E-09
HRES-10	Constant-rate pumping test (10 hours)	Tal	8E-01 - 3E+00	N/D	N/D
HRES-11	Constant-rate pumping test (48 hours)	Tal	2E-01	N/D	N/D

Well tested	Test type	HGUs tested	Hydraulic Conductivity Range (ft/day)[1]	Specific Yield Range	Specific Storage Range (/ft)
HRES-12	Constant-rate pumping test (7.5 hours)	Tal	4E-04 - 4E-03	N/D	N/D
HRES-13	Constant-rate pumping test (12 hours)	Tal	1E+00	N/D	N/D
HRES-14	Constant-rate pumping test (48 hours)	Tal	4E-01 - 6E-01	N/D	N/D
HRES-15	Constant-rate pumping test (48 hours)	Tal, Tvo	3E+00	N/D	N/D
HRES-17	Constant-rate pumping test (24 hours)	Tal	9E-02	N/D	N/D
HRES-18	Slug test	Tal	9E-03	N/D	N/D
HRES-20	Long-term constant rate pumping test (90 days)	Tal	3E-01 - 6E-01	2E-03	4E-08
Oak Flat	Constant-rate pumping test (3 hours)	Tal	3E-03 - 7E-02	N/D	N/D
A-06	Constant-rate pumping test (8.5 hours)	Tal	5E-01 - 6E-01	N/D	N/D
MJ-11	Constant-rate pumping test (5 hours)	Tal	4E-01	N/D	N/D

Table 2.2: Hydraulic Properties - East of the Concentrator Fault – Whitetail Conglomerate

Well tested	Test type	HGUs tested	Hydraulic Conductivity Range (ft/day)[1]	Specific Yield Range	Specific Storage Range (/ft)
DHRES-15	Long-term constant rate pumping test (70 days)	Tw3 & Tw4	1E-07 – 1E-03	N/D	1E-08 – 1E-06
HRES-08D	Slug test in deep perforated zone	Tw	1E-04	N/D	N/D

[1]*Values in range include reported values by M&A reports and recalculated values. Full details in Appendix A.*

EAST OF CONCENTRATOR FAULT – DEEP GROUNDWATER SYSTEM

Testing for the deeper units (below the Whitetail Conglomerate), which form the host rocks for the orebody, present a low permeability system with most of the groundwater flow being dominated by secondary fracture flow. Hydraulic conductivity values calculated for the Cretaceous volcaniclastics (Kvs) range from 0.05 – 0.1 ft/d based on the aquifer testing of DHRES-01 (Table 2.3). Similarly, values calculated for the aquifer test conducted in DHRES-02, which is screened across Kvs and pCy (diabase), resulted in values ranging between 0.1 - 0.6 ft/d.

Hydraulic conductivity values calculated for the undifferentiated Paleozoic rocks (Pz) range from 0.04 to 0.2 ft/d. This is based on values of 0.04-0.06 ft/d for a long-term aquifer test in DHRES-15, 0.07-0.1 ft/d for an aquifer test in DHRES-06, and 0.01 to 0.2 ft/d for slug tests in DHRES-07. An aquifer test conducted in DHRES-11 screened across both Pz and pCy yielded much lower hydraulic conductivity values of 2E-04 to 4E-04 ft/d. Specific storage values for the Paleozoic rocks were calculated to range between 7E-09 and 1E-06 for the test in DHRES-15 based on drawdown in observation wells.

Hydraulic conductivity values calculated for the undifferentiated Apache Group (pCy) range from 3E-04 to 1E-02 ft/d. The only test conducted entirely in the pCy alone was DHRES-9 with hydraulic conductivity ranging from 6E-03 to 1E-02 ft/d. Other tests were screened across multiple hydrogeologic units, resulting in values of 2E-04 to 0.6 ft/d for tests conducted across pCy along with pCpi, Pz, or Kvs.

No tests were conducted completely in the Pinal Schist (pCpi), but the test in DHRES-13 was screened across the pCy and pCpi and yielded hydraulic conductivity values of 4E-03 to 5E-03 ft/d. Given that this is an average of the two hydrogeologic units, the Pinal Schist likely has lower hydraulic conductivity than this average.

All rocks in the Deep Groundwater System are of generally low hydraulic conductivity and minimal storage properties, in line with literature values for sedimentary and metamorphic rocks (Freeze and Cherry, 1979). Due to the low values of these hydraulic properties, these rocks would not be classified as economical aquifers.

Table 2.3: Hydraulic Properties - East of the Concentrator Fault – Deep System

Well tested	Test type	HGUs tested	Hydraulic Conductivity (ft/day) [1]	Storativity	Specific Storage (/ft)
DHRES-01	Constant-rate pumping test (72 hours)	Kvs	5E-02 - 1E-01	N/D	N/D
DHRES-02	Constant-rate pumping test (188 hours)	Kvs and pCy (pCdiab)	1E-01 - 6E-01	5E-04	N/D
DHRES-06	Constant-rate pumping test (24 hours)	Pz	7E-02 - 1E-01	N/D	N/D
DHRES-07	Slug test	Pz (Dm, Cb)	1E-02 to 2E-01	N/D	N/D
DHRES-09	Constant-rate pumping test (24 hours)	pCy (pCdiab and pCdsg)	6E-03 - 1E-02	N/D	N/D
DHRES-11	Variable-rate pumping test (31 hours)	Pz, pCy	2E-04 - 4E-04	N/D	N/D
DHRES-13	Constant-rate pumping test (24 hours)	pCy, pCpi	4E-03 - 5E-03	N/D	N/D
DHRES-15	Constant rate pumping test (70 days)	Pz (Pn Me, DM Cb)	4E-02 - 6E-02	N/D	7E-09 – 2E-08

[1]*Values in range include reported values by M&A reports and recalculated values. Full details in Appendix A.*

WEST OF THE CONCENTRATOR FAULT

Hydraulic properties of the hydrogeologic units in the West Plant Site were characterized through constant rate aquifer tests and slug tests (Table 2.4). Hydraulic conductivity values calculated for 13 wells tested in the Gila Conglomerate range from 2E-05 to 3E-01 ft/d, with a geometric mean of 2E-03 ft/d, with the higher values generally from the shallower wells (i.e., wells less than 150 ft deep). The hydraulic conductivity calculated for the mudstone unit in the Gila Conglomerate is 4E-06 ft/d, based on slug testing of MCC-3B. No specific yield or storage values were reported for these tests.

The hydraulic conductivity calculated for the younger Tertiary volcanics is 3E-02 to 4E-02 ft/d, based on aquifer testing of DHRES-04. The hydraulic conductivity of the alluvium is 9E-02 to 0.1 ft/d based on aquifer testing of Smelter Pond POC well.

Apart from the alluvium, hydraulic conductivity of all the rocks tested are too low to support economical groundwater supply exploitation.

Table 2.4: Hydraulic Properties - West of the Concentrator Fault

Well tested	Test type	HGUs tested	Hydraulic Conductivity Range (ft/day)[1]	Specific Yield Range	Specific Storage Range (/ft)
MCC-1	slug tests	QTg	4E-04 - 3E-03	N/D	N/D
MCC-2	slug tests	QTg	1E-04 - 1E-03	N/D	N/D
MCC-3B	slug tests	Mudstone	4E-06	N/D	N/D
MCC-3C	slug tests	QTg	1E-03 - 3E-03	N/D	N/D
MCC-4	slug tests	QTg	5E-04 - 8E-04	N/D	N/D
MCC-6A	slug tests	QTg	3E-04 - 7E-04	N/D	N/D
MCC-6B	slug tests	QTg	1E-04 - 8E-04	N/D	N/D
MCC-6C	slug tests	QTg	2E-03	N/D	N/D
MCC-9	constant rate pumping test	QTg	3E-01	N/D	N/D
Settling Ponds 1 & 2	constant rate pumping test	QTg	2E-03 - 5E-03	N/D	N/D
Tailings Pond 5 POC	constant rate pumping test	QTg	8E-04 - 2E-03	N/D	N/D

Well tested	Test type	HGUs tested	Hydraulic Conductivity Range (ft/day)[1]	Specific Yield Range	Specific Storage Range (/ft)
GAI-02-01	constant rate pumping test	QTg	3E-03 - 5E-03	N/D	N/D
GAI-02-02	constant rate pumping test	QTg	6E-02 - 7E-02	N/D	N/D
Smelter Pond POC	constant rate pumping test	Alluvium	9E-02 - 1E-01	N/D	N/D
DHRES-04	constant rate pumping test	Tvy	2E-02	N/D	N/D
DHRES-05	slug tests	QTg	2E-05	N/D	N/D

[1]*Values in range include reported values by M&A reports and recalculated values. Full details in Appendix A.*

2.2.4 WATER LEVELS, HYDRAULIC GRADIENTS, AND GROUNDWATER FLOW

Virtually all groundwater movement in the project area occurs by fracture flow (except for flow in the alluvium). Although there is some interconnected primary porosity within certain units (Apache Leap Tuff), most of the flow is related to secondary porosity (fractures, joints and some minor vugs and cavities). However, at the scale of the model, the hydrogeologic units are assumed to behave as equivalent porous media (EPM), where the bulk hydraulic behavior of the rocks can be reasonably conceptualized as a continuous porous medium.

EAST OF CONCENTRATOR FAULT

The water table in the Apache Leap Tuff in the East Plant Site area is 200 to 400 ft bgs, but is essentially at ground surface in Devils Canyon and Mineral Creek along frequently wet and continuously saturated reaches (other reaches are usually dry, except during and immediately after storm events). The reports *Surface Water Baseline Survey: Devils Canyon, Mineral Creek, and Queen Creek Watersheds* (M&A, 2013) and *Surface Water Baseline Addendum: Upper Queen Creek, Devils Canyon, and Mineral Creek Watersheds* (M&A, 2017b) have comprehensive details on this behavior. Water levels in the area of the proposed mine are at 3,600-3,700 ft amsl, with lower water levels near Shafts 9 and 10 and Queen Creek (Figure 2.6). There is a broad correlation between groundwater levels and topography, with the highest groundwater levels around the Top of the World (about 4,100 ft amsl) and lowest levels around the confluence of Devils Canyon and Mineral Creek drainages (about 2,300 ft amsl), approximately four miles southeast of the East Plant Site.

The horizontal hydraulic gradient in the Apache Leap Tuff is generally north-south as seen in Figure 2.6. The main path of groundwater flow in the Apache Leap Tuff occurs in a north-south direction from the Top of the World area and the northern groundwater divides (Devils Canyon/Pinto Creek and Queen Creek/Pinto Creek), to the discharge areas along the lower part of Devils Canyon and Mineral Creek (Figure 2.6). Flow occurs southward along the prominent structural trend (Devils Canyon and JI Ranch faults) to the discharge area around the drainages to the southeast of the project area. Above the proposed mine, the horizontal hydraulic gradient in the Apache Leap Tuff System is relatively flat and a groundwater divide is observed in the area around HRES-21.

Vertical hydraulic gradients within the Apache Leap Tuff are generally low. Where piezometer pairs are available, small downward gradients are typically observed. Downward vertical gradients are steeper in the immediate vicinity of Shaft 9 due to its dewatering effects.

Within the upper and middle part of the Whitetail in the East Plant Site area, potentiometric heads show a typical range between 3,400 and 3,800 ft amsl. Toward the very top of the unit, heads are typically similar to (slightly lower than) the heads in the overlying Apache Leap Tuff. Much lower heads and a stronger downward gradient occurs in the lower part of the Whitetail. Heads near the base of the unit within the graben are as low as 1,500 ft amsl. The downward gradient is observed in all drill holes where there are multi-level piezometers (e.g., DHRES-01, DHRES-02, DHRES-08). All potentiometric data indicate that the Whitetail is an aquitard between the overlying Apache Leap Tuff and the underlying Deep Groundwater System (Figures 2.3 and 2.4).

Under natural conditions (pre-mining), most of the Deep Groundwater System would have been fully confined by the overlying low permeability Whitetail Conglomerate. However, the historic dewatering program has created an unsaturated zone in the Deep Groundwater System below the Whitetail, thus creating a localized unconfined area. The Deep Groundwater System is also unconfined in a narrow zone on the east side of the Concentrator Fault where the overlying Whitetail Conglomerate outcrops and is absent (Figure 2.2 and 2.3) along the Apache Leap escarpment (shown on a plan view map in Figure 2.1 and on east-west cross sections in Figures 2.2 and 2.3). Significant drawdown exists in this area as a result of historic dewatering.

The Resolution Graben is a prominent hydrogeologic feature of the Deep Groundwater System. The historical dewatering program has caused a strong inward gradient towards the graben. In early 2009, the potentiometric levels inside the graben were approximately 2,100 ft. Outside the graben in the Deep Groundwater System, heads were generally between 2,700 and 3,500 ft amsl. The ongoing pumping from Shaft 9 and Shaft 10 since 2009 has strengthened the inward gradient because of the greater depth of pumping and subsequently greater drawdown with as much as 2,400 ft of drawdown measured in DHRES-02, between 2009 and 2015. In 2015, piezometric levels outside the graben ranged from 2,700 to 3,670 ft amsl, whereas piezometric levels inside the graben ranged from about 300 ft amsl to 300 ft below mean sea level (Figures 2.3 and 2.4). Over this time period, from 2009 to 2015, and within the Deep Groundwater System inside the graben, piezometric levels dropped 2,400 feet or more, whereas piezometer levels outside of the graben dropped between 100-400 feet.

Water level monitoring in the Deep Groundwater System immediately outside the Resolution Graben, indicate that the graben faults are leaky barriers and greatly impede flow. However, west of the West Boundary Fault (but east of the Concentrator Fault, i.e., at DHRES-13), and north of the North Boundary and Conley Springs faults (i.e., at DHRES-11), there is some drawdown attributable to Shaft 9 and 10 pumping. Additional faults outside the graben work to further impede flow (i.e. Concentrator Fault, Devils Canyon Fault) but also are not full barriers to flow.

Two changes occurred to the Deep Groundwater System as the Magma workings were progressively deepened and groundwater levels were lowered. First, a relatively large underground void and thus a mechanism for groundwater discharge was created, because groundwater was able to flow from the surrounding rocks into mine workings, where it was then pumped to the surface. Second, groundwater from above was able to percolate downwards into the Deep Groundwater System as a result of hydraulic connections opened up by the historical shafts and drilling. Thus, the historic mining has created a localized groundwater flow system within the Deep Groundwater System around the mine workings.

WEST OF CONCENTRATOR FAULT

The water table at the West Plant Site is deepest below the northern areas of higher ground, and may be greater than 200 ft bgs in some places. The water table is shallowest to the south, toward Queen Creek, where it may be less than 30 ft in depth. Potentiometric elevations generally range between about 2,750 – 2,950 ft amsl. Water levels to the west of the Concentrator Fault in the shallower zones of the QTg are generally stable and have not been affected significantly by the historic or ongoing dewatering program. Water levels within deeper zones beneath the Gila Conglomerate have generally shown downward trends.

The hydraulic gradient at the West Plant Site is primarily to the south, although some local variations are evident from the water level data, with apparent components to the southeast and southwest. Groundwater flow in the southeastern area of Superior Basin (Arnett Creek) is generally to the northwest. Farther west in the Superior Basin, data from wells shows that flow is to the west toward Whitlow Ranch Dam and the eastern Salt River Basin (M&A, 2013).

2.2.5 RECHARGE AND DISCHARGE

RECHARGE

The primary source of groundwater recharge to the groundwater system is infiltration of precipitation. Recharge to the groundwater system is a function of precipitation (magnitude, timing, intensity and nature of precipitation), surface soil characteristics which controls the percentage of runoff versus infiltration, and vegetation which influences evapotranspiration. Due to a combination of poorly developed soils and vegetation, varying topography, and the short duration-high intensity precipitation common in the region, the system is strongly runoff dominated (i.e. most precipitation ends up as runoff). Moreover, any standing water or shallow soil moisture will mostly be consumed by evapotranspiration, therefore local rates of recharge are low. Recharge to the Apache Leap Tuff in the East Plant Site area has been studied extensively and is summarized in Woodhouse (1997). Among the conclusions it is estimated that upwards of 90% precipitation leaves as evapotranspiration, 6% exits as runoff, and only 4% is available for recharge.

Recharge to the Deep Groundwater System is derived from a combination of downward flow through the Whitetail and potentially some recharge through the Paleozoic and Precambrian Apache Group hydrogeologic units, where exposed along the Apache Leap escarpment and in Queen Creek Canyon, particularly during and following periods when Queen Creek is flowing. Details regarding modeling of recharge and associated recharge rates are described in more detail in the recharge section of Section 3.

DISCHARGE

Under natural conditions (pre-mining), it is thought that most groundwater discharge from the Apache Leap Tuff occurred where the pre-1910 water table intersected the topography, primarily to springs and seeps along the main drainages of Queen Creek, Devils Canyon, and Mineral Creek. Minor groundwater discharge from the Apache Leap Tuff is currently observed in springs and pools along the frequently wet reaches of Devils Canyon and Mineral Creek (M&A, 2013 and 2017b), but historically, it is possible that groundwater from the Apache Leap Tuff also discharged to springs and seeps along Queen Creek. At present, the only known discharge from the Deep Groundwater System is from pumping of shafts and historic workings.

In the Superior Basin, shallow groundwater discharge is likely to be through evapotranspiration along the bottom of Queen Creek and its tributaries, as well as some small springs, but the primary groundwater discharge point is at the west end of the basin at Whitlow Ranch Dam where groundwater is forced to the surface and piped through the dam. It is also worth noting that within the Superior Basin and along the length of Queen Creek between Superior and Queen Valley there are numerous groundwater extraction wells. Water is also pumped from a sump at a small perlite mine (located at the base of the east side of Picketpost Mountain) and two wells at the Boyce Thompson Arboretum (along Queen Creek north of Picketpost Mountain).

2.2.6 INFLUENCE OF FAULTS ON GROUNDWATER FLOW

In many situations, major faults delineate hydrogeologic domain boundaries, either because they contain distinct properties that influence the overall head and flow field, or because they coincide with abrupt changes in geology and associated changes in bulk hydraulic parameters in the local system. A combination of the observed groundwater head distributions, the observed response to historic and more recent dewatering, recent long-term pumping tests, and observation of the geologic system has allowed the hydrogeologic role of some of the primary faults in the project area to be defined.

Fault zones can act as barriers to flow, conduits to flow, or a combination (usually a barrier across the fault and a conduit parallel to the fault). Faults generally do not act as a full barrier, but rather impede flow to various degrees. Faults can lead to discontinuity in groundwater flow either by 1) having hydraulic properties that limit groundwater movement across the faults (clay gouge, mineral infilling), 2) offsetting conductive zones within formations, and 3) juxtaposing hydrogeologic units with dissimilar hydraulic properties against one another, or 4) some combination thereof. Wickham Geogoup LLC undertook an investigation on the hydraulic behavior of faults that involved reviewing geologic logs and available core for fault intercepts and provided guidance on how to implement them in the groundwater model (Wickham Geogroup, 2015a).

CONCENTRATOR FAULT

The Concentrator Fault (and its splays including the Main Fault; see Figure 2.1) is a regionally significant structural feature. It delineates a major east-west geologic and hydrogeologic domain change. Neither the historic Magma Mine dewatering or the recent ongoing Shafts 9 and 10 dewatering have induced significant drawdown to the west, across the Concentrator/Main fault and into the Superior Basin, supporting the hypothesis that there is not significant groundwater flow across the fault.

RESOLUTION GRABEN

The Resolution Graben is a fault bounded system that creates offsets to the geologic units in the Deep Groundwater System across the fault planes. The piezometric responses to dewatering pumping from inside the graben reflect this and are typical of a bounded but leaky reservoir, with the piezometer data showing some water level difference across the faults. This is particularly evident comparing water levels for wells and VWPs within the graben (DHRES-01, DHRES-02, and DHRES-08) relative to those outside the graben, as shown on cross sections in Figures 2.3 and 2.4 (see hydrographs in Appendix C for DHRES-06, DHRES-07, and DHRES-15 south of the South Boundary Fault, DHRES-13 west of the West Boundary Fault, DHRES-11 north of the North Boundary and Conley Springs Faults, and DHRES-14 east of the Ranch Rio, Devils Canyon, and Conley Springs Faults). Most of the Resolution Graben faults are older than the Tertiary so they only intersect the Deep Groundwater System. Geologic logs and core (as available) were reviewed to evaluate the function of faults in the groundwater flow system and assist in guiding the the groundwater flow modeling effort (Wickham GeoGroup, 2015a).

ANXIETY FAULT

The Anxiety Fault is a major north-south trending fault that runs through the graben and extends north and curves northwest paralleling upper Queen Creek. The Anxiety Fault is discontinuous and offset approximately 1,200 ft east across the Conley Springs Fault. Data suggest that within the graben the Anxiety Fault isn't hydraulically significant and therefore not included in the groundwater model. Recent data trends however, to the north of the Conley Springs Fault suggest that the Anxiety Fault is acting as a conduit to flow along the fault. The drawdown response observed in DHRES-11_WL and piezometer DHRES-11_231 are thought to be due to this hydraulic behavior.

PRE-LARAMIDE FAULTS

The pre-laramide faults are generally east-west trending faults which offset the Paleozoic (Pz) and Precambrian Apache Group (pCy) units. These faults present vertical offset with a strike-slip component. They are pre-Cretaceous, older than the Tertiary rock present (Tw and Tal), hence they are only present below the Whitetail unit. As they are covered by the Whitetail, they are only visible where the Paleozoic and Apache Group outcrop on the slopes of the Apache Leap escarpment. These faults are mineralized, which could reduce hydraulic conductivity and cause them to impede groundwater flow across them. These faults have only been included in the numerical model north of the Resolution graben where they can be extrapolated from faults mapped at the ground surface, but are likely to be present south of the graben as well, where the Paleozoic and Apache Group are hidden beneath the Apache Leap Tuff.

DEVILS CANYON FAULT

The observed responses to the long-term pumping test in HRES-20 indicates that the Devils Canyon Fault and associated structural fabric in the Apache Leap Tuff creates a north-south anisotropy in the groundwater flow system. Piezometers to the north and south responded strongly to pumping of HRES-20, whereas piezometers offset in an east-west orientation did not (M&A, 2014).

3 GROUNDWATER FLOW MODEL

3.1 MODEL SETUP

3.1.1 OVERVIEW

WSP has developed a 3D numerical groundwater flow model of the proposed Resolution Copper Mine and surrounding region. The purpose of the model is to represent the key aspects of the hydrogeological system within a numerical framework, and simulate the potential response in the system to the proposed Resolution Copper Mine activity.

Groundwater modeling followed a standard approach conducted in three main phases, including:

— Construction of the model domain incorporating the appropriate framework and features to represent the main components of the hydrogeologic system.

— Calibration of the model to reasonably replicate historical hydrogeologic conditions and responses in the RC project area.

— Implementation of predictive simulations, to evaluate hydrogeologic responses and potential impacts that may arise from proposed RC mine plan and subsequent closure.

This section of the report describes the model construction and calibration for the historical model, including details of the model components and their relationships to the field data and conceptual model. Construction of the predictive models is described in Section 4.

3.1.2 CODE SELECTION

A numerical model is needed to simulate the groundwater system and potential impacts of the proposed Resolution Copper Mine and associated infrastructure. Although the system is fractured rock, it would not be practical to model the groundwater system with a discrete fracture or dual porosity simulator due to the regional scale of the domain. As previously stated, given the scale of the systems and nature of the fracturing, the Equivalent Porous Medium (EPM) approximation is a valid assumption (USFS, 2007). Furthermore, given the complexities that need to be modeled, a numerical model (finite difference or finite element model) is necessary rather than an analytical model.

The USGS code MODFLOW (MacDonald and Harbaugh, 1988) is the most widely used numerical groundwater modeling code, it is industry standard, and is widely accepted by the regulatory and scientific communities (USFS, 2007 and USGS, 2004). The finite difference solution to the groundwater flow equation used in MODFLOW has been thoroughly validated against analytical solutions to ensure an accurate solution. However, there are limitations with the standard version of MODFLOW, particularly when modeling systems with steep hydraulic gradients and unsaturated zones. Thus, The MODFLOW-SURFACT code was selected for this project because it has the capabilities to simulate complex hydrogeologic conditions and mining features that need to be incorporated in the model.

The 3D finite-difference MODFLOW-SURFACT code version 4 (Hydrogeologic Inc. https://www.hgl.com) is based on the MODFLOW code and retains its major features. However, MODFLOW-SURFACT has the advantages of being more numerically stable when solving for groundwater flow in systems with steep hydraulic gradients and large differences in hydraulic conductivity across short distances, and in systems where drying and rewetting of model cells occurs. MODFLOW-SURFACT has been used on numerous large, complex mining projects, and is the most appropriate code for this project. Groundwater Vistas (GWV) version 7 was used as the pre- and post-processor for model construction and results analysis.

3.1.3 MODEL DOMAIN

Figure 3.1 presents the model domain and the watershed delineation. The overall domain dimensions are 18.3 miles east-west and 16.6 miles north-south. The model domain is 191.5 mi^2 and covers all, or a portion of, three watersheds:

- Queen Creek drainage
- Devils Canyon drainage
- Mineral Creek drainage

The Devils Canyon and Queen Creek (above Whitlow Ranch Dam) watersheds are included in their entirety. The model domain includes only a western portion of the Mineral Creek watershed, truncated on the east side along Mineral Creek tributary Lyon's Fork, which flows north to south. The use of hydrologic watersheds is common practice within groundwater modeling as it provides good estimates to flow divides (Anderson, Woessner, and Hunt, 2015).

The model domain extent was limited to the three watersheds where RC mine infrastructure will be constructed and the area where expected groundwater effects associated with the RC mine would occur.

Table 3.1 shows the relative areas of the watersheds within the model domain.

Table 3.1: Watershed areas within the model domain

Watershed	Area ($mile^2$)	Percent of overall domain
Queen Creek	142.5	74.4 %
Devils Canyon	34.9	18.2 %
Mineral Creek	15.3	7.4 %
Total area	191.5	100 %

3.1.4 MODEL GRID AND LAYERS

The cells within the grid vary in size, allowing an area of greater detail to be centered on the proposed mine and coarsening toward the outlying areas. The row and column spacing around the refined mine area is 200x200 feet. Towards the periphery of the model, the row and column spacing increases to 1,000 feet. To reduce numerical errors, the grid size increases by 50% or less for adjacent cells as cell size increases and the aspect ratio (cell length to width) is limited to a maximum five to one ratio. The MODFLOW finite-difference grid is shown in Figure 3.2.

Table 3.2: Model grid details

Rows	157
Columns	210
Layers	39
Total Cells	1,285,830
Active Cells	792,449

The model layers are horizontal, with varying thickness from 150 to 300 feet. Relatively thin layers (150 ft) are applied in the upper parts (layers 6 -22) of the model where vertical hydraulic gradients may be most important to hydrogeologic system and potential impacts at groundwater dependent ecosystems (GDEs), typically seeps, springs, and continuously saturated reaches of streams. Below layer 22, the layers increase in thickness reaching 300 ft. The bottom of the domain (bottom of layer 39) is at 3,400 feet below sea level and the top of the domain (top of layer 1) is set at 5,600 ft amsl.

The effective top of the model domain (active cells) is defined by the ground surface, which varies between 2,040 ft amsl at Whitlow Ranch Dam on the far west side of the domain and 5,600 ft amsl at Hutton Peak in the extreme northeast area of the domain. As all layers are horizontal, the top (active) layer of the model varies for all row-columns. Cells were set to inactive if their center point was above the cell areal average compared to a 10 meter Digital Elevation Map (DEM).

3.1.5 TIME DISCRETIZATION

The historical (calibration) model runs from January 1, 1910 through December 31, 2016. The year 1910 was selected because historical records indicate dewatering activity began then, hence the beginning of the model represents pre-mine dewatering baseline conditions. MODFLOW-SURFACT allows assignment of different stress period types within a model (steady state or transient), therefore the first stress period was set as steady state and represents baseline conditions. Subsequent stress periods were set in transient mode with a range of different lengths. Stress periods were set up to represent particular changes in the flow regime due to historical property changes (mining and tunnel development) from the Magma Mine.

Calibration was generally focused around the 1998 to 2016 period as this is the period where Resolution Copper acquired the property and started an intensive hydrogeologic characterization program. As a result, the period 1998 to 2016 was much more useful for calibration given the extensive water level data set available for calibration targets (see Section 3.2). As a result, stress periods range from 2 to 10 years for the period 1910-1998 for which only limited data are available, and are all one month long for the period 1998-2016. The MODFLOW-SURFACT Adaptive Time-Steppings Options (ATO) package was used allowing the model to set the timestep lengths based on numerical stability (the maximum timestep size allowed was 20 days).

3.1.6 BOUNDARY CONDITIONS

Boundary conditions are numerical representations of the physical and hydraulic elements that represent flow into or out of the model – i.e. sources and sinks. There are three basic types of boundary conditions: specified head, specified flux, and head-dependent flux boundaries. MODFLOW has multiple packages that are used to represent these boundary conditions. The following packages were used where appropriate:

- No-flow cells (NF)
- General Head Boundary (GHB)
- Constant Head (CH)
- Drains (DRN)
- Fractured Wells (FWL4)
- Recharge (RCH)

The following sections will describe the setup for each of the different types of boundary conditions. Figure 3.3 summarizes all the different model boundary conditions in a collapsed plan view, however the distribution of these conditions is in three dimensions.

NO-FLOW CELLS

A no-flow boundary is a specified flux boundary in which the flow rate is set at zero. There are two uses for no-flow boundaries in the model: to represent hydraulic features where no flow is expected (such as a watershed boundaries), and to inactivate cells that are within the model grid but are outside of the active domain area.

Cells outside the active area of the domain (as defined in Section 3.1.1) are set as inactive, which is numerically equivalent to a no-flow cell. These cells can be seen in Figure 3.3 as greyed out. Cells above the ground surface, as defined by the digital elevation model, are also set as inactive cells to represent the atmosphere. The bottom of the model grid is also set as no-flow as it is considered deep enough to avoid no-flow boundary effects from interfering with the model stresses.

GENERAL HEAD BOUNDARY (GHB)

General head boundaries are a form of head-dependent flux boundary condition, which allow water to flow in and out of the model based on a reference head value and a hydraulic resistance (conductance). GHBs are assigned for all edges of the model domain in the Queen Creek and Devils Canyon Watersheds (Figure 3.3). The reference head assigned to each cell at the domain boundary was derived from a separate steady-state model run at baseline conditions where no-flow conditions were set up instead of GHBs. The purpose of this was to establish a model solution where heads are set at expected values for a closed groundwater watershed, but still allow small amounts of flow in or out of the model if stresses were to extend outwards. The head results of this no-flow run were used to assign reference head values for all GHBs in these two watersheds.

Setup of GHBs in the Mineral Creek watershed was different. As only a portion of the watershed was included, it was not appropriate to set up the entire model edge with no-flow equivalent heads. For the shallow unit (Apache Leap Tuff), drains were set in the highest active layer (described in section below) with reference head equivalent to the topography. However, for the Deep Groundwater System, GHBs were set at the same head elevations as the surface drains for each row-column combination. This allows the water table to discharge at surface for the shallow system and allow small flows to move in or out of the model in the deeper units.

CONSTANT HEAD BOUNDARY

Constant head boundary conditions are a form of specified head, where the head values assigned are always maintained via flows in or out of the domain with no hydraulic resistance. A single, constant head boundary cell was used to represent the Whitlow Ranch Dam outlet structure (shown in Figure 3.3). Groundwater flow is assumed to be forced up and through the Whitlow Ranch Dam outlet by very low permeability rock below. Accordingly, precipitation runoff reports to Queen Creek and then leaves the system through the Whitlow Ranch Dam outlet. The specified-head boundary was set to 2,040 feet, the approximate elevation of the outlet structure at the dam. This boundary was assumed to be an invariant feature, active throughout the duration of the simulation.

DRAINS

Drains are a type of head-dependent flux boundary condition; a reference head is specified and the model determines the flux that passes through the boundary based on the gradient and hydraulic resistance. The main difference with respect to GHBs, is that drains can only remove water from the model domain, they cannot add water. Furthermore, they can only remove water when the water level is above the drain level. The flux leaving the model through a drain boundary condition is proportional to the difference between the head in the aquifer and a reference head condition assigned to the drain (drain stage) and hydraulic resistance.

The MODFLOW drain package was used to represent removal of water from the model along streams (discharge to surface). As the drains are used to represent losses in the regional groundwater flow system to surface streams, the drains were set with a sufficiently high conductance value so that they would not exhibit resistance to flow. These boundaries are implemented in the main reaches of Queen Creek, Devils Canyon, Mineral Creek and Arnett Creek as well as several tributaries to these streams (Figure 3.3). The stage elevations (reference heads) were set using the 10-meter Digital Elevation Model, carefully setting up areas such as Devils Canyon such that the lowest elevation from each cell was used to set the drain elevations, rather then the elevation at the center of the cell. This was necessary because when the elevation of the center points were used, there were some areas where the drain elevations increased when going downstream, which happened in areas where the stream channel meandered away from the center of the cell.

To organize multiple drain cells that represent a specific feature, reaches are used in MODFLOW. Reaches are a tracking tool within the MODFLOW framework that simplify flow calculations by aggregating flow values within the same reach number. The model has 41 different reaches representing 2,226 drains, grouped along surface water features.

FRACTURED WELL PACKAGE

The fractured well (FWL4) package is a form of specified flux boundary available in MODFLOW-SURFACT. It is used to simulate point sinks or sources that remove or inject flow based on specific well characteristics. The FLW4 package was used in the RC model to represent dewatering of the groundwater system, in both the historical Magma Mine Workings and the East Plant Site (Resolution Graben).

Historical dewatering records of the Magma Mine are available dating back to 1963 from status reports prepared by BHP Superior Operations mine management and the dewatering rates necessary to mine were estimated for the period 1910 to 1963. As is described in Section 3.1.8 below, the Magma Mine workings were incorporated into the model using the TMP package, where hydraulic properties were increased to represent rock voids. The FWL4 timing was set up to coincide with the TMP property change, representing mining and simultaneous dewatering. FWL4 nodes were distributed in the different parts of the workings (East, West, Koerner, etc) as shown in Figure 3.4. Historical records do not divide up total dewatering flow by zone, rather give a total value. Hence, flow to each node was distributed based on timing of mining, dividing up flow as new zones were mined, but keeping the overall flows for all nodes consistent with the records.

More recently, Resolution Copper began dewatering the Magma Mine workings in March 2009 via Shaft 9. Because Shaft 9 is connected to the Magma Workings, dewatering of Shaft 9 resulted in dewatering of the Magma Workings. Hence from March 2009, modeled flows from the Magma Workings were removed solely from an FWL4 node at the bottom of Shaft 9. Observed dewatering flow rates were averaged monthly to coincide with the stress periods. The average monthly pumping rates were calculated from daily pumped volumes that were recorded and provided by RC.

Additional shafts were also included as FWL4 nodes, representing the dewatering of the Magma Workings by Shafts 8 and 10. Their elevation and pumping time series are shown in the Figure 3.5. Dewatering by Shaft 10 has the additional complexity that it was being sunk during the model simulation period. Hence, the actual node that removes water is dropping in elevation as the model progresses. To achieve this, a series of vertical model nodes (across model layers) were set up with individual pumping time-series that switch on and off per the pump schedule, as the shaft was sunk.

Conversely, RC has also been staging water in the west side of the Magma workings for delivery to the NMIDD. To represent this, an additional FWL4 model node was added at Shaft 5 inputting water into the model.

In order to encompass all major sinks in the model, RC has provided pumping data for the Perlite Mine sump (average pumping rate 90 gpm) and the Boyce Thompson Arboretum well (average pumping rate of 34 gpm from from Gallery and West wells). Discharge from these points was simulated with transient FWLs.

AREAL RECHARGE

Recharge is another specified flux boundary condition used in the model. Net areal recharge is defined as the flux of water that is derived from precipitation and directly recharges the aquifer. No evapotranspiration boundary conditions were implemented in the model, rather recharge rates are assumed to be net recharge to the aquifer. The estimates for recharge rates are based on precipitation rates and recharge percentages.

The precipitation values are derived from the PRISM (Parameter-elevation Relationships on Independent Slopes Model) model that spatially estimates precipitation into an interpolated digital elevation model of rainfall using all available data and regression factors (Oregon State University, 2012). Recommendations for modeling of areal recharge were provided in *Recommendations for Representing Recharge in the Numerical Groundwater Flow Model, RCML* (Wickham GeoGroup, 2015b). From the 29 PRISM stations within the model domain, a bimodal distribution of precipitation was observed. Based on the topography, two regions were delineated - high elevation and low elevation. The cutoff between these was set at 3,600 amsl as recommended in Wickham GeoGroup, 2015b). The 3,600 ft elevation contour is on the Apache Leap escarpment with the Superior Basin to the west at lower elevations and the East Plant Site and Oak Flat to the east at higher elevations. The stations within each zone (high and low elevation) were averaged to create two Mean Annual Precipitation (MAP) values - High Elevation MAP = 22.7 in/yr and Low Elevation MAP = 16.6 in/yr.

Some reliable estimates of recharge percentages in the project area come from the document *Perched Water in Fractured, Welded Tuff: Mechanism of Formation and Characteristics of Recharge* (Woodhouse, 1997), a study completed near the East Plant Site. Based on these estimates, recharge was set between 0.1% and 4% of annual rainfall. In addition to more precipitation in the higher elevation areas, the percent of precipitation resulting in recharge also was assumed to be greater for higher elevations (1.0% for low elevation areas and 4.1% for high elevation areas).

From calibration (and to avoid model cell flooding issues), exceptions to the general recharge zones outlined above were required, generating additional recharge zones. Zones with outcropping geology that exhibit low hydraulic conductivity were set at the low end of recharge rates because rock with lower hydraulic conductivity (e.g., 1E-04 ft/day) will generally accept less infiltration (0.10-0.25% of precipitation).

Additionally, two enhanced recharge zones were defined alongside the two main drainages in the model – Queen Creek and Devils Canyon. These zones were conceptualized to concentrate runoff that would lead to higher infiltration rates, which were set at 4% and 8% for the lower and higher elevation areas, respectively. As runoff is concentrated in these areas, water is stored in surface soils longer, providing more time for infiltration and hence a higher recharge rate. This is consistent with hydrological studies in western United States that divide recharge between focused versus diffuse areas (Meixner, 2015).

The recharge rates used in the model are provided in Table 3.3 and their spatial distribution is shown in Figure 3.6. Modeled recharge rates were assumed to be constant through time.

Table 3.3: Recharge Rates

Zone	Name	Value (ft/day)	% MAP
1	Low Elevation	3.77E-05	1.0 %
2	Low Elevation, Enhanced Stream	1.54E-04	4.1 %
3	High Elevation	1.31E-04	2.5 %
4	High Elevation, Enhanced Stream	4.39E-04	8.4 %
5	Low Elevation, Low Kz	3.78E-06	0.1 %
6	High Elevation, Low Kz	1.32E-05	0.3 %

3.1.7 INITIAL CONDITIONS

Transient simulations require initial heads to solve for a specific solution. Conceptually, initial heads represent a steady-state equilibrium prior to the start of significant mine dewatering in the area, which began in 1910. As discussed previously, the model contains a steady state stress period at the beginning of the simulation representing baseline conditions; this provides the initial heads for the transient calibration. There are no water levels records from this period for which to compare to, but the resulting heads (from the steady state) are generally consistent with the conceptual model where groundwater discharge was present at the portion of Queen Creek above Superior. Potentiometric contours from the steady state solution representing 1910 groundwater heads are presented on Figure 3.7. Additionally, the transient calibration period is sufficiently long that slight differences in the initial conditions would have little effect on model calibration statistics, as the model was run for nearly 100 years (1910 – 2009) when dewatering of Shaft 9 for construction of Shaft 10 began.

3.1.8 MATERIAL PROPERTIES

Material properties are assigned to each model cell to define the hydraulic characteristics of the simulated geological media. The two main property parameters defined in a groundwater flow model are the hydraulic conductivity (K) and the storativity (S). The hydraulic conductivity controls the rate of flow of water and the storativity defines the transient uptake and release of water to or from storage. The sections below describe how these properties were spatially defined for all HGUs within the model. Hydraulic properties of faults and underground workings are also described below, providing an explanation of how they were simulated and correlate to hydraulic behavior observed during field testing.

HYDRAULIC CONDUCTIVITY

Hydraulic conductivity is the primary material property that defines groundwater flow. To reasonably represent the hydraulic conductivity for the purposes of modeling, hydraulic conductivity is defined for a limited set of hydrogeological units (HGU) based on geologic units. The HGUs and a detailed description their geologic and hydrogeologic characteristics were described in Section 2.

In this report, the term HGU refers to one or more geologic units that have been combined for the purposes of simplification, based on their spatial distribution and similarity in hydraulic properties. For example, the Naco Formation, the Escabrosa Limestone Formation, the Martin Formation, and the Bolsa Quartzite Formation are combined into one HGU called the Paleozoic. There are ten HGUs defined in the project area. They are summarized and related to the published geologic units in Table 3.4 below. The spatial distribution of these HGUs is shown for representative layers, as well as representative cross sections, in Appendix B.

Table 3.4: Hydrogeological Units

Name	HGU Zone	Description
Quaternary Alluvium	Qal	Unconsolidated gravel, sand, silt, and clay. Includes active and older deposits, generally along stream beds
Quaternary-Tertiary Gila Conglomerate	QTg	Older alluvial fan and terrace deposits, Landslide deposits, Conglomerate and sandstone (Gila) interbedded with volcanics
Tertiary Volcanics - Younger	Tvy	Gila Group volcanic and intrusive rocks and equivalent units (younger than Apache Leap Tuff, includes Picketpost Mountain Formation).
Tertiary Apache Leap Tuff	Tal	Tertiary (early Miocene) Apache Leap Tuff, crystal-rich, quartz latite, ashflow deposit
Tertiary Volcanics - Older	Tvo	Superstition Group volcanic rocks and equivalent units (older than Apache Leap Tuff), Older volcanic rocks (include felsic lavas and associated tuffs)
Tertiary Whitetail Conglomerate	Tw	Fluvial deposit, matrix of coarse-grained poorly sorted sandstone to siltstone, avalanche breccia, mudstone, and minor volcanic flows
Createaceous Volcaniclastics	Kvs	Andesitic/felsic volcaniclastic sequence (Kvs) and underlying Quartz-rich sandstone (Kqs) within the Resolution graben. HGU also includes diorite and dacite porphyry (Kdp) and quartz diorite (Kqd)
Paleozoic Sediments - Undifferentiatied	Pz	Naco Formation, Escabrosa Limestone, Martin Formation, and Bolsa Quartzite
Precambrian Apache Group - Undifferentiated	p€y	Apache Group meta-sedimentary rocks (Mescal Limestone, Dripping Spring Quartzite, Pioneer Shale) and diabase; HGU also includes Troy Quartzite
Precambrian Pinal Schist	p€pi	Schist with granite, granodiorite, and diorite

The HGUs were then assigned values of hydraulic conductivity based on field measured values from pumping tests, slug tests, etc., in order to derive values to be input into the model (see Tables 2.1 – 2.4). During calibration, the hydraulic conductivities of these units were allowed to vary within the defined ranges until an acceptable statistical fit to the head distribution (based on calibration target water levels) was achieved. Section 3.2 of this report will go into the details of this calibration exercise. The final values for hydraulic conductivity assigned to the model for each HGU are provided in Section 3.2.

STORATIVITY

In a transient simulation, the storativity of the rock must also be defined, as it controls the uptake and release of water from storage of the geological medium. In MODFLOW (for non-fully confined simulations), one must define both the unconfined storage defined as specific yield (Sy) and the specific storage (Ss). Similar to hydraulic conductivity, storage was defined by HGU. Range of values defined from the available field data are provided in Tables 2.1 - 2.4.

The final values for storage assigned to the model for each HGU were defined through calibration and are provided in Section 3.2.

FAULTS

Faults affect groundwater flow in a variety of ways, causing potential hydrogeologic compartmentalization within the system. The model includes the following major faults that are suggested to effect groundwater flow based on field measurments: North Graben, South Graben, West Graben, Conley Springs, Rancho Rio, Devils Canyon, Anxiety, pre-Laramide, JI Ranch, Main, Mineral Creek, Concentrator, Concentrator West, Arnett Creek, and Roblas-Wood Canyon.

The geometry of the faults is based on published geologic maps and modeling by RC geologists. Faults were represented in the model via one-cell thick HGU zones, which depending on their conceptualization (barrier, leaky, transmissive) were assigned hydraulic parameters differing from the surrounding rock. The final values for the hydraulic parameters assigned to the faults were also subject to calibration and are summarized in Section 3.2.

UNDERGROUND WORKINGS

The underground workings, Magma Workings and RC shafts, were represented by rock zones (encompassing the volume of the workings) whose hydraulic properties vary in time during the simulation. Timing of the mining for different sections (West, East, Koerner etc) were obtained from Magma Mine annual reports. This information was used to implement model stress periods and cells that most accurately represent the excavation; these cells increase in hydraulic conductivity and storage to represent the workings (see Figure 3.4). The increase in hydraulic property values (K, Sy, Ss) through time was implemented using the Time-varying Material Property (TMP) package in MODFLOW-SURFACT.

3.2 MODEL CALIBRATION

This section presents the results of the RC groundwater model calibration process. The general objective of the model calibration is to estimate parameter values that allow the model to represent the major hydrogeologic system components true to the conceptual model, and to statistically match observed groundwater levels. An adequately calibrated model builds confidence that the major conceptual components of the hydrogeologic system are understood and provides a basis for conducting predictive simulations in response to varying conditions or stresses in the future.

3.2.1 CALIBRATION APPROACH

There are two broad methods used to calibrate groundwater models: manual calibration and automated inverse methods using programs such as PEST (Doherty, 2016). Both methods were used to calibrate the groundwater model, with the initial phase focused around manual testing and the final phases using automated inverse methods to refine the calibration. Both methods are discussed as valid methodologies in the literature, each one with advantages and disadvantages (*Guidelines for evaluating Ground-Water Flow Models*, USGS, 2015). Modeling references such as Anderson, Woessner, and Hunt (2015) were followed throughout the process.

The model was calibrated in transient mode, with one steady state stress period at the beginning (1910). As discussed in Section 3.1.5, the historical model for calibration covered the period from January 1910 to December 2016, however the majority of the calibration targets are from the Resolution field efforts undertaken after 2002.

3.2.2 CALIBRATION TARGETS

Calibration targets are various field measurements (e.g., water levels) of the hydrogeological system, which a numerical model attempts to replicate. During model calibration, the measured values at targets are compared to simulated values computed by the model and compared to assess the model's fit. When a target and simulated value are subtracted, a residual (also referred to as error) is calculated. In essence, calibration is the process of minimizing these residual values through iterative methods. For the RC model, head measurements for the various monitoring wells and piezometers (both those installed by RC and local wells from external sources) were the main calibration target.

To facilitate calibration of the RC groundwater model, two sets of water level targets were defined – one for the shallow system and one for the deep system (see Table 3.5). As described in Section 2.2 above, the Resolution hydrogeology has two distinct flow systems: the deep, less permeable, partially confined system below the Whitetail Conglomerate (Tw) and the shallow unconfined system in the sedimentary volcanic Apache Leap Tuff (Tal). Due to the large differences in their heads and the disconnecting aquitard unit, the two systems were evaluated separately in the statistical calibration analysis.

Table 3.5 summarizes the calibration targets for the model including the number of water level observations for 1998-2016. Figure 3.8 shows the distribution of the monitoring network with calibration target locations shown in different colors on the map for shallow system and Deep Groundwater System targets.

Table 3.5: Calibration Target Summary

	All Targets
Number of Calibration Target locations	93
Number of Observations	5992
Average Target Value	3249 [ft]
Maximum Value	4097 [ft]
Minimum Value	-450 [ft]

For locations with frequent monitoring, water levels were averaged to provide monthly target values to reduce the potential bias in inverse models towards targets with larger datasets where there are many points through time (e.g., VWPs where water levels are being collected continuously). The DHRES series of wells have multiple sensors installed in the same borehole and hence represent a three-dimensional target dataset.

3.2.3 ASSESSING CALIBRATION PERFORMANCE

The calibration process was carried out in accordance with industry-standard guidelines and practices described in Anderson, Woessner, and Hunt, (2015), Barnett et al. (2012), Nevada BLM (2008), and several ASTM Standards (D 5918-96, D 5490-93). Both quantitative and qualitative methods were used to assess the calibration including the following:

— The calibration statistics of head residuals including mean error, mean absolute error, and root mean squared (RMS) error.

— Statistical fit of transient hydrographs (simulated and observed heads through time)
— Scatter plots comparing simulated versus observed heads
— Quantitative assessment of the water budget reasonableness compared to estimates based on field measurements
— Replication of HRES-20 and HRES-09 aquifer tests
— Qualitative assessment of the model fluxes for stream reaches
— Qualitative assessment of potentiometric contours (gradients, flow directions, etc.)
— Soft knowledge – evaluation of model results from the standpoint of hydrogeologic reasonableness, ability to replicate the conceptual model and overall system response.

3.2.4 CALIBRATION RESULTS

This section presents the results of the calibration with regards to different types of assessments.

HEAD TARGET STATISTICS

Head target statistics were assessed by comparing measured water levels within the model domain area to model-predicted heads in the corresponding model cells. Calibration statistics are presented for all data and for Apache Leap Tuff wells separately in Table 3.6 below. The Apache Leap Tuff targets are discussed separately because this system is separated from the Deep Groundwater System by the Whitetail Conglomerate and the GDEs along Devils Canyon are in the Apache Leap Tuff.

Table 3.6: Calibration Statistics

Statistical Measure	All Data	Apache Leap Tuff[1]
Number of Observations	5.992	2,330
Range in Observations	4,547 [ft]	1,272 [ft]
Residual Mean	24 [ft]	-14 [ft]
Absolute Residual Mean	91 [ft]	32 [ft]
Residual Std. Deviation	133 [ft]	40 [ft]
RMS Error	136 [ft]	42 [ft]
Min. Residual	-387 [ft]	-133 [ft]
Max. Residual	681 [ft]	54 [ft]
Scaled RMS Error	3.0 [%]	3.3 [%]

[1]The Apache Leap Tuff statistics did not include HRES-01, as it if highly influenced by Shaft 9 dewatering and does not reflect water levels of the general shallow aquifer system.

The RMS error, which is evaluated in the same units as the head targets (feet), potentially provides the best (least biased) value to assess the error for groups of targets. The scaled RMS error (also called the normalized RMS error) is an often-cited statistic which can be compared between models, and is calculated by dividing the RMS error by the range in heads of the observations. Some researchers suggest that a Scaled RMS Error value of 10% or less is acceptable (ASTM, 2008), whereas other researchers suggest that an acceptable Scaled RMS Error value is site-specific and not a guarantee of a well calibrated model (Anderson, Woessner, and Hunt, 2015).

In total 93 targets were assessed with 5,992 observations through model time. Overall the calibration statistics indicate a good fit between the measured and simulated data. The residual mean (24 ft) indicates the model is slightly underestimating heads on average. The RMS value of 136 ft results in a Scaled RMS of 3.0%, which is much less than the 10% rule of thumb and indicates that the fit is very good overall for the scale of the model.

Apache Leap Tuff targets were evaluated separately to assess the shallow system independently from the Deep Groundwater System, due to its importance to the potential impacts to GDEs to be simulated. The residual mean for the Apache Leap Tuff (-14 ft) indicates that the model slightly overestimates heads in that zone. The RMS value is 42 ft and the scaled RMS is 3.3%, indicating an excellent match. This gives confidence that the shallow system is well represented.

SCATTER PLOTS

Another useful way to visualize model calibration fit is to look at scatter plots of the simulated water level values versus measured water levels. Errors are indicated by deviations from the 1:1 line – points that are above the 1:1 line are overestimated (predicted values of head are higher than measured values) and points that are below the 1:1 line are underestimated (predicted values are lower than measured values).

Figure 3.9 shows the scatter plot of all calibration head targets. The majority of targets are clustered between 2,500 and 4,000 feet at the top right corner of the plot. The lower half of the scatter mainly centers around three specific piezometers: DHRES-01_WL, DHRES-02_WL and DHRES-08_231. These piezometers are highly influenced by the main dewatering signal propagated by Shafts 9 and 10, showing nearly 2,500 feet of drawdown between March 2009 and December 2016. The model, despite not having a perfect fit to these three targets, shows an excellent match in their overall behavior. This was a key metric for the calibration and builds additional confidence in the model.

Generally, the scatter is fairly even, with no bias of over or under prediction present. There is approximately the same number of simulated values that are greater than the observed values as there are simulated values that are less than the observed values.

A scatter plot has also been provided for only the Apache Leap Tuff targets in Figure 3.10. The shallow system tends to slightly overestimate the heads for the targets but overall the 1:1 match is shown to be adequate.

HYDROGRAPHS

Hydrographs plotting simulated and measured water levels for individual wells also offer valuable insight into the calibration. In addition to statistical assessment of residuals as detailed above, comparison of model-predicted versus measured data trends, especially for highly transient systems (such as the Deep Groundwater System), provides additional insight into the calibration.

The strong drawdown responses shown in the Deep Groundwater System in response to dewatering of Shafts 9 and 10, is clearly seen in some of the wells inside Resolution graben, specifically DHRES-01_WL, DHRES-02_WL and DHRES-08_231. These wells were prioritized as key targets to match, as pumping of Shafts 9 and 10 essentially represents a large-scale aquifer test. The fit of these three targets is good and gives an indication of how the model will respond to a large stress on the system, such as the development of the RC mine.

Appendix C includes all target hydrographs, with model-predicted values compared to field-measured data.

AQUIFER TEST MATCHING

Two long term pumping tests (at HRES-09 and at HRES-20) were recreated with the model to validate modeled hydraulic parameters within the Apache Leap Tuff. The HRES-09 test was a 23-day test performed with an average pumping rate of 73 gpm and the HRES-20 test was a 90-day test performed with an average pumping rate of 77 gpm. Because the groundwater model was already calibrated using the full suite of calibration targets in the historical period, the purpose of this exercise was to serve as a benchmark specifically targeting storage parameters.

The two pumping test models show that the hydraulic parameter values set in the Apache Leap Tuff within the historical calibration model are reasonable and allow for the re-creation of transient stresses as shown in Figures 3.12 and 3.13. The HRES-09 test helped improve the values set for local specific yield to be more in line with the analytical solution and match the drawdown response. Overall, the benchmarking exercise increased the confidence in the overall calibration and in the parameters values used.

WATERSHED FLOW BUDGET

The groundwater model simulates the saturated groundwater component of the hydrological budget, the two outputs that were quantified for comparison were areal recharge and surface discharge. In order to compare these values with the watershed flow budget, one must consider that only 16% of the Mineral Creek watershed is encompassed in the groundwater model domain and the shallow alluvial (perched) groundwater system is not included in the groundwater model. Comparing the values shown in Table 3.7 below, and scaling the values for the watershed water balance, show good agreement.

Table 3.7: Model Flow Budget by Watershed

	Watershed					
	Queen Creek		Devils Canyon		Mineral Creek	
	[AF/yr]	gpm	[AF/yr]	gpm	[AF/yr]	gpm
Areal Recharge	710	440	1020	632	140	87
Drain Outflow	530	329	660	409	560	347

WATER BUDGET (MASS BALANCE)

Water budget values are provided by MODFLOW-SURFACT output, which calculates the inflows and outflows of the model. Computed water budgets itemize all sources and sinks, including releases or uptake from storage for transient simulations, and help assess the accuracy of the numerical solution. As the governing equations of groundwater flow is derived from mass conservation and Darcy's Law, the numerical solution should be mass conservative as well. The water budget should be as close to zero with values less than 1% acceptable (Konikow, 1978, Anderson, Woessner, and Hunt, 2015).

The budget for the calibrated model is shown in the tabTable 3.8 below. The cumulative budget error (in minus out) is 0.94%, which indicates the numerical accuracy of the model is acceptable.

Table 3.8: Water Budget

Boundaries	Cumulative In [ft^3/d]	Cumulative Out [ft^3/d]	In - Out [ft^3/d]
Storage	4.43E+09	7.93E+08	3.64E+09
Constant Head	0.00	6.80E+07	-6.80E+07
Well Storage	8.85E+05	1.90E+05	6.95E+05
Wells	1.07E+08	5.05E+08	-3.98E+08
Drains	0.00	1.34E+10	-1.34E+10
Recharge	1.01E+10	0.00E+00	1.01E+10
General Head Boundaries	1.19E+06	4.57E+07	-4.45E+07
Total	1.46E+10	1.48E+10	-1.37E+08
Percent Discrepancy*			-0.94%

**Percent discrepancy is calculated as the imbalance (in – out) divided by the average of the cumulative (in and out).*

3.2.5 CALIBRATED HYDRAULIC PARAMETERS

HYDRAULIC CONDUCTIVITY

Following calibration, final hydraulic conductivity values for all HGUs were compiled in Table 3.9. As certain HGUs are divided into multiple zones with different values (e.g., Tal), a range is presented. For a full list and three-dimensional view (plan view and cross sectional) of the values of individual zones, see Appendix B. Additionally, Figure 3.12 shows the ranges of hydraulic conductivity for each HGU in the model alongside the corresponding measured field values. The geometric mean hydraulic conductivity values for each HGU are also plotted.

All units, are modeled as isotropic in the horizontal direction (x and y), hence the range in values is due to heterogeneity (multiple zones per HGU). The Tal, which did show some anisotropy in test HRES-20 with hydraulic conductivity in the north-south direction greater than the east-west direction (as described in Section 3.2.4), was achieved by heterogeniety rather than anisotropy. Appendix B, shows the elongated zone 16 which was set as higher hydraulic conductivity allowing for the north-south response to be matched.

Vertical hydraulic conductivity for all units is also shown in Table 3.9, however sparse field data exists and given the nature of fracturing, most units were set as isotropic. The Alluvium and the Whitetail units, whose sedimentary geology was conceptualized with support from field data, to have lower vertical hydraulic conductivity than horizontal, were the only two units with vertical anisotropy.

The values in the table, also displayed in Figure 3.14, show that the modeled values are consistent with the field data, with the highest values present in the shallow units, lower values in the Deep Groundwater System and very low values in the Whitetail Conglomerate. The Kvs shows some discrepancy between modeled value and the field data, however as values in this unit are highly sensitive to the large drawdowns seen during dewatering and the model does a good job of replicating this signal (as detailed section 3.2.4 above), these modeled values are justifiable.

Table 3.9: Calibrated Hydraulic Conductivity Values

Unit	Horizontal (ft/d)	Vertical (ft/d)
Qal	2E+00	2E-01
QTg	2E-03 to 3E-04	2E-03 to 3E-04
Tal	3E-00 to 1E-03	3E-00 to 1E-03
Tw	3E-03 to 3E-06	3E-03 to 5E-07
Kvs	3E-04 to 1E-04	3E-04 to 1E-05
Pz	1E-02 to 1E-05	1E-02 to 1E-05
pCy	1E-02 to 1E-04	1E-03 to 1E-04
pCpi	1E-03 to 1E-04	1E-03 to 1E-04

STORAGE

Calibrated storage values, specific yield and specific storage, are shown in Table 3.10 below. The largest values are seen in the shallow Apache Leap Tuff and Alluvial units, with the deep HGU units presenting low storage. Field storage values are available from the long-term pumping tests carried out in the Tal units, and the model values fall within this range.

Table 3.10: Calibrated Storage Values

Unit	Ss (1/ft)	Sy
Qal	1E-05	2E-01
QTg	4E-08	1E-02
Tal	5E-08	5E-03 to 1E-03
Tw	4E-08	1E-02
Kvs	5E-08 to 1E-08	7E-03 to 5E-03
Pz	5E-08 to 2E-08	1E-02 to 5E-03
pCy	1E-08	1E-02 to 5E-03
pCpi	1E-08	6E-03

FAULTS

The calibrated values for the fault hydraulic conductivities are shown in Table 3.11. These calibrated values incorporated both the calibration to head observations and guidance from consultants and RC geologists (Wickham GeoGroup, 2015a).

Faults can affect groundwater flow through several ways as discussed in section 2.2.5. Reduced hydraulic conductivity was used to represent these properties. Most of the hydraulic conductivities assigned, as shown below, are modeled similar or slightly lower than the surrounding rock. This is consistent with field data and the general view that fault in the area behave as weak (or leaky-type) barriers to flow. Parallel to strike, faults can act as conduits to flow. All faults, apart from the Anxiety Fault, are modeled as isotropic, for simplicity.

The Anxiety Fault, is hypothesized to show conduit-like behavior along its strike and greater impedance across it based on head data collected from the modeled area. This is conceptualized as a potential reason for the dewatering drawdown signal extending further northward to DHRES-11_WL and DHRES-11_-231. The North-South trace of the fault allowed for hydraulic conductivity components in the x and y (ky parallel with fault and kx is perpendicular to fault) directions to be are aligned with the coordinate axis.

Table 3.11: Calibrated Fault Hydraulic Conductivities

Fault	K (ft/d)
North Boundary	6E-04
Rancho Rio	3E-04
South Boundary	2E-05
West Boundary	1E-05
Concentrator	1E-03
Conley Springs	4E-05
Anxiety*	5E-04
Pre-Laramide	1E-05

**Anxiety Fault is horizontally anisotropic, with a value of 1E-02 ft/d for Ky.*

3.2.6 PARAMETER SENSITIVITY

ASTM standard D5611-4 *Standard Guide for Conducting a Sensitivity Analysis for a Groundwater Flow Model Application* (ASTM International, 2016) has been used as the reference to guide sensitivity analysis for the Resolution Copper groundwater model. In alignment with the concepts of the ASTM, the first step in the analysis was to determine which parameters had the largest impact on the model calibration (i.e., most sensitive). This task was achieved using the inverse model code PEST (Watermark Numerical Computing, 2016) which can be used to quantify the effect parameters have on the calibration (evaluated based on the sum of squared residuals). With this tool, a preliminary list of parameters was derived to test for predictive purposes. However, through discussions with the Groundwater Modeling Workgroup, this list was expanded to test a broader range of parameters due to their significance at groundwater dependent ecosystems (GDE) (e.g., springs). Additionally, parameters not present in the calibration but included in the predictive models were added (e.g., storage parameters for the damaged zone associated with the block cave mine).

Parameters with a logarithmic distribution (e.g., hydraulic conductivity) were varied by one order of magnitude in each direction and non-logarithmic parameters (e.g., specific yield and recharge) were varied by +/- 50%. The range of specific yields tested for the block-caved material, were constrained by the ranges of sensitivity values presented in *Assessment of Surface Subsidence Associated with Caving - Resolution Copper Mine Plan of Operations* (ITASCA, 2017). A full list of all 87 predictive model runs (43 parameter increases, 43 parameter decreases and 1 change in boundary condition type), including parameter zone, corresponding Hydrogeologic Unit (HGU), and the tested values are included in Table 1.

For each sensitivity scenario, the historical model was run with the corresponding parameter change to ensure model calibration statistics had not degraded above an acceptable point, which for our analysis was defined as >10% Normalized Root Mean Squared Error (NRMS) value for the shallow and deep targets separately. No-Action and Proposed Action The full list of parameters tested in the sensitivity analysis is shown below.

- Hydraulic conductivity (K_x, K_y, K_z) of all zones within the Apache Leap Tuff (Tal)
- Hydraulic conductivity (K_x, K_y, K_z) of the Gila Conglomerate (QTg)
- Hydraulic conductivity (K_x, K_y, K_z) of the Lower Whitetail Conglomerate (Tw)
- Hydraulic conductivity (K_x, K_y, K_z) of the Paleozoic units (Pz) north and south of graben
- Hydraulic conductivity (K_x, K_y, K_z) of the Younger pre-Cambrian unit (pCy) north of graben
- Hydraulic conductivity (K_x, K_y, K_z) of the Pinal Schist (pCpi)
- Hydraulic conductivity (K_x, K_y, K_z) of the Devils Canyon, JI Ranch and graben faults
- Recharge of high elevation zone
- Recharge of low elevation zone
- Specific yield of all zones within the Apache Leap Tuff
- Specific yield of the Paleozoic unit south of graben
- Specific yield of the Younger pre-Cambrian unit south of graben
- Specific yield of block caved material
- Conversion of General Head Boundaries to No-Flow Boundaries.

The results of the sensitivity analysis can be found in the memo *Resolution Copper Groundwater Flow Model – Sensitivity Analysis* (WSP, 2018b).

4 PREDICTIVE MODELS

The calibrated groundwater model as presented in the previous section reasonably represents the historic behavior and hydraulic stresses on the regional groundwater system. Therefore, the model was deemed appropriate for making future predictions about how the groundwater system is expected to respond to the proposed mining and associated infrastructure. Given that the life of mine (LoM) and closure/post closure periods have different activities and features, it was more efficient to construct two different predictive models:

- Life of Mine Model – which encompasses the permitting period, mine development period, and life of mine when mine dewatering activities will occur.
- Closure/Post-Closure Model – which encompasses the post-mining closure and post-closure period, when the dewatering system will be decommissioned and groundwater levels are allowed to recover.

Both models use the calibrated historical model with the same domain, grid, layering, boundary conditions, hydraulic properties, etc. The model was modified for each phase to simulate new features not in the historic calibration period (e.g., the block cave mine). Construction of the LoM model is described in Section 4.1 and construction of the Closure/Post-Closure model is described in Section 4.2. Predictive results are presented in *Resolution Copper Groundwater Flow Model - Predictive Results Memo* (WSP, 2018a).

4.1 LIFE OF MINE MODEL

The life of mine predictive modeling is to quantify the potential impacts that the proposed block cave mine will have on the groundwater system. The predictive LoM model simulates two distinct scenarios to address the issues identified in section 1.5 above:

1. Proposed Action (PA) – simulates the planned block cave mine development and life of mine as described in the GPO (www.resolutionmineeis.us, RC, 2014).
2. No Action (NA) alternative – simulates continued dewatering of the historical Magma workings from existing and permitted insfrastructure (Shafts 9 and 10) without developing the planned RC block cave mine.

The LoM model was run forward for 51years that includes:

- The permitting period/care and maintenance, which is currently simulated as four years. During this time, Shaft 9 will be deepened to a depth similar to Shaft 10 to allow for safe means of maintaining the shaft infrastructure.
- The mine development period, which is currently simulated as seven years after the permitting period. During this time, mine infrastructure including Shafts 11 through 14 and tunnels for haulage, ventilation, etc. will be constructed.
- The life of mine period during ore production, which was simulated as 40 years through the end of life of mine/start of closure.

4.1.1 PREDICTIVE SCENARIOS

PROPOSED ACTION

The Proposed Action simulates the implementation of RC's proposed mine plan, as outlined in the GPO, including the care and maintenance/permitting period, mine development period, and through LoM. Underground workings and the block cave was modeled using time-varying material property values for hydraulic conductivity, specific storage, and specific yield.

NO ACTION ALTERNATIVE

The No Action alternative is essentially the existing condition of care and maintenance of the mine infrastructure and thus an extension of the historical model in which there is no further mine development beyond the deepening of Shaft 9 to allow safer care and maintenance (secondary means of egress). This model scenario simulates continued dewatering via Shafts 8, 9 and 10 to preserve the asset through continued dewatering. It was run forward for 51 years to match the duration and timing of the Proposed Action simulation. Management of water levels within the shafts and underground workings was implemented using drains. Drains are conceptually considered to be equivalent to the extraction of groundwater from pumping in Shafts 8, 9 and 10, to maintain a consistent head between the series of historical, connected underground workings.

4.1.2 UNSATURATED FLOW

Unsaturated flow was simulated using the MODFLOW-SURFACT Pseudo Soil function, an unsaturated flow analog that allows for the model to run successfully by reducing unsaturated flow to a simplified step function rather than a non-linear curve that is dependent on accurate estimation of unsaturated parameters. The Pseudo Soil function allows for numerical stability within the model and simplifies the system by allowing unsaturated model cells to freely drain, eliminating the unsaturated cells retaining residual water within pores. The Pseudo Soil function does not include a detailed simulation of unsaturated flow in the vadose zone, but rather is a simplification.

For purposes of assessing the maximum impacts from regional groundwater drawdowns, this numerical simplification means all water within the block cave limits are simulated as drawn from the regional groundwater system via drains that represent the underlying underground workings. Therefore, the drawdown within the block cave limits and the flowrates and volume of water removed via dewatering infrastructure are overestimated and incorporates a significant level of conservatism in the model.

4.1.3 TIME DISCRETIZATION

The Proposed Action and No Action alternatives were built with the same time discretization.

— LoM model years 1-4: Care and Maintenance/Permitting Period
— LoM model years 5-11: Development Period
— LoM model years 12-51: Mining Life of Mine years 1-40.

The time setup for the mine production phase was directly coupled with the geotechnical datasets.

The LoM models was run in a transient mode throughout the entire 51-year period to simulate future stresses imparted on the groundwater system by the proposed RC project.

Table 4.1 summarizes the stress periods.

Table 4.1: Summary of mine plan and model stress periods

LoM Model Year	Stress Period	Stress Period Length
1 - 10	1 – 10	1 year
11 - 49	11 - 88	6 months
50 - 51	89 – 90	1 year

4.1.4 INITIAL HEADS

The initial heads for the Proposed Action and No Action alternative were obtained from the final heads in the calibrated historical model (December 31, 2016). Both predictive LoM model cases (Proposed Action and No Action alternative) used the same starting heads. As such, any errors in the calibrated historical model are carried into the predictive LoM model.

4.1.5 MATERIAL PROPERTIES

PROPOSED ACTION

The material properties for the HGUs in the Proposed Action model were the same as the calibrated historical model for the permitting period (years 1-4), but required material changes for the development and mining phases. New material property zones in the Proposed Action model were assigned to cells where future RC mine development and block caving, or geotechnical changes (subsidence) would occur, as determined from the mine plans and geotechnical subsidence model results.

Future infrastructure and block cave cells initially were assigned material properties (K, Ss and Sy values) that correspond to the original intact rock zone from the calibrated historical model. For cells where material property changes are expected, the assignment of individual cells to individual zones were required to account for the time-varying nature of properties for each cell within the subsidence zone.

Mine Infrastructure. Future mine infrastructure simulated in the Proposed Action model included the sinking of Shafts 11-14 and tunnels for five infrastructure levels utilizing plans that showed the progression of mine development over time. The material properties of the model cells representing the future mine infrastructure were modified to represent these features at the following times:

- Deepening of Shaft 9 – LoM model years 3-4 (in both Proposed Action and No Action alternative)
- Sinking of Shaft 11 – LoM model years 6-10.5
- Sinking of Shaft 12 – LoM model years 9-13
- Sinking of Shaft 13 – LoM model years 6-10.5
- Sinking of Shaft 14 – LoM model years 6-10
- Development of tunnels – begins in LoM model year 5
- First undercut for LoM ore production – LoM model year 11

Cave Zone. The alteration of hydraulic conductivity values were implemented based on plastic strain data obtained from the subsidence geotechnical model (Itasca, 2017). The timing and magnitude of change applied to each cell are dependent on the timing and proximity to caving. In general, the hydraulic conductivity of model cells are initially modified at the fracture propagation front preceding the caving front or fully rubblized zone. Thereafter, hydraulic conductivity will continue to increase to maximum values once model cells are fully fractured and considered "cave." Maximum hydraulic conductivity values were altered by a multiplier of 1E+6 or to a hydraulic conductivity of 100 ft/day, whichever occurs first, based on initial hydraulic conductivity values of HGUs. The maximum hydraulic conductivity value of 100 ft/day was selected because it is much higher than the natural, un-altered bedrock, but higher values caused the model to become unstable.

Storage parameters (specific storage and specific yield) are also altered to account for increasing porosity and storage that would result from the fracturing and fragmentation (bulking) of the rock mass. Simulation of changing storage parameters were implemented in a similar fashion to hydraulic conductivity. The changes in rock volume over time were estimated from the subsidence geotechnical model and converted to changes in porosity, based on the swell factor simulated in the geotechnical model. The changes in porosity were represented in the model as changes in specific yield (Sy) and occurred throughout the cave zone, but were greatest towards the center of the cave when cells become rubblized.

NO ACTION ALTERNATIVE

The No Action alternative utilizes the calibrated historical model's hydraulic conductivity (K) and storage (Ss and Sy). The deepening of Shaft 9 occurs during LoM model years 3 and 4. The deepening of Shaft 9 required additional zones to be added to the existing zones from the historical model. These zones allowthe material properties for model cells representing Shaft 9 to be altered as the shaft is deepened.

4.1.6 AREAL RECHARGE

The areal recharge zones defined in the historical model were incorporated into the LoM model. However, the presence of fracturing at the ground surface required an additional recharge zone to account for differences within the Proposed Action LoM model for the subsidence zone.

For the Proposed Action model, an enhanced recharge zone were incorporated into the model to simulate increased infiltration of precipitation to the subsidence zone overlying the cave. The enhanced recharge zone was implemented with a transient approach to mimic the propagation of the influenced cave footprint over time. The enhanced recharge zone was given a recharge rate of 4.4E-04 ft/day (1.9 inch/year), which is approximately 8.5% of mean annual precipitation. The recharge rate was chosen to correspond with the value used for enhanced recharge along streambeds within the Apache Leap Tuff as conceptually the modes of recharge are similar:

1. Accumulation of direct precipitation and runoff
2. Increased infiltration through higher K materials compared to surrounding rock.

4.1.7 BOUNDARY CONDITIONS

Boundary conditions for the LoM model on the edges of the model domain (General Head Boundaries, Constant Head Boundaries and No-Flow Boundaries) were maintained from the historical calibrated model. For a detailed description see Section 3. The boundary conditions related to the underground workings (i.e. drains) were included in the LoM model as described below.

Drains are implemented in the LoM model to simulate the removal of water from the groundwater system due the mine development. The features represented with drains are as follows:

- Underground workings
  - Historic Magma workings (in both Proposed Action and No Action alternative)
  - Future workings during block cave development and production (in Proposed Action model only)
- Shafts 9 and 10 (in both Proposed Action and No Action alternative)
- Shafts 11-14 (in Proposed Action model only)

Model cells representing mine infrastructure were simulated with drains to remove groundwater from the system to simulate dry working conditions.

East Workings. The East Workings are interconnected to Shafts 9 and 10 which will be used for future dewatering. The East Workings are assumed to be dry throughout the 51 years for both the Proposed Action and No Action alternative.

West Workings. Future water levels in the West Workings will be managed by Shaft 8 pumping, similar to the current strategy. Data from DHRES-10 show that water levels in this area are being maintained near 375 ft below sea level. Based on this, the West Workings drain stage elevation were set to maintain levels at -375 ft for both the Proposed Action and No Action alternative. For cells that lie above -375 ft, the stage were set to maintain cells as dry.

Future Underground Workings. Use of drains to simulate future underground workings is only implemented in the Proposed Action model. The mine plan was used to delineate model cells where underground workings would be present and the time when those workings would be completed. A graphical representation of model cells designated as mine infrastructure and assigned drains is shown in Figure 4.1.

4.2 CLOSURE/POST-CLOSURE MODEL

Upon completion of mining, the mine will be decommissioned and the dewatering system will be shut down as part of closure. Groundwater levels within the area of the graben will slowly rise, flooding the void spaces of the mine levels and the cave zone. The closure/post-closure model was constructed to simulate the changes to the hydrogeological system during the closure and post closure periods. The closure model was run for a period of 150 years post life of mine, allowing the system to recover to quasi-steady-state conditions. The setup of the models representing the Proposed Action and No Action alternative for the closure/post-closure period included:

1. Proposed Action – 150 years of water level recovery during the closure and post-closure period, following the 51 year Proposed Action LoM simulation that included dewatering of the mine infrastructure and execution of the block cave mine as outlined in the GPO.
2. No Action alternative – 150 years of water level recovery following the 51 year No Action alternative simulation that included dewatering of the Magma workings and Shafts 9 and 10.

For the Proposed Action, the closure model was built using the final properties of the altered hydrogeological system from the end of the Proposed Action LoM model. Final hydraulic conductivity and storage values of the cave zone model cells and enhanced recharge over the subsidence area have been assigned. For comparison, the No Action alternative closure model was constructed to predict conditions over the same time period assuming the mine is not constructed, so there is no enhanced recharge added. The No Action alternative closure model assumes that the dewatering of the Magma Workings and Shafts 9 and 10 are continued through the entire LoM period, but are discontinued during the closure period. Comparison of the Proposed Action and No Action alternative models were used to estimate potential long term impacts through LoM and post closure.

4.2.1 TIME DISCRETIZATION

The closure/post-closure model was run in transient mode for 1,000 years. It was set up with a single (1) stress period, spanning the full model time. As no time-variable model components will exist in the transient simulation, multiple stress periods were not implemented.

4.2.2 INITIAL HEADS

Initial heads for the Proposed Action and No Action alternative were taken from the final heads of the corresponding LoM models (e.g., the final heads of the Proposed Action LoM model were used as the initial heads of the Proposed Action closure model). This ensures continuity of the simulations from mine operations to closure and post-closure.

4.2.3 MATERIAL PROPERTIES

The Proposed Action closure /post-closure model includes the calibrated hydraulic property values derived from the historical model and the final altered hydraulic property values from the LoM model. The No Action alternative closure model used the material properties from the No Action alternative model, which were the same as the calibrated properties determined in the historical period.

4.2.4 AREAL RECHARGE

Areal recharge in the closure/post-closure models was set to the values used in the historical model, as described in Section 3.1.6. For the Proposed Action model, the enhanced recharge zone implemented in the final time step of the LoM model, representing the full extent of the cave zone on the land surface (based on the geotechnical model) will remain throughout the 150-year closure/post-closure simulation period. The enhanced recharge zone was assigned a recharge rate of 4.4E-4 ft/day, which is approximately 8.5% of mean annual precipitation over the of subsidence. The No Action alternative model does not include the enhanced recharge zone over the mine area as there would be no subsidence zone.

4.2.5 BOUNDARY CONDITIONS

All boundary conditions in the closure models were the same as those used in the corresponding LoM models. The only change that was made in the setup is the removal of all drains associated with all underground workings (Magma workings, RC workings, Shafts 9-14). The removal of the drains represents the decommissioning of dewatering infrastructure and will allow water to remain within the model, thus allowing water level recovery.

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APPENDICES

East Plant Site - Shallow System

Well Tested	Test Type	Ground Surface Elevation	HGU Tested	Well Feature(s): Screens, Packer Intervals, Open Boreholes	Depth to		Elevation of		Feature Interval Length	Transmissivity (ft^2/day)	Feature for K Calculation	Thickness (b) for K Calculation	Hydraulic Conductivity	Calculation Source	Storativity	Specific Storage (/ft)	Specific Yield	Reference	Remarks
					Top	Bottom	Top	Bottom											
HRES-01	Constant-rate tests in multiple zones	4168.9	Tal	Screen 1	1055	1077	-1055	-1077	22	0.75	Screened Section 1 in Interval A	22	3E-02	Recomputed by WSP	N/D	N/D	N/D	M&A, 2005	Use computed T for corresponding interval with screened portion in interval
				Screen 2	1360	1403	-1360	-1403	43	7.1	Screened Section 2 in Interval B	43	2E-01	Recomputed by WSP					Use computed T for corresponding interval with screened portion in interval
				Screen 3	1578	1598	-1578	-1598	20	2.4	Screened Section 3 in Interval C	20	1E-01	Recomputed by WSP					Use computed T for corresponding interval with screened portion in interval
				Packer Interval A-C	1033	1111	-1033	-1111	78	10.2	Test 1 - Packer Intervals A, B, C	226	5E-02	Reported by M&A					Test 1 - Zones A, B, C; Q = 10 gpm; Sy = 0.1
					1344	1420	-1344	-1420	75										3 separate pumping tests in cased well and packed off intervals
					1527	1600	-1527	-1600	73										
				Packer Interval B-C	1344	1420	-1344	-1420	75	9.5	Test 2 - Packer Intervals B, C	148	6E-02	Reported by M&A					Test 2 - Zones B, C; Q = 9 gpm; Sy = 0.12
					1527	1600	-1527	-1600	73										
				Packer Interval A	1033	1111	-1033	-1111	78	0.75	Filter Pack Interval A	78	1E-02	Reported by M&A					Computed by subtraction
				Packer Interval B	1345	1420	-1345	-1420	75	7.1	Filter Pack Interval B	75	9E-02	Reported by M&A					Computed by subtraction
				Packer Interval C	1527	1600	-1527	-1600	73	2.4	Test 3 - Filter Pack Interval C	73	3E-02	Reported by M&A					Test 3 - Zone C; Q = 8.5 gpm; Sy = 0.11
				Open	879	1600	-879	-1600	721	57	Open Borehole	721	8E-02	Reported by M&A					Open borehole test; Q = 87 gpm
HRES-02	Constant-rate tests in multiple zones	3979.1	Tal	Screen 1	656	678	-656	-678	22	194	Screened Section 1 in Interval A	22	9E+00	Recomputed by WSP	N/D	N/D	N/D	M&A, 2005	Use computed T for corresponding interval with screened portion in interval
				Screen 2	1026	1048	-1026	-1048	22	3.1	Screened Section 2 in Interval B	22	1E-01	Recomputed by WSP					Use computed T for corresponding interval with screened portion in interval
				Screen 3	1266	1310	-1266	-1310	44	2.9	Screened Section 3 in Interval C	44	7E-02	Recomputed by WSP					Use computed T for corresponding interval with screened portion in interval
				Packer Interval A-C	646	692	-646	-692	46	204	Test 1 - Packer Intervals A, B, C	139	1E+00	Reported by M&A					Test 1 - Zones A, B, C; Q = 17 gpm
					1017	1053	-1017	-1053	36										3 separate pumping tests in cased well and packed off intervals
					1256	1313	-1256	-1313	57										
				Packer Interval B-C	1017	1053	-1017	-1053	36	6	Test 2 - Packer Intervals B, C	93	6E-02	Reported by M&A					Test 2 - Zones B, C; Q = 7.5 gpm
					1256	1313	-1256	-1313	57										
				Packer Interval A	646	692	-646	-692	46	194	Filter Pack Interval A	46	4E+00	Reported by M&A					Computed by subtraction
				Packer Interval B	1017	1053	-1017	-1053	36	3.1	Filter Pack Interval B	36	9E-02	Reported by M&A					Computed by subtraction
				Packer Interval C	1256	1313	-1256	-1313	57	2.9	Test 3 - Packer Interval C	57	5E-02	Reported by M&A					Test 3 - Zone C; Q = 4.6 gpm
				Open	298	1310	-298	-1310	1011	150	Open Borehole	1011	1E-01	Reported by M&A					Open borehole test; Q = 205 gpm
HRES-03	Constant-rate tests in multiple zones	4075.6	Tal	Open	397	1500	-397	-1500	1103	21.5	Open Borehole	1103	2E-02	Reported by M&A	N/D	N/D	N/D	M&A, 2005	Open borehole test; Q = 24 gpm
				Packer Interval A	1444	1502	-1444	-1502	58	N/T	Test 1 - Packer Interval A	58	N/D	Reported by M&A					Pumping can't be sustained; test abandoned
HRES-03D	Slug test in deep perforated zone	4075.6	Tal	Screen 2	1456	1500	-1456	-1500	44	N/A	Screened Section	44	7E-04	Reported by M&A	N/D	N/D	N/D	M&A, 2012	Slug volume = 3,744 cm^3
				Isolated Interval	1444	1502	-1444	-1502	58		Filter Pack	58		Recomputed by WSP					
HRES-04	Constant-rate tests in multiple zones	4074.7	Tal	Screen 1	584	624	-584	-624	40	710	Screened Section 1 & 2	80	9E+00	Recomputed by WSP	N/D	N/D	N/D	M&A, 2005	Use computed T for corresponding interval with screened portion in interval
				Screen 2	724	764	-724	-764	40										
				Screen 3	1284	1304	-1284	-1304	20	N/T	Screened Section 3 & 4	41	N/D	Recomputed by WSP					Interval not tested due to low flow rate
				Screen 4	1419	1440	-1419	-1440	21										
				Packer Interval A-B	569	782	-569	-782	213	710	Test 1 - Packer Interval A, B	390	2E+00	Reported by M&A					Test 1 - Zones A, B; Q = 23 gpm
					1270	1447	-1270	-1447	177										
				Packer Interval B	1270	1447	-1270	-1447	177	N/T	Test 2 - Packer Interval B	177	N/D	Reported by M&A					Test 2 - Zone B; Low & variable pumping rates; test abandoned
				Open	396	1440	-396	-1440	1044	1313	Open Borehole	1044	1E+00	Recomputed by WSP					Open borehole test; Q = 105 gpm
HRES-04	Long-term constant rate pumping test (25 days)	4074.7	Tal	Screen 1	584	624	-584	-624	40	380	Screened Sections	80	5E+00	Recomputed by WSP	1E-4 to 9E-4	8E-8 to 7E-7	N/D	M&A, 2006	Q = 35.6 gpm
				Screen 2	724	764	-724	-764	40										
				Filter Pack 1	569	782	-569	-782	213		Filter Pack	400	1E+00	Recomputed by WSP					
				Filter Pack 2	1270	1457	-1270	-1457	187										T calculated as average from observation wells
				Aquifer Thickness	-	-	-	-	1312		Aquifer Thickness	1312	3E-01	Reported by M&A					T calculated from aquifer thickness as defined by M&A as 400 meters
HRES-05	Constant-rate tests in multiple zones	3992.1	Tal	Screen 1	385	425	-385	-425	40	1033	Screened Section 1, 2 & 3	80	1E+01	Recomputed by WSP	N/D	N/D	N/D	M&A, 2005	Use computed T for Test 1 with screened portion for well
				Screen 2	585	605	-585	-605	20										
				Screen 3	1015	1035	-1015	-1035	20										
				Packer Interval A-C	374	435	-374	-435	61	1033	Test 1 - Packer Intervals A, B, C	137	8E+00	Reported by M&A					Test 1 - Zones A, B, C; Q = 96 gpm
					576	615	-576	-615	39										
					1005	1042	-1005	-1042	37										
				Packer Interval B-C	576	615	-576	-615	39	N/T	Test 2 - Packer Intervals B, C	76	N/A	Reported by M&A					Test 2 - Zones B, C; Low & variable pumping rates; test abandoned
					1005	1042	-1005	-1042	37										
				Packer Interval C	1005	1042	-1005	-1042	37	N/T	Test 3 - Packer Interval C	37	N/A	Reported by M&A					No test performed
				Open	321	1055	-321	-1055	733	957	Open Borehole	733	1E+00	Reported by M&A					Open borehole test; Q = 89 gpm
HRES-06	Constant-rate pumping test (12 hours)	4331.9	Tal	Screen 1	340	800	-340	-800	460	N/A	Screened Section	460	N/D	Recomputed by WSP	N/D	N/D	N/D	M&A, 2012	Q = 15.8 gpm
				Filter Pack	296	820	-296	-820	524		Filter Pack	524	N/D	Recomputed by WSP					
				Static WL to Hole Bottom	392	820	-392	-820	428		Static WL to Hole Bottom	428	N/D	Recomputed by WSP					
				Saturated Screen	392	800	-392	-800	408		Saturated Screen	408	N/D	Recomputed by WSP					
				Fracture Domain	-	-	-	-	-		Fracture Domain	-	2E-01	Reported by M&A					Fracture domain estimate; No dicussion about tested interval. No T value reported, only K calculated for fractures and matrix
				Matrix	-	-	-	-	-		Matrix	-	6E-02	Reported by M&A					Matrix; No dicussion about tested interval. No T value reported, only K calculated for fractures and matrix
HRES-07	Constant-rate pumping test (8 hours)	4016.5	Tal	Screen 1	335	749	-335	-749	414	1183	Screened Section	414	N/C	Recomputed by WSP	N/D	N/D	N/D	M&A, 2012	Q = 35 gpm
				Filter Pack 1	295	769	-295	-769	474		Filter Pack	474	N/C	Recomputed by WSP					
				Static WL to Interval Bottom	381	769	-381	-769	388		Static WL to Interval Bottom	388	3E+00	Recomputed by WSP					
				Saturated Screen 1	381	749	-381	-749	368		Saturated Screen	368	3E+00	Reported by M&A					
HRES-07	Long-term constant rate pumping test (25 days)	4016.5	Tal	Screen 1	335	749	-335	-749	414	898	Screened Section 1	414	2E+00	Reported by M&A	N/D	N/D	0.015 to 0.07	M&A, 2010	T = 898 from pumped well average
				Screens 1 & 2	335	749	-335	-749	414		Screened Sections 1 & 2	621	1E+00	Recomputed by WSP					
					812	1019	-812	-1019	207										
				Filter Pack 1	295	769	-295	-769	474		Filter Pack 1	474	2E+00	Recomputed by WSP					
				Filter Pack - Screen 1 & 2	295	769	-295	-769	474		Filter Pack 1 & 2	745	1E+00	Recomputed by WSP					
					797	1068	-797	-1068	271										
				Static WL to Bottom Filter Pack 1	382	769	-382	-769	387		Static WL to Bottom Filter Pack 1	387	2E+00	Recomputed by WSP					Sy = 0.015 - 0.07
				Static WL to Hole Bottom	382	1068	-382	-1068	686		Static WL to Hole Bottom	686	1E+00	Recomputed by WSP					
				Saturated Screens 1 & 2*	382	749	-382	-749	367		Saturated Screens 1 & 2	574	2E+00	Recomputed by WSP					Shallow zone perforated interval as aquifer thickness; More permissive shallow than deep; assumed deep is less permeable
					812	1019	-812	-1019	207										
HRES-07D	Slug test in deep perforated zone	4016.5	Tal	Screen 1	812	1019	-812	-1019	207	N/A	Screened Section	207	6E-02	Reported by M&A	N/D	N/D	N/D	M&A, 2012	Slug volume = 637 cm^3
				Filter Pack	797	1054	-797	-1054	257		Filter Pack	257		Recomputed by WSP					
HRES-09	Constant-rate pumping test (24 hours)	3923.3	Tal	Screen 1	271	1078	-271	-1078	807	50	Screened Section	807	6E-02	Reported by M&A	N/D	N/D	N/D	M&A, 2012	Q = 79 gpm
				Filter Pack	215	1125	-215	-1125	910		Filter Pack	910	5E-02	Recomputed by WSP					
				Static WL to Hole Bottom	251	1125	-251	-1125	874		Static WL to Hole Bottom	874	6E-02	Recomputed by WSP					
HRES-09	Long-term constant rate pumping test (23 days)	3923.3	Tal	Screen 1	271	1078	-271	-1078	807	150	Screened Section	807	2E-01	Reported by M&A	2.30E-06	2.70E-09	4.00E-02	M&A, 2016	Q = 77 gpm
				Filter Pack	215	1125	-215	-1125	910		Filter Pack	910	-	Recomputed by WSP					
				Static WL to Hole Bottom	251	1125	-251	-1125	874		Static WL to Hole Bottom	874	2E-01	Recomputed by WSP					
HRES-10	Constant-rate pumping test (10 hours)	2935.1	Tal	Screen 1	158	398	-158	-398	240	646	Screened Section 1	240	3E+00	Reported by M&A	N/D	N/D	N/D	M&A, 2011	Q = 27 gpm
				Screened Sections 1 & 2	158	398	-158	-398	240		Screened Sections 1 & 2	641	1E+00	Recomputed by WSP					
					698	1099	-698	-1099	401										
				Filter Pack 1	110	424	-110	-424	314		Filter Pack 1	314	2E+00	Recomputed by WSP					
				Filter Pack 1 & 2	110	424	-110	-424	314		Filter Pack 1 & 2	764	8E-01	Recomputed by WSP					
					679	1129	-679	-1129	450										
HRES-11	Constant-rate pumping test (48 hours)	3466.1	Tal	Screen 1	598	1078	-598	-1078	480	108	Screened Section	480	-	Recomputed by WSP	N/D	N/D	N/D	M&A, 2011	Q = 9.5 gpm
				Filter Pack	95	1111	-95	-1111	1016		Filter Pack	1016	-	Recomputed by WSP					
				Saturated Screen	638	1078	-638	-1078	440		Saturated Screen	440	2E-01	Reported by M&A					
				Static WL to Hole Bottom	638	1111	-638	-1111	473		Static WL to Hole Bottom	473	2E-01	Recomputed by WSP					
HRES-12	Constant-rate pumping test (7.5 hours)	4168.6	Tal	Screen 1	1767	1967	-1767	-1967	200	0.75	Screened Section	200	4E-03	Reported by M&A	N/D	N/D	N/D	M&A, 2011	Q = 8 gpm; No filter pack; open annulus borehole
				Open	80	1988	-80	-1988	1908		Open Annulus	1908	4E-04	Recomputed by WSP					
HRES-13	Constant-rate pumping test (12 hours)	4199.1	Tal	Screen 1	423	860	-423	-860	437	420	Screened Section	437	-	Recomputed by WSP	N/D	N/D	N/D	M&A, 2012	Q = 12.7 gpm
				Filter Pack	30	907	-30	-907	877		Filter Pack	877	-	Recomputed by WSP					
				Saturated Screen	471	860	-471	-860	389		Saturated Screen	389	1E+00	Reported by M&A					
				Static WL to Hole Bottom	471	907	-471	-907	436		Static WL to Hole Bottom	436	1E+00	Recomputed by WSP					
HRES-14	Constant-rate pumping test (48 hours)	4214.7	Tal	Screen 1	962	1440	-962	-1440	478	269	Screened Section	478	6E-01	Reported by M&A	N/D	N/D	N/D	M&A, 2012	Q = 12.7 gpm
				Filter Pack	802	1452	-802	-1452	650		Filter Pack	650	4E-01	Recomputed by WSP					
HRES-15	Constant-rate pumping test (48 hours)	4315.4	Tal, Tvo	Screen 1	679	1530	-679	-1530	851	N/A	Screened Sections	1059	3E+00	Reported by RCM	N/D	N/D	N/D	RCM	Found in table modified by Heather Gluski
				Screen 2	1750	1958	-1750	-1958	208										
				Filter Pack 1	60	1672	-60	-1672	1612		Filter Pack Intervals	1892							
				Filter Pack 2	1704	1984	-1704	-1984	280										
				Static WL to Hole Bottom	642	1984	-642	-1984	1342		Static WL to Hole Bottom	1342							
HRES-17	Constant-rate pumping test (24 hours)	4392.3	Tal	Screen 1	726	1330	-726	-1330	604	N/A	Screened Section	604	9E-02	Reported by RCM	N/D	N/D	N/D	RCM	Found in table modified by Heather Gluski
				Filter Pack	685	1400	-685	-1400	715		Filter Pack	715							
				Saturated Screen	742	1330	-742	-1330	588		Saturated Screen	588							
				Static WL to Hole Bottom	742	1400	-742	-1400	658		Static WL to Hole Bottom	658							

N/A - Not Applicable N/D - No Data N/T - Not Tested N/C - Not Calculated

East Plant Site - Shallow System (continued)

Well Tested	Test Type	Ground Surface Elevation	HGU Tested	Well Feature(s): Screens, Packer Intervals, Open Boreholes	Depth to Top	Depth to Bottom	Elevation of Top	Elevation of Bottom	Feature Interval Length	Transmissivity (ft^2/day)	Feature for K Calculation	Thickness (b) for K Calculation	Hydraulic Conductivity	Calculation Source	Storativity	Specific Storage (/ft)	Specific Yield	Reference	Remarks
HRES-18	Slug test	4090.4	Tal	Screen 1	462	940	-462	-940	478	N/A	Screened Section	478	9E-03	Reported by RCM	N/D	N/D	N/D	RCM	Found in table modified by Heather Gluski
				Open	45	976	-45	-976	931		Open Borehole	931							
				Saturated Screen	687	940	-687	-940	253		Saturated Screen	253							
				Static WL to Hole Bottom	687	976	-687	-976	289		Static WL to Hole Bottom	289							
HRES-20	Long-term constant rate pumping test (90 days)	4318.1	Tal	Screen 1	597	1035	-597	-1035	438	260	Screened Section	438	6E-01	Recomputed by WSP	4.00E-05	4.10E-08	2.20E-03	M&A, 2010	Q = 77 gpm
				Filter Pack	577	1057	-577	-1057	480		Filter Pack	480	5E-01	Recomputed by WSP					Average of observation well derived T
				Aquifer Thickness	-	-	-	-	983		Aquifer Thickness at HRES-15	983	3E-01	Reported by M&A					Aquifer Thickness assumed 983 ft at HRES-15
Oak Flat	Constant-rate pumping test (3 hours)	4076.9	Tal	Static WL Open Borehole	294	1054	-294	-1054	760	2.1	Static WL Open Borehole	760	3E-03	Recomputed by WSP	N/D	N/D	N/D	M&A, 2012	Q = 8 gpm
				Saturated Perforations	401	432	-401	-432	31		Saturated Perforations	31	7E-02	Reported by M&A					Excessive drawdown shortened test
A-06	Constant-rate pumping test (8.5 hours)	4167.8	Tal	Static WL to Hole Bottom	523	1665	-522.8	-1665	1142.2	538	Static WL to Hole Bottom	1142.2	5E-01	Recomputed by WSP	N/D	N/D	N/D	M&A, 2012	Q = 8 gpm
				Static WL to Bottom of Tal*	523	1475	-522.8	-1475	952.2		Static WL to Bottom of Tal	952.2	6E-01	Reported by M&A					
MJ-11	Constant-rate pumping test (5 hours)	3918.3	Tal	Static WL to Hole Bottom*	298	786	-298	-786	488	183	Static WL to Hole Bottom	488	4E-01	Reported by M&A	N/D	N/D	N/D	M&A, 2012	Q = 9.5 gpm

N/A - Not Applicable N/D - No Data N/T - Not Tested N/C - Not Calculated

East Plant Site - Whitetail Conglomerate

Well Tested	Test Type	Ground Surface Elevation	HGU Tested	Well Feature(s): Screens, Packer Intervals, Open Boreholes	Depth to Top	Depth to Bottom	Elevation of Top	Elevation of Bottom	Feature Interval Length	Transmissivity (ft^2/day)	Feature for K Calculation	Thickness (b) for K Calculation	Hydraulic Conductivity	Calculation Source	Storativity	Specific Storage (/ft)	Specific Yield	Reference	Remarks
DHRES-15	Long-term constant rate pumping test (70 days)	3990.8	Tw3 & Tw4	Aquitard Thickness	-	-	-	-	-	N/D	Assumed HGU Thickness	1466	6.40E-04	Reported by M&A	N/D	2.30E-07	N/A	M&A, 2015	Observation well utilized for analysis: DHRES-07
			Tw3 & Tw4	Aquitard Thickness	-	-	-	-	-	N/D	Assumed HGU Thickness	810	1E-3 - 1E-05	Reported by M&A	N/D	1.0E-06 - 1.0E-08			Observation well utilized for analysis: DHRES-07
			Tw4	Aquitard Thickness	-	-	-	-	-	N/D	Assumed HGU Thickness	128	2E-05 - 2E-07	Reported by M&A	N/D	1.0E-06 - 1.0E-08			Observation well utilized for analysis: DHRES-07
			Tw4	Aquitard Thickness	-	-	-	-	-	N/D	Assumed HGU Thickness	128	1E-05 - 1E-07	Reported by M&A	N/D	1.0E-06 - 1.0E-08			Observation well utilized for analysis: DHRES-07
HRES-08D	Slug test in deep perforated zone	4046.8	Tw	Screen 1	793	1000	-793	-1000	207	N/A	Screened Section	207	1E-04	Reported by M&A	N/D	N/D	N/D	M&A, 2012	Slug volume = 637 cm^3
				Filter Pack	736	1010	-736	-1010	274		Filter Pack	274		Recomputed by WSP					

Notes: N/A - Not Applicable N/D - No Data

East Plant Site - Deep System

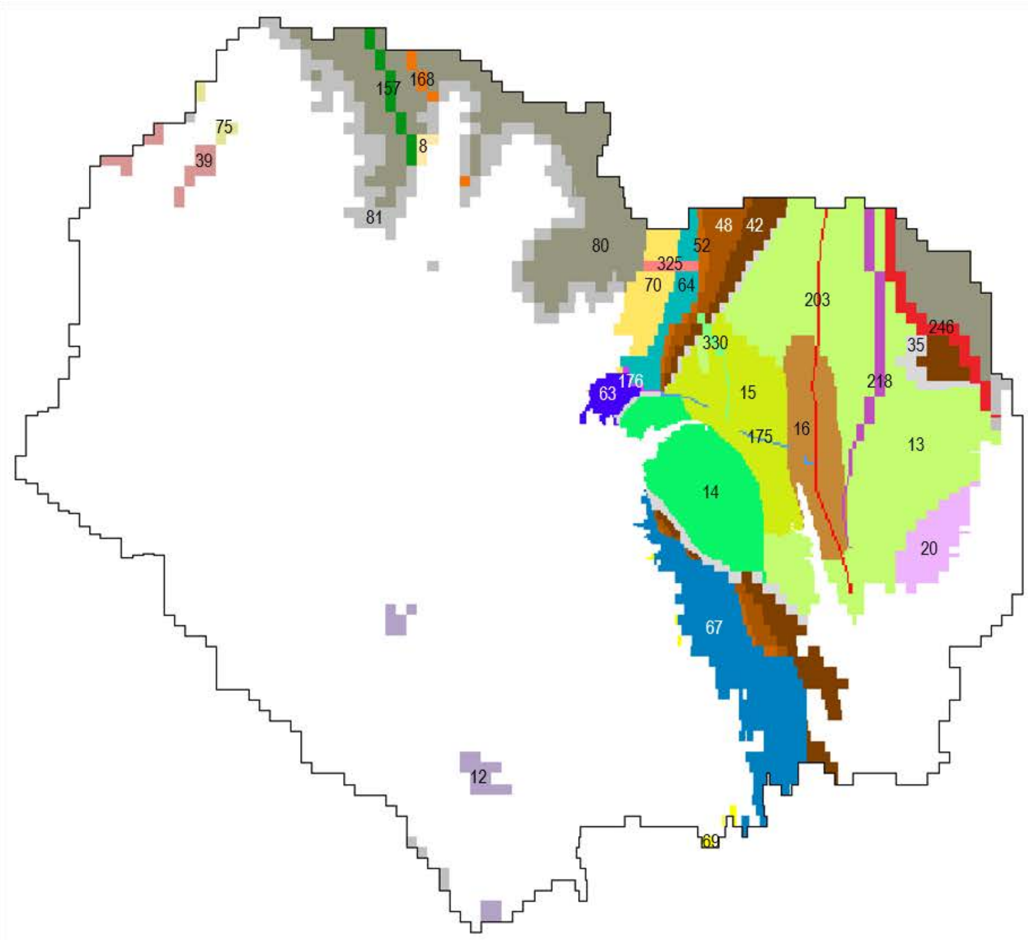
Well Tested	Test Type	Ground Surface Elevation	HGU Tested	Well Feature(s): Screens, Packer Intervals, Open Boreholes	Depth to Top	Depth to Bottom	Elevation of Top	Elevation of Bottom	Feature Interval Length	Transmissivity (ft^2/day)	Feature for K Calculation	Thickness (b) for K Calculation	Hydraulic Conductivity	Calculation Source	Storativity	Specific Storage (/ft)	Specific Yield	Reference	Remarks
DHRES-01	Constant-rate pumping test (72 hours)	4076.3	Kvs	Screen 1	4793	4978	-717	-902	185	72	Screened Sections*	518	1.39E-01	Reported by M&A	N/D	N/D	N/A	M&A, 2010	*No final report; assumed screened sections used for analysis
				Screen 2	5304	5489	-1228	-1413	185										4 perforated zones lumped for K calculation
				Screen 3	5594	5618	-1518	-1542	24										
				Screen 4	5814	5938	-1738	-1862	124										
				Screens 1-4	4793	5938	-717	-1862	1145		Top Screen to Bottom Screen	1145	6.29E-02	Recomputed by WSP					
				Open	4547	6018	-471	-1942	1471		Open Annulus	1471	4.89E-02	Recomputed by WSP					
DHRES-02	Constant-rate pumping test (188 hours)	3973.392	Kvs and pCy (pCdiab)	Screen 1	3506	3732	467	241	226	129	Screened Sections	432	2.99E-01	Reported by M&A	N/D	N/D	N/A	M&A, 2010	Q = 6 gpm
				Screen 2	5904	6007	-1931	-2034	103										Interval 1 Unsaturated
				Screen 3	6430	6533	-2457	-2560	103										
				Annulus Packer Interval 1	3330	4203	-3330	-4203	873		Annulus Packer Intervals - Open Annulus Borehole	873	-	Recomputed by WSP					
				Annulus Packer Interval 2	5683	6713	-5683	-6713	1030			1030	1.25E-01	Recomputed by WSP					
				Screens 2-3	5904	6533	-1931	-2560	629		Top Screen to Bottom Screen (Saturated)	629	2.05E-01	Recomputed by WSP					
				Saturated Screens (2, 3)	5904	6007	-5904	-6007	103		Saturated Screened Sections	206	6.26E-01	Recomputed by WSP					
					6430	6533	-6430	-6533	103										
DHRES-06	Constant-rate pumping test (24 hours)	4045.6	Pz	Screen 1	1636	2649	2410	1397	1013	108	Screened Section	1013	1.07E-01	Recomputed by WSP	N/D	N/D	N/A	M&A, 2011	Q = 25 gpm
				Open	1262	2891	2784	1155	1629		Open Annulus	1629	6.63E-02	Reported by M&A					
DHRES-07	Slug test	3922.8	Pz (Dm, Cb)	Open	4025	4428	-101	-505	404	N/A	en Borehole - Packer Isolated Interval, Pre-Well Constructi	404	1.1E-2 to 2.0E-1	Reported by M&A			N/A	M&A, 2010	Range due to uncertainty regarding density of water during testing; volume of slug = 100 gallons
DHRES-09	Constant-rate pumping test (24 hours)	3115.9	pCy (pCdiab and pCdsg)	Screen 1	431	911	2685	2205	480	7.5	Screened Sections	640	1.17E-02	Reported by M&A	N/D	N/D	N/A	M&A, 2011	Q = 6 gpm
				Screen 2	1611	1671	1505	1445	60										
				Screen 3	1971	2071	1145	1045	100										
				Filter Pack Interval 1	345	950	2771	2166	605		Filter Pack Intervals	1159	6.47E-03	Recomputed by WSP					
				Filter Pack Interval 2	1538	1816	1578	1300	278										
				Filter Pack Interval 3	1847	2123	1269	993	276										
DHRES-11	Variable-rate pumping test (31 hours)	4168.3	Pz, pCy	Screen 1	4910	6679	-742	-2511	1769	0.65	Screened Section	1769	3.67E-04	Reported by M&A	N/D	N/D	N/A	M&A, 2011	Q = 5 gpm
				Open	3703	6724	465	-2556	3021		Open Annulus	3021	2.15E-04	Recomputed by WSP					
DHRES-13	Constant-rate pumping test (24 hours)	3443.3	pCy, pCpi	Screen 1	1768	2296	1675	1147	528	7.5	Screened Sections	1601	4.68E-03	Reported by M&A	N/D	N/D	N/A	M&A, 2011	Q = 19 gpm
				Screen 2	2457	3530	986	-87	1073										
				Screens 1-2	1768	3530	1675	-87	1762		Top Screen to Bottom Screen	1762	4.26E-03	Recomputed by WSP					
				Open	1528	3571	1915	-128	2043		Open Annulus	2043	3.67E-03	Recomputed by WSP					
DHRES-15	Long-term constant rate pumping test (70 days)	3990.8	Pz (Pn Me, Dm Cb)	Interpreted Aquifer Thickness	-	-	-	-	690	38	Aquifer Thickness based on "Fractured Rock Zones"	690	5.51E-02	Reported by M&A	1.50E-05	N/D	N/A	M&A, 2015	Q = 130 gpm
				Screen 1	2872	3633	1119	358	761		Screened Sections	761	4.99E-02	Recomputed by WSP					Maximum drawdown = 360.6 ft
				Open	2872	3920	1119	71	1048		Open Annulus	1048	3.63E-02	Recomputed by WSP					
			Pz	Aquifer Thickness	-	-	-	-	-	38	Assumed HGU Thickness	690	5.50E-02	Reported by M&A	1.50E-05	2.20E-08			Observation well utilized for analysis: DHRES-15, DHRES-07, DHRES-06
			Pz	Aquifer Thickness	-	-	-	-	-	29	Assumed HGU Thickness	690	4.20E-02	Reported by M&A	4.90E-06	7.10E-09			Observation well utilized for analysis: DHRES-07, DHRES-06
			Cb	Aquitard Thickness	-	-	-	-	-	N/D	Assumed HGU Thickness	14	2.8E-07 - 2.8E-09	Reported by M&A	N/D	1.0E-06 - 1.0E-08			Observation well utilized for analysis: DHRES-07

Notes: N/A - Not Applicable N/D - No Data

West Plant Site

Well Tested	Test Type	Ground Surface Elevation (ft amsl)	HGU Tested	Well Feature(s): Screens, Packer Intervals, Open Boreholes	Depth to Top	Depth to Bottom	Elevation of Top	Elevation of Bottom	Feature Interval Length (ft)	Transmissivity (ft^2/day)	Feature for K Calculation	Thickness (b) for K Calculation (ft)	Hydraulic Conductivity (ft/day)	Calculation Source	Storativity	Specific Storage (/ft)	Specific Yield	Reference	Remarks
MCC-1	Slug Tests	2964	QTg	Screen 1	453	483	-453	-483	30	N/D	-	-	4.0E-4 to 3.0E-3	Reported by B&C	N/D	N/D	N/D	B&C (1999)	Unconfined
				Open	450	483	-450	-483	33										Rising and Falling Head Slug Tests
MCC-2	Slug Tests	2851.3	QTg, Mudstone	Screen 1	133	183	-133	-183	50	N/D	-	-	1.0E-4 ot 1.0E-3	Reported by B&C	N/D	N/D	N/D	B&C (1999)	Shallow Unconfined
				Open	128	220	-128	-220	92										Rising and Falling Head Slug Tests
MCC-3B	Slug Tests	2798.1	Mudstone	Screen 1	321	381	-321	-381	60	N/D	-	-	4.0E-06	Reported by B&C	N/D	N/D	N/D	B&C (1999)	Unconfined
				Open	305	391	-305	-391	86										Theis Solution
MCC-3C	Slug Tests	2798.4	QTg	Screen 1	499	579	-499	-579	80	N/D	-	-	1.0E-3 to 3.0E-3	Reported by B&C	N/D	N/D	N/D	B&C (1999)	Confined
				Open	487	590	-487	-590	103										Rising and Falling Head Slug Tests
MCC-4	Slug Tests	2674	QTg	Screen 1	200	250	-200	-250	50	N/D	-	-	5.0E-4 to 8.0E-4	Reported by B&C	N/D	N/D	N/D	B&C (1999)	Confined
				Open	197	255	-197	-255	58										Rising and Falling Head Slug Tests
MCC-6A	Slug Tests	2811.1	QTg	Screen 1	160	220	-160	-220	60	N/D	-	-	3.0E-4 to 7.0E-4	Reported by B&C	N/D	N/D	N/D	B&C (1999)	Unconfined
				Open	151	222	-151	-222	71										Rising and Falling Head Slug Tests
MCC-6B	Slug Tests	2811.9	QTg	Screen 1	500	580	-500	-580	80	N/D	-	-	1.0E-4 to 8.0E-4	Reported by B&C	N/D	N/D	N/D	B&C (1999)	Unconfined
				Open	487	586	-487	-586	99										Rising and Falling Head Slug Tests
MCC-6C	Slug Tests	2811.4	QTg	Screen 1	76	116	-76	-116	40	N/D	-	-	2.0E-03	Reported by B&C	N/D	N/D	N/D	B&C (1999)	Unconfined
				Open	66	122	-66	-122	56										Falling Head Slug Tests
MCC-9	Constant-rate pumping test	2769.2	QTg	Screen 1	28	48	-28	-48	20	N/D	-	-	3.0E-01	Reported by B&C	N/D	N/D	N/D	B&C (1999)	Shallow Unconfined
				Open	20	60	-20	-60	40										
Settling Ponds 1 & 2	Constant-rate pumping test	2977.5	QTg	Screen 1	36	76	-36	-76	40	N/D	-	-	2.0E-3 to 5.0E-3	Reported by Golder	N/D	N/D	N/D	Golder Associates (2007)	Unconfined
				Open	30	88	-30	-88	58										Cooper-Jacob Drawdown & Theis Recovery
				Static WL to Screen Bottom	59	76	-59	-76	17										
				Static WL to Bottom Hole	59	88	-59	-88	29										
Tailings Pond 5 POC	Constant-rate pumping test	2963.3	QTg	Screen 1	80	120	-80	-120	40	N/D	-	-	8.0E-4 to 2.0E-3	Reported by Golder	N/D	N/D	N/D	Golder Associates (2007)	Unconfined
				Open	-	125	-	-125	-										Cooper-Jacob Drawdown & Theis Recovery
GAI-02-01	Constant-rate pumping test	3006.15	QTg	Screen 1	165	195	-165	-195	30	N/D	-	-	3.0E-3 to 5.0E-3	Reported by Golder	N/D	N/D	N/D	Golder Associates (2007)	Shallow Unconfined
				Open	150	205	-150	-205	55										Cooper-Jacob Drawdown & Theis Recovery
GAI-02-02	Constant-rate pumping test	2782.5	QTg	Screen 1	22	53	-22	-53	31	N/D	-	-	6.0E-2 to 7.0E-2	Reported by Golder	N/D	N/D	N/D	Golder Associates (2007)	Shallow Unconfined
				Open	-	56	-	-56	-										Cooper-Jacob Drawdown & Theis Recovery
Smelter Pond POC	Constant-rate pumping test	2743.1	Alluvium	Screen 1	7	17	-7	-17	10	N/D	-	-	9.0E-2 to 1.0E-1	Reported by Golder	N/D	N/D	N/D	Golder Associates (2007)	Cooper-Jacob Drawdown & Theis Recovery
				Open	5	17	-5	-17	12										
DHRES-04	Constant-rate pumping test (12 hours)	3021.6	Tvy	Screen 1	1770	2318	1252	704	548	22	Screened Section	548	4.01E-02	Reported by M&A	N/D	N/D	N/D	M&A, 2011	West Plant Site
				Open	1518	2340	1504	682	822		Open Annulus	822	2.68E-02	Recomputed by WSP					Q = 6 gpm
DHRES-05	Slug test	2776	QTg	Screen 1	1628	2366	1148	410	738	N/A	Screened Sections	823	2.00E-05	Reported by M&A	N/D	N/D	N/D	M&A, 2011	West Plant Site
				Screen 2	2830	2914	-54	-138	84										Monitored 19 days; 2 zones used for K; Slug volume = 1 gallon

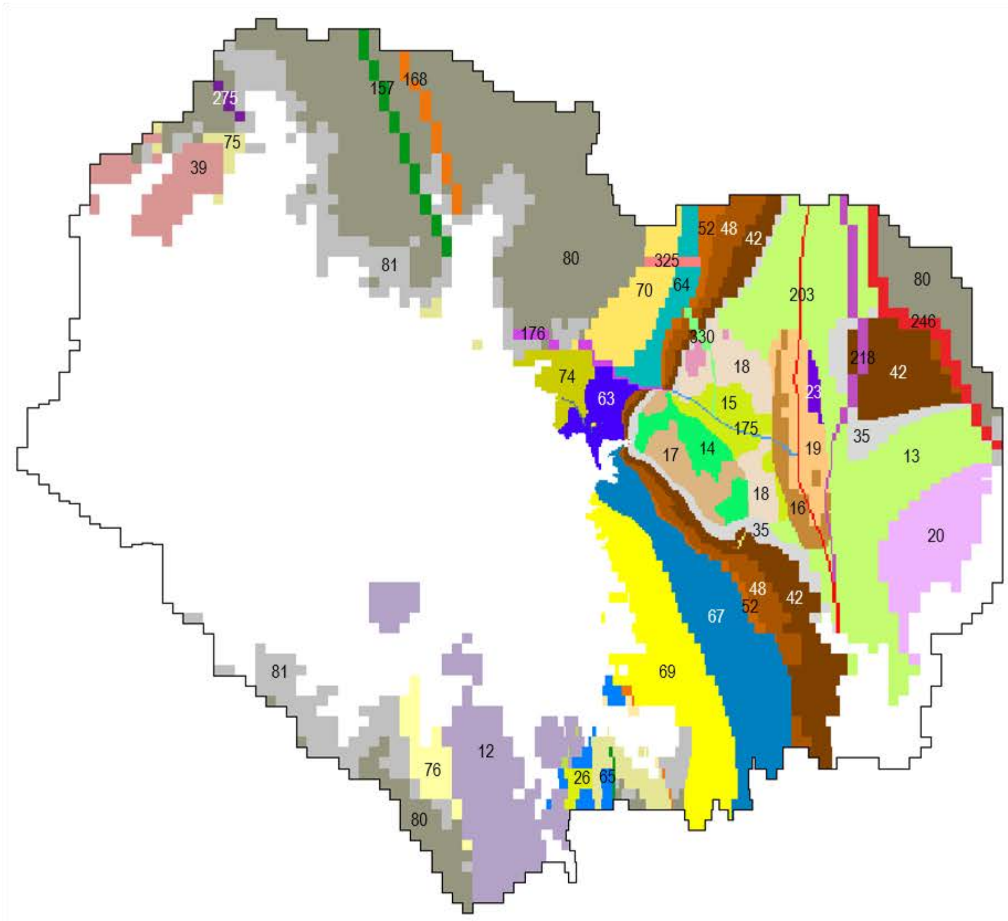
Notes: N/A - Not Applicable N/D - No Data



Color	HGU	Zone	Kx (ft/d)	Ky (ft/d)	Kz (ft/d)	Ss (1/ft)	Sy
	QTg	8	2.03E-03	2.03E-03	2.03E-03	3.71E-08	1.00E-02
	Tvy	12	6.25E-03	6.25E-03	6.25E-03	5.00E-08	5.00E-03
	Tal	13	6.25E-02	6.25E-02	6.25E-02	5.00E-08	5.00E-03
	Tal	14	2.50E-01	2.50E-01	2.50E-01	5.00E-08	1.00E-03
	Tal	15	1.26E-02	1.26E-02	1.26E-02	5.00E-08	5.00E-03
	Tal	16	3.00E+00	3.00E+00	3.00E+00	5.00E-08	5.00E-03
	Talv	35	1.00E-03	1.00E-03	1.00E-03	5.00E-08	5.00E-03
	Tvo	39	8.71E-02	8.71E-02	8.71E-02	5.76E-07	5.00E-03
	Tw	42	2.74E-03	2.74E-03	2.74E-03	3.50E-08	1.00E-02
	Tw	48	8.51E-05	8.51E-05	8.51E-05	3.50E-08	1.00E-02
	Tw	52	1.25E-05	1.25E-05	1.25E-05	3.50E-08	1.00E-02
	Pz	63	5.00E-04	5.00E-04	5.00E-04	4.65E-08	1.00E-02
	Pz	64	1.48E-05	1.48E-05	1.48E-05	4.40E-08	8.75E-03
	Pz	67	1.00E-04	1.00E-04	1.00E-04	4.40E-08	8.75E-03
	pCy	69	1.00E-03	1.00E-03	1.00E-03	1.25E-08	8.75E-03
	pCy	70	1.28E-04	1.28E-04	1.28E-04	1.25E-08	8.75E-03
	pCy	75	1.00E-03	1.00E-03	1.00E-03	1.25E-08	8.75E-03
	pCpi	80	1.00E-04	1.00E-04	1.00E-04	1.00E-08	6.00E-03
	pCpi	81	1.00E-03	1.00E-03	1.00E-03	1.00E-08	6.00E-03
	Arnett	157	1.00E-03	1.00E-03	1.00E-03	1.00E-08	1.00E-04
	Concentrator	168	1.00E-04	1.00E-04	1.00E-04	1.00E-08	1.00E-04
	Conley Springs - Shallow	175	1.00E-04	1.00E-04	1.00E-04	1.00E-08	1.00E-04
	Conley Springs - Deep	176	3.61E-05	3.61E-05	3.61E-05	1.00E-08	1.00E-04
	Devils Canyon	203	1.00E-01	1.00E-01	1.00E-01	1.00E-08	1.00E-04
	JI Ranch	218	1.00E-03	1.00E-03	1.00E-03	1.00E-08	1.00E-04
	Mineral Creek	246	1.00E-02	1.00E-02	1.00E-02	1.00E-08	1.00E-04
	Laramide	325	1.00E-05	1.00E-05	1.00E-05	1.00E-08	1.00E-04
	Anxiety	330	5.00E-04	1.00E-02	5.00E-04	1.00E-08	1.00E-04

HGU Material Property Values – Elevation 3,800 ft amsl, Layer 8 (Plan View)

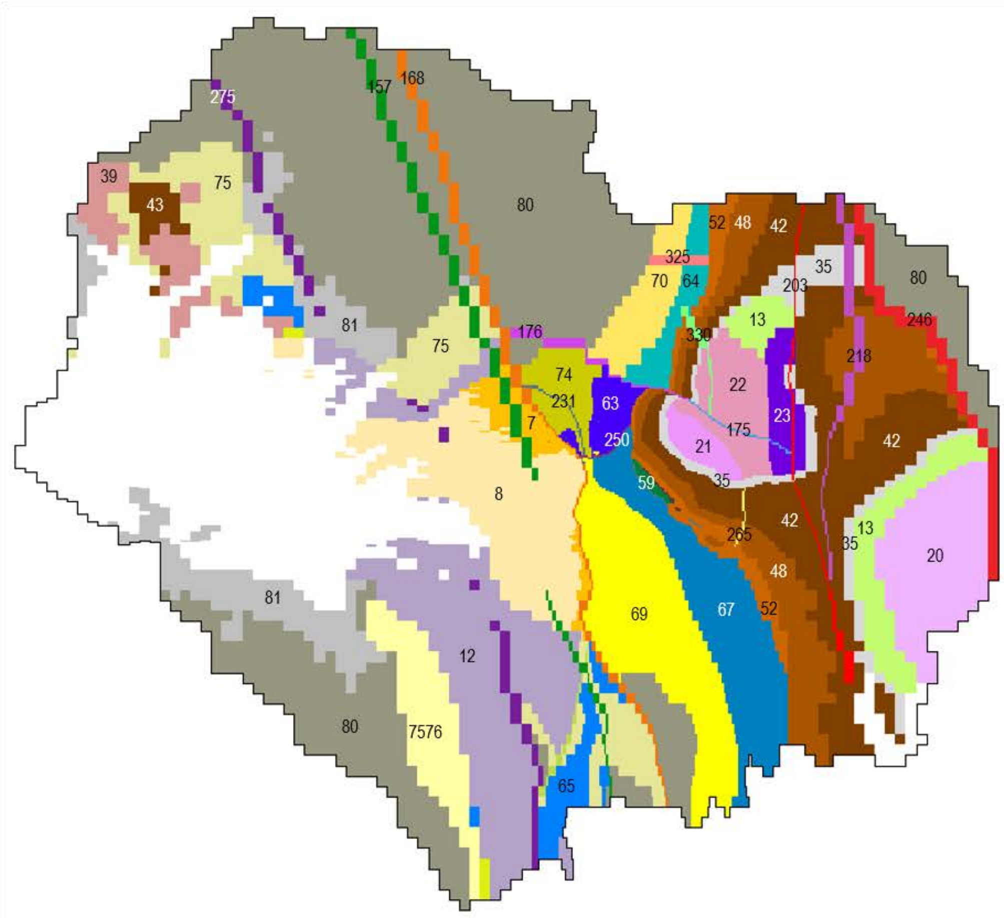
CLIENT:	Resolution Copper	PROJECT:	Regional Groundwater Model		
JOB:	31400968.001	DRAWN:	CP	CHECKED:	DO
DATE:	January 2019	FIGURE:	Appendix B		



Color	HGU	Zone	Kx (ft/d)	Ky (ft/d)	Kz (ft/d)	Ss (1/ft)	Sy
	Tvy	12	6.25E-03	6.25E-03	6.25E-03	5.00E-08	5.00E-03
	Tal	14	2.50E-01	2.50E-01	2.50E-01	5.00E-08	1.00E-03
	Tal	15	1.26E-02	1.26E-02	1.26E-02	5.00E-08	5.00E-03
	Tal	16	3.00E+00	3.00E+00	3.00E+00	5.00E-08	5.00E-03
	Tal	17	6.00E-02	6.00E-02	6.00E-02	5.00E-08	5.00E-03
	Tal	18	5.00E-03	5.00E-03	5.00E-03	5.00E-08	5.00E-03
	Tal	19	1.00E+00	1.00E+00	1.00E+00	5.00E-08	5.00E-03
	Tal	20	4.00E-01	4.00E-01	4.00E-01	5.00E-08	5.00E-03
	Tal	23	4.00E-01	4.00E-01	4.00E-01	5.00E-08	5.00E-03
	Tal	26	1.00E-03	1.00E-03	1.00E-03	5.00E-08	5.00E-03
	Talv	35	1.00E-03	1.00E-03	1.00E-03	5.00E-08	5.00E-03
	Tvo	39	8.71E-02	8.71E-02	8.71E-02	5.76E-07	5.00E-03
	Tw	42	2.74E-03	2.74E-03	2.74E-03	3.50E-08	1.00E-02
	Tw	48	8.51E-05	8.51E-05	8.51E-05	3.50E-08	1.00E-02
	Tw	52	1.25E-05	1.25E-05	1.25E-05	3.50E-08	1.00E-02
	Pz	63	5.00E-04	5.00E-04	5.00E-04	4.65E-08	1.00E-02
	Pz	64	1.48E-05	1.48E-05	1.48E-05	4.40E-08	8.75E-03
	Pz	65	7.36E-04	7.36E-04	7.36E-04	4.40E-08	8.75E-03
	Pz	67	1.00E-04	1.00E-04	1.00E-04	4.40E-08	8.75E-03
	pCy	69	1.00E-03	1.00E-03	1.00E-03	1.25E-08	8.75E-03
	pCy	70	1.28E-04	1.28E-04	1.28E-04	1.25E-08	8.75E-03
	pCy	74	7.00E-04	7.00E-04	1.00E-03	1.28E-08	1.00E-02
	pCy	75	1.00E-03	1.00E-03	1.00E-03	1.25E-08	8.75E-03
	pCy	76	2.71E-04	2.71E-04	2.71E-04	1.25E-08	8.75E-03
	pCpi	80	1.00E-04	1.00E-04	1.00E-04	1.00E-08	6.00E-03
	pCpi	81	1.00E-03	1.00E-03	1.00E-03	1.00E-08	6.00E-03
	Arnett	157	1.00E-03	1.00E-03	1.00E-03	1.00E-08	1.00E-04
	Concentrator	168	1.00E-04	1.00E-04	1.00E-04	1.00E-08	1.00E-04
	Conley Springs - Shallow	175	1.00E-04	1.00E-04	1.00E-04	1.00E-08	1.00E-04
	Conley Springs - Deep	176	3.61E-05	3.61E-05	3.61E-05	1.00E-08	1.00E-04
	Devils Canyon	203	1.00E-01	1.00E-01	1.00E-01	1.00E-08	1.00E-04
	JI Ranch	218	1.00E-03	1.00E-03	1.00E-03	1.00E-08	1.00E-04
	Mineral Creek	246	1.00E-02	1.00E-02	1.00E-02	1.00E-08	1.00E-04
	Roblas Woods	275	1.00E-03	1.00E-03	1.00E-03	1.00E-08	1.00E-04
	Laramide	325	1.00E-05	1.00E-05	1.00E-05	1.00E-08	1.00E-04
	Anxiety	330	5.00E-04	1.00E-02	5.00E-04	1.00E-08	1.00E-04

HGU Material Property Values – Elevation 3,200 ft amsl, Layer 12 (Plan View)

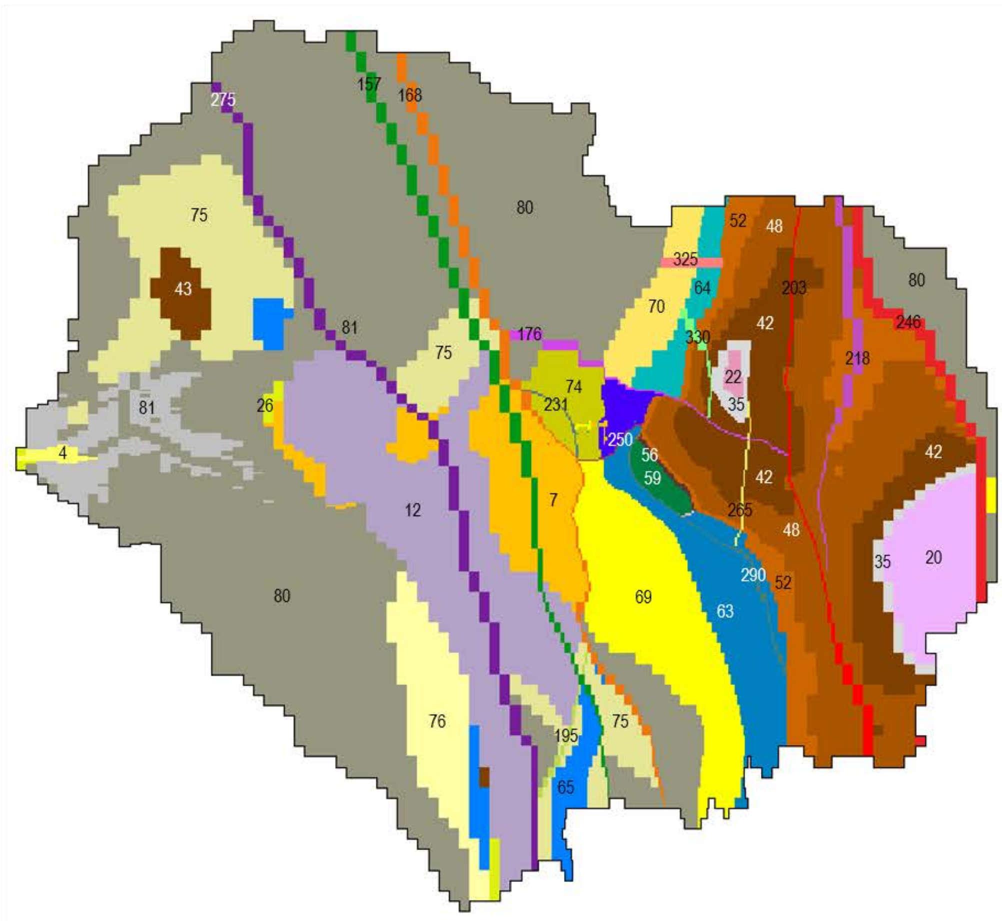
CLIENT:	Resolution Copper	PROJECT:	Regional Groundwater Model		
JOB:	31400968.001	DRAWN:	CP	CHECKED:	DO
DATE:	January 2019	FIGURE:	Appendix B		



Color	HGU	Zone	Kx (ft/d)	Ky (ft/d)	Kz (ft/d)	Ss (1/ft)	Sy
	QTg	7	2.54E-04	2.54E-04	2.54E-04	3.71E-08	1.00E-02
	QTg	8	2.03E-03	2.03E-03	2.03E-03	3.71E-08	1.00E-02
	Tvy	12	6.25E-03	6.25E-03	6.25E-03	5.00E-08	5.00E-03
	Tal	13	6.25E-02	6.25E-02	6.25E-02	5.00E-08	5.00E-03
	Tal	20	4.00E-01	4.00E-01	4.00E-01	5.00E-08	5.00E-03
	Tal	21	1.07E-02	1.07E-02	1.07E-02	5.00E-08	5.00E-03
	Tal	22	1.00E-03	1.00E-03	1.00E-03	5.00E-08	5.00E-03
	Tal	23	4.00E-01	4.00E-01	4.00E-01	5.00E-08	5.00E-03
	Talv	35	1.00E-03	1.00E-03	1.00E-03	5.00E-08	5.00E-03
	Tvo	39	8.71E-02	8.71E-02	8.71E-02	5.76E-07	5.00E-03
	Tw	42	2.74E-03	2.74E-03	2.74E-03	3.50E-08	1.00E-02
	Tw	43	7.00E-04	7.00E-04	7.00E-04	3.50E-08	1.00E-02
	Tw	48	8.51E-05	8.51E-05	8.51E-05	3.50E-08	1.00E-02
	Tw	52	1.25E-05	1.25E-05	1.25E-05	3.50E-08	1.00E-02
	KVS	59	1.00E-04	1.00E-04	1.00E-04	5.00E-08	7.07E-03
	Pz	63	5.00E-04	5.00E-04	5.00E-04	4.65E-08	1.00E-02
	Pz	64	1.48E-05	1.48E-05	1.48E-05	4.40E-08	8.75E-03
	Pz	65	7.36E-04	7.36E-04	7.36E-04	4.40E-08	8.75E-03
	Pz	67	1.00E-04	1.00E-04	1.00E-04	4.40E-08	8.75E-03
	pCy	69	1.00E-03	1.00E-03	1.00E-03	1.25E-08	8.75E-03
	pCy	70	1.28E-04	1.28E-04	1.28E-04	1.25E-08	8.75E-03
	pCy	74	7.00E-04	7.00E-04	1.00E-03	1.28E-08	1.00E-02
	pCy	75	1.00E-03	1.00E-03	1.00E-03	1.25E-08	8.75E-03
	pCy	76	2.71E-04	2.71E-04	2.71E-04	1.25E-08	8.75E-03
	pCpi	80	1.00E-04	1.00E-04	1.00E-04	1.00E-08	6.00E-03
	pCpi	81	1.00E-03	1.00E-03	1.00E-03	1.00E-08	6.00E-03
	Arnett	157	1.00E-03	1.00E-03	1.00E-03	1.00E-08	1.00E-04
	Concentrator	168	1.00E-04	1.00E-04	1.00E-04	1.00E-08	1.00E-04
	Conley Springs - Shallow	175	1.00E-04	1.00E-04	1.00E-04	1.00E-08	1.00E-04
	Conley Springs - Deep	176	3.61E-05	3.61E-05	3.61E-05	1.00E-08	1.00E-04
	Devils Canyon	203	1.00E-01	1.00E-01	1.00E-01	1.00E-08	1.00E-04
	JI Ranch	218	1.00E-03	1.00E-03	1.00E-03	1.00E-08	1.00E-04
	Main	231	1.00E-04	1.00E-04	1.00E-04	1.00E-08	1.00E-04
	Mineral Creek	246	1.00E-02	1.00E-02	1.00E-02	1.00E-08	1.00E-04
	North Boundary	250	6.25E-04	6.25E-04	6.25E-04	1.00E-08	1.00E-04
	Rancho Rio	265	2.50E-04	2.50E-04	2.50E-04	1.00E-08	1.00E-04
	Roblas Woods	275	1.00E-03	1.00E-03	1.00E-03	1.00E-08	1.00E-04
	Laramide	325	1.00E-05	1.00E-05	1.00E-05	1.00E-08	1.00E-04
	Anxiety	330	5.00E-04	1.00E-02	5.00E-04	1.00E-08	1.00E-04

HGU Material Property Values – Elevation 2,600 ft amsl, Layer 16 (Plan View)

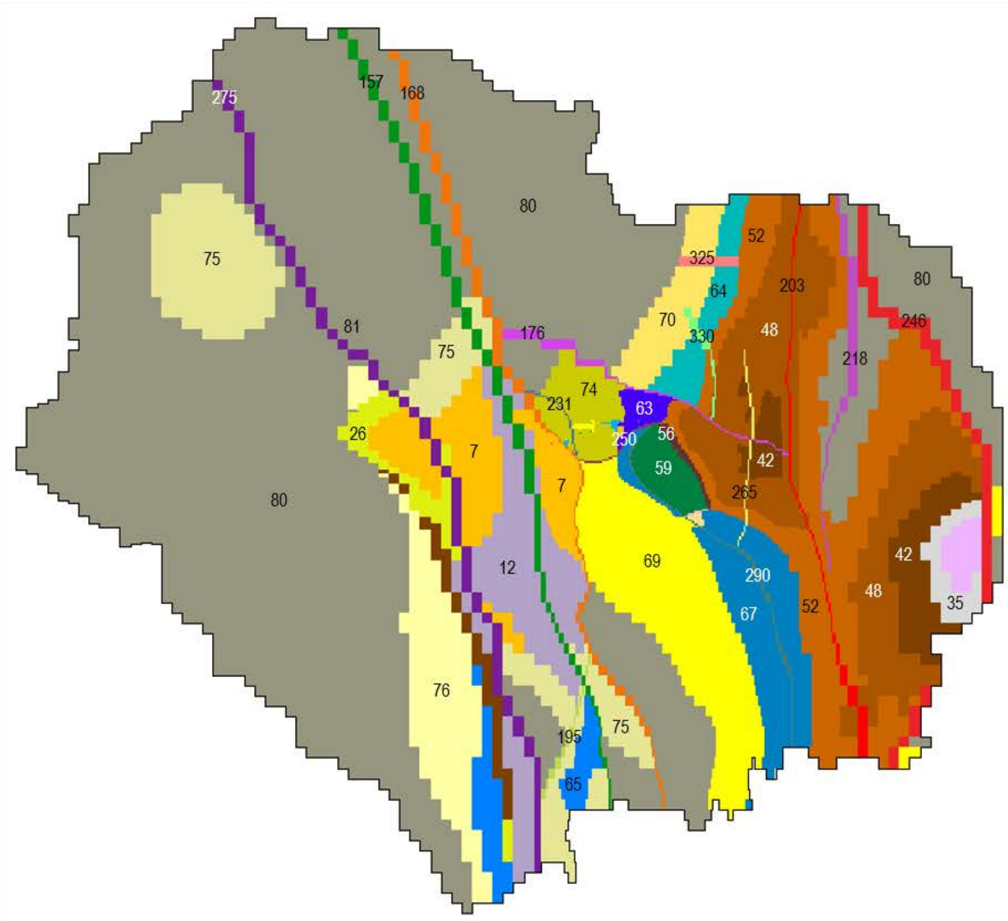
CLIENT: Resolution Copper
PROJECT: Regional Groundwater Model
JOB: 31400968.001
DRAWN: CP
CHECKED: DO
DATE: January 2019
FIGURE: Appendix B



Color	HGU	Zone	Kx (ft/d)	Ky (ft/d)	Kz (ft/d)	Ss (1/ft)	Sy
	QTg	7	2.54E-04	2.54E-04	2.54E-04	3.71E-08	1.00E-02
	Tvy	12	6.25E-03	6.25E-03	6.25E-03	5.00E-08	5.00E-03
	Tal	20	4.00E-01	4.00E-01	4.00E-01	5.00E-08	5.00E-03
	Tal	22	1.00E-03	1.00E-03	1.00E-03	5.00E-08	5.00E-03
	Tal	26	1.00E-03	1.00E-03	1.00E-03	5.00E-08	5.00E-03
	Talv	35	1.00E-03	1.00E-03	1.00E-03	5.00E-08	5.00E-03
	Tw	42	2.74E-03	2.74E-03	2.74E-03	3.50E-08	1.00E-02
	Tw	43	7.00E-04	7.00E-04	7.00E-04	3.50E-08	1.00E-02
	Tw	48	8.51E-05	8.51E-05	8.51E-05	3.50E-08	1.00E-02
	Tw	52	1.25E-05	1.25E-05	1.25E-05	3.50E-08	1.00E-02
	Tw	56	3.03E-06	3.03E-06	5.00E-07	4.01E-08	1.00E-02
	KVS	59	1.00E-04	1.00E-04	1.00E-04	5.00E-08	7.07E-03
	Pz	63	5.00E-04	5.00E-04	5.00E-04	4.65E-08	1.00E-02
	Pz	64	1.48E-05	1.48E-05	1.48E-05	4.40E-08	8.75E-03
	Pz	65	7.36E-04	7.36E-04	7.36E-04	4.40E-08	8.75E-03
	Pz	67	1.00E-04	1.00E-04	1.00E-04	4.40E-08	8.75E-03
	pCy	69	1.00E-03	1.00E-03	1.00E-03	1.25E-08	8.75E-03
	pCy	70	1.28E-04	1.28E-04	1.28E-04	1.25E-08	8.75E-03
	pCy	74	7.00E-04	7.00E-04	1.00E-03	1.28E-08	1.00E-02
	pCy	75	1.00E-03	1.00E-03	1.00E-03	1.25E-08	8.75E-03
	pCy	76	2.71E-04	2.71E-04	2.71E-04	1.25E-08	8.75E-03
	pCpi	80	1.00E-04	1.00E-04	1.00E-04	1.00E-08	6.00E-03
	pCpi	81	1.00E-03	1.00E-03	1.00E-03	1.00E-08	6.00E-03
	Arnett	157	1.00E-03	1.00E-03	1.00E-03	1.00E-08	1.00E-04
	Concentrator	168	1.00E-04	1.00E-04	1.00E-04	1.00E-08	1.00E-04
	Conley Springs - Deep	176	3.61E-05	3.61E-05	3.61E-05	1.00E-08	1.00E-04
	Concentrator West	195	1.00E-03	1.00E-03	1.00E-03	1.00E-08	1.00E-04
	Devils Canyon	203	1.00E-01	1.00E-01	1.00E-01	1.00E-08	1.00E-04
	JI Ranch	218	1.00E-03	1.00E-03	1.00E-03	1.00E-08	1.00E-04
	Main	231	1.00E-04	1.00E-04	1.00E-04	1.00E-08	1.00E-04
	Mineral Creek	246	1.00E-02	1.00E-02	1.00E-02	1.00E-08	1.00E-04
	North Boundary	250	6.25E-04	6.25E-04	6.25E-04	1.00E-08	1.00E-04
	Rancho Rio	265	2.50E-04	2.50E-04	2.50E-04	1.00E-08	1.00E-04
	Roblas Woods	275	1.00E-03	1.00E-03	1.00E-03	1.00E-08	1.00E-04
	West	290	1.25E-05	1.25E-05	1.25E-05	1.00E-08	1.00E-04
	Laramide	325	1.00E-05	1.00E-05	1.00E-05	1.00E-08	1.00E-04
	Anxiety	330	5.00E-04	1.00E-02	5.00E-04	1.00E-08	1.00E-04

HGU Material Property Values – Elevation 2,000 ft amsl, Layer 20 (Plan View)

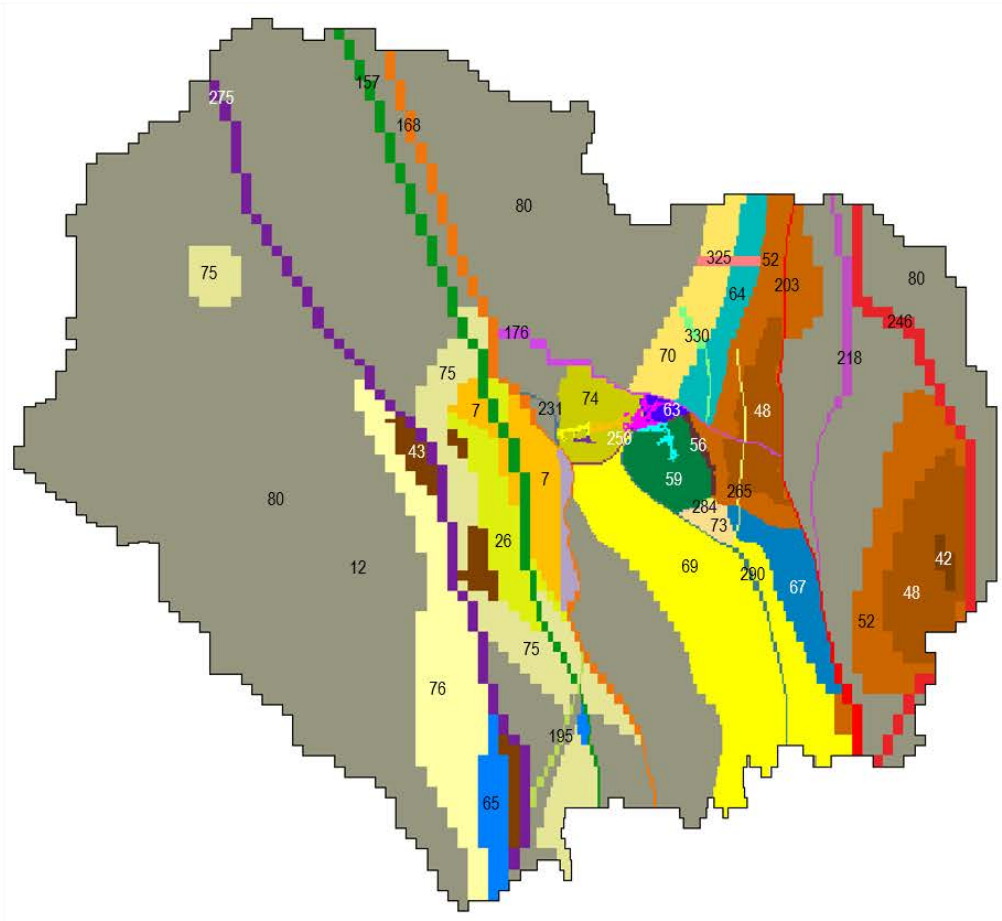
CLIENT:	Resolution Copper	PROJECT:	Regional Groundwater Model
JOB:	31400968.001	DRAWN:	CP CHECKED: DO
DATE:	January 2019	FIGURE:	Appendix B



Color	HGU	Zone	Kx (ft/d)	Ky (ft/d)	Kz (ft/d)	Ss (1/ft)	Sy
	QTg	7	2.54E-04	2.54E-04	2.54E-04	3.71E-08	1.00E-02
	Tvy	12	6.25E-03	6.25E-03	6.25E-03	5.00E-08	5.00E-03
	Tal	20	4.00E-01	4.00E-01	4.00E-01	5.00E-08	5.00E-03
	Tal	26	1.00E-03	1.00E-03	1.00E-03	5.00E-08	5.00E-03
	Talv	35	1.00E-03	1.00E-03	1.00E-03	5.00E-08	5.00E-03
	Tw	42	2.74E-03	2.74E-03	2.74E-03	3.50E-08	1.00E-02
	Tw	48	8.51E-05	8.51E-05	8.51E-05	3.50E-08	1.00E-02
	Tw	52	1.25E-05	1.25E-05	1.25E-05	3.50E-08	1.00E-02
	Tw	56	3.03E-06	3.03E-06	5.00E-07	4.01E-08	1.00E-02
	KVS	59	1.00E-04	1.00E-04	1.00E-04	5.00E-08	7.07E-03
	Pz	63	5.00E-04	5.00E-04	5.00E-04	4.65E-08	1.00E-02
	Pz	64	1.48E-05	1.48E-05	1.48E-05	4.40E-08	8.75E-03
	Pz	65	7.36E-04	7.36E-04	7.36E-04	4.40E-08	8.75E-03
	Pz	67	1.00E-04	1.00E-04	1.00E-04	4.40E-08	8.75E-03
	pCy	69	1.00E-03	1.00E-03	1.00E-03	1.25E-08	8.75E-03
	pCy	70	1.28E-04	1.28E-04	1.28E-04	1.25E-08	8.75E-03
	pCy	74	7.00E-04	7.00E-04	1.00E-03	1.28E-08	1.00E-02
	pCy	75	1.00E-03	1.00E-03	1.00E-03	1.25E-08	8.75E-03
	pCy	76	2.71E-04	2.71E-04	2.71E-04	1.25E-08	8.75E-03
	pCpi	80	1.00E-04	1.00E-04	1.00E-04	1.00E-08	6.00E-03
	Arnett	157	1.00E-03	1.00E-03	1.00E-03	1.00E-08	1.00E-04
	Concentrator	168	1.00E-04	1.00E-04	1.00E-04	1.00E-08	1.00E-04
	Conley Springs - Deep	176	3.61E-05	3.61E-05	3.61E-05	1.00E-08	1.00E-04
	Concentrator West	195	1.00E-03	1.00E-03	1.00E-03	1.00E-08	1.00E-04
	Devils Canyon	203	1.00E-01	1.00E-01	1.00E-01	1.00E-08	1.00E-04
	JI Ranch	218	1.00E-03	1.00E-03	1.00E-03	1.00E-08	1.00E-04
	Main	231	1.00E-04	1.00E-04	1.00E-04	1.00E-08	1.00E-04
	Mineral Creek	246	1.00E-02	1.00E-02	1.00E-02	1.00E-08	1.00E-04
	North Boundary	250	6.25E-04	6.25E-04	6.25E-04	1.00E-08	1.00E-04
	Rancho Rio	265	2.50E-04	2.50E-04	2.50E-04	1.00E-08	1.00E-04
	Roblas Woods	275	1.00E-03	1.00E-03	1.00E-03	1.00E-08	1.00E-04
	West	290	1.25E-05	1.25E-05	1.25E-05	1.00E-08	1.00E-04
	Laramide	325	1.00E-05	1.00E-05	1.00E-05	1.00E-08	1.00E-04
	Anxiety	330	5.00E-04	1.00E-02	5.00E-04	1.00E-08	1.00E-04

HGU Material Property Values – Elevation 1,250 ft amsl, Layer 24 (Plan View)

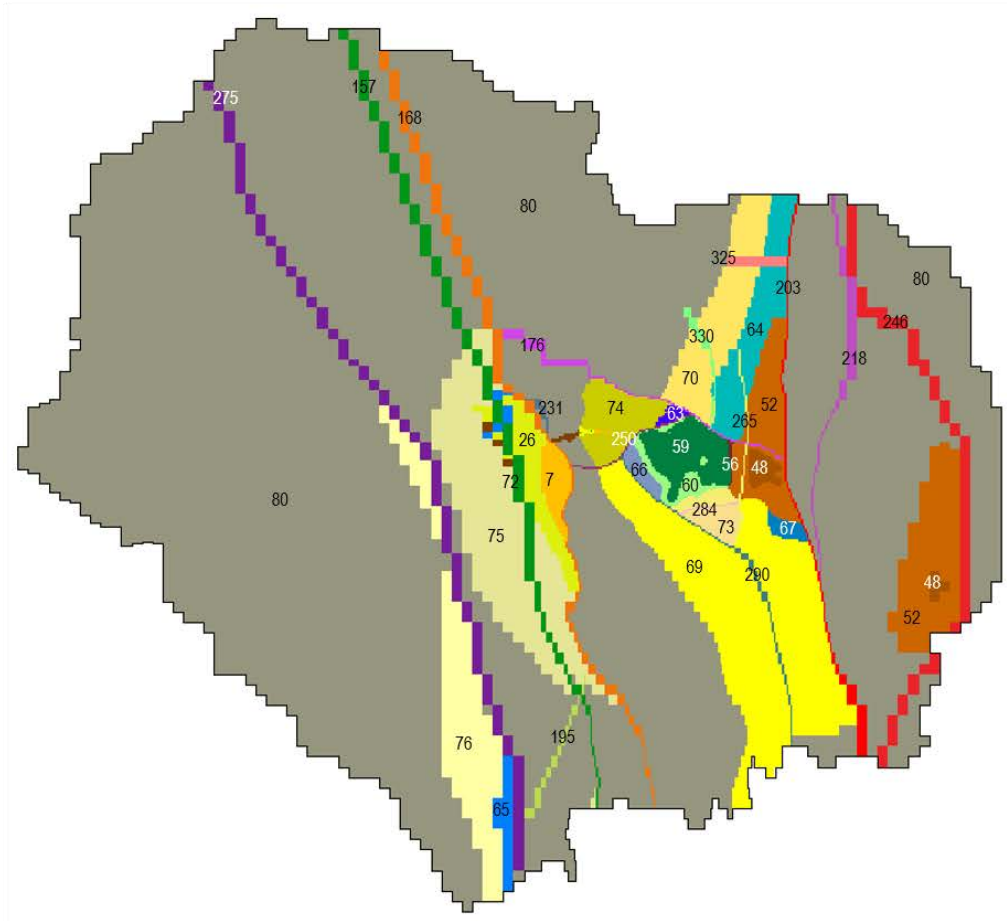
CLIENT:	Resolution Copper	PROJECT:	Regional Groundwater Model		
JOB:	31400968.001	DRAWN:	CP	CHECKED:	DO
DATE:	January 2019	FIGURE:	Appendix B		



Color	HGU	Zone	Kx (ft/d)	Ky (ft/d)	Kz (ft/d)	Ss (1/ft)	Sy
	QTg	7	2.54E-04	2.54E-04	2.54E-04	3.71E-08	1.00E-02
	Tvy	12	6.25E-03	6.25E-03	6.25E-03	5.00E-08	5.00E-03
	Tal	26	1.00E-03	1.00E-03	1.00E-03	5.00E-08	5.00E-03
	Tw	42	2.74E-03	2.74E-03	2.74E-03	3.50E-08	1.00E-02
	Tw	48	8.51E-05	8.51E-05	8.51E-05	3.50E-08	1.00E-02
	Tw	52	1.25E-05	1.25E-05	1.25E-05	3.50E-08	1.00E-02
	Tw	56	3.03E-06	3.03E-06	5.00E-07	4.01E-08	1.00E-02
	KVS	59	1.00E-04	1.00E-04	1.00E-04	5.00E-08	7.07E-03
	Pz	63	5.00E-04	5.00E-04	5.00E-04	4.65E-08	1.00E-02
	Pz	64	1.48E-05	1.48E-05	1.48E-05	4.40E-08	8.75E-03
	Pz	65	7.36E-04	7.36E-04	7.36E-04	4.40E-08	8.75E-03
	Pz	67	1.00E-04	1.00E-04	1.00E-04	4.40E-08	8.75E-03
	pCy	69	1.00E-03	1.00E-03	1.00E-03	1.25E-08	8.75E-03
	pCy	70	1.28E-04	1.28E-04	1.28E-04	1.25E-08	8.75E-03
	pCy	73	1.00E-03	1.00E-03	1.00E-04	1.25E-08	8.75E-03
	pCy	74	7.00E-04	7.00E-04	1.00E-03	1.28E-08	1.00E-02
	pCy	75	1.00E-03	1.00E-03	1.00E-03	1.25E-08	8.75E-03
	pCy	76	2.71E-04	2.71E-04	2.71E-04	1.25E-08	8.75E-03
	pCpi	80	1.00E-04	1.00E-04	1.00E-04	1.00E-08	6.00E-03
	Arnett	157	1.00E-03	1.00E-03	1.00E-03	1.00E-08	1.00E-04
	Concentrator	168	1.00E-04	1.00E-04	1.00E-04	1.00E-08	1.00E-04
	Conley Springs - Deep	176	3.61E-05	3.61E-05	3.61E-05	1.00E-08	1.00E-04
	Concentrator West	195	1.00E-03	1.00E-03	1.00E-03	1.00E-08	1.00E-04
	Devils Canyon	203	1.00E-01	1.00E-01	1.00E-01	1.00E-08	1.00E-04
	JI Ranch	218	1.00E-03	1.00E-03	1.00E-03	1.00E-08	1.00E-04
	Main	231	1.00E-04	1.00E-04	1.00E-04	1.00E-08	1.00E-04
	Mineral Creek	246	1.00E-02	1.00E-02	1.00E-02	1.00E-08	1.00E-04
	North Boundary	250	6.25E-04	6.25E-04	6.25E-04	1.00E-08	1.00E-04
	Rancho Rio	265	2.50E-04	2.50E-04	2.50E-04	1.00E-08	1.00E-04
	Roblas Woods	275	1.00E-03	1.00E-03	1.00E-03	1.00E-08	1.00E-04
	South	284	1.60E-05	1.60E-05	1.60E-05	1.00E-08	1.00E-04
	West	290	1.25E-05	1.25E-05	1.25E-05	1.00E-08	1.00E-04
	Laramide	325	1.00E-05	1.00E-05	1.00E-05	1.00E-08	1.00E-04
	Anxiety	330	5.00E-04	1.00E-02	5.00E-04	1.00E-08	1.00E-04

HGU Material Property Values – Elevation 50 ft amsl, Layer 28 (Plan View)

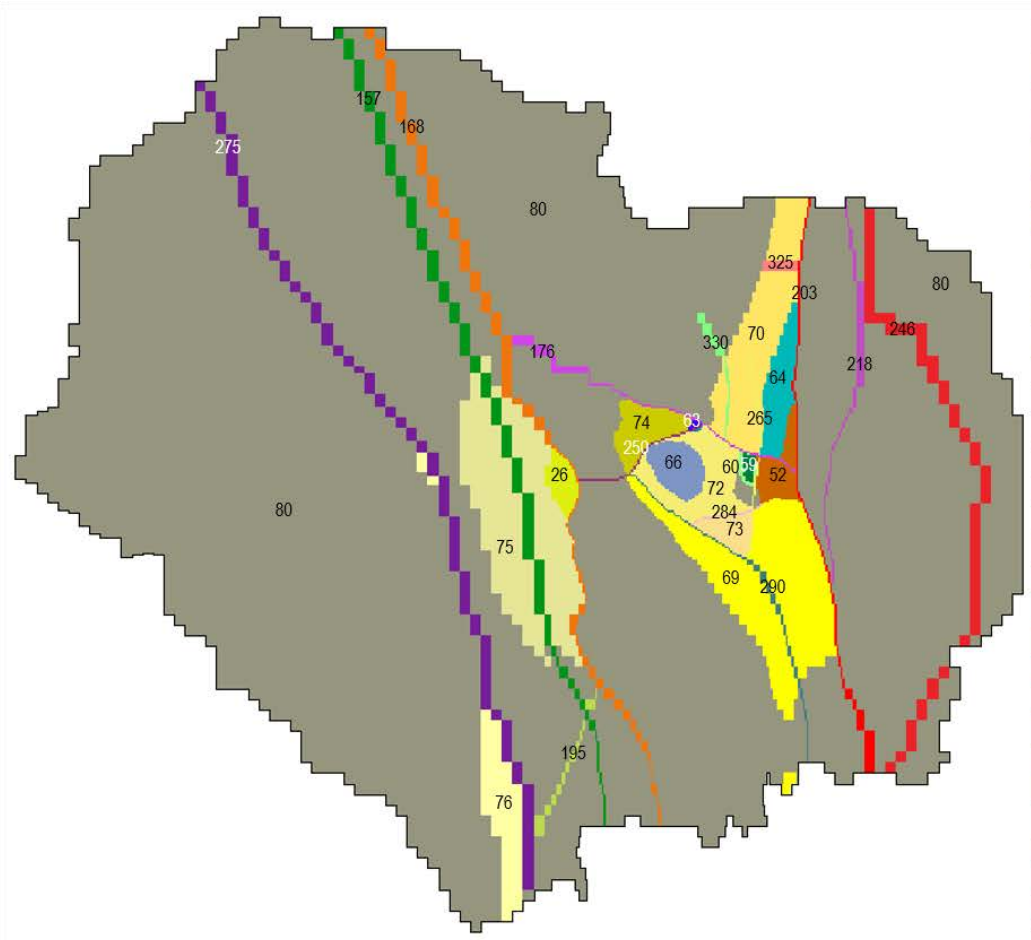
CLIENT:	Resolution Copper	PROJECT:	Regional Groundwater Model		
JOB:	31400968.001	DRAWN:	CP	CHECKED:	DO
DATE:	January 2019	FIGURE:	Appendix B		



Color	HGU	Zone	Kx (ft/d)	Ky (ft/d)	Kz (ft/d)	Ss (1/ft)	Sy
	QTg	7	2.54E-04	2.54E-04	2.54E-04	3.71E-08	1.00E-02
	Tw	48	8.51E-05	8.51E-05	8.51E-05	3.50E-08	1.00E-02
	Tw	52	1.25E-05	1.25E-05	1.25E-05	3.50E-08	1.00E-02
	Tw	56	3.03E-06	3.03E-06	5.00E-07	4.01E-08	1.00E-02
	KVS	59	1.00E-04	1.00E-04	1.00E-04	5.00E-08	7.07E-03
	KVS	60	2.85E-04	2.85E-04	1.00E-04	1.30E-08	5.00E-03
	Pz	63	5.00E-04	5.00E-04	5.00E-04	4.65E-08	1.00E-02
	Pz	64	1.48E-05	1.48E-05	1.48E-05	4.40E-08	8.75E-03
	Pz	65	7.36E-04	7.36E-04	7.36E-04	4.40E-08	8.75E-03
	Pz	66	1.00E-02	1.00E-02	1.00E-02	2.00E-08	5.00E-03
	Pz	67	1.00E-04	1.00E-04	1.00E-04	4.40E-08	8.75E-03
	pCy	69	1.00E-03	1.00E-03	1.00E-03	1.25E-08	8.75E-03
	pCy	70	1.28E-04	1.28E-04	1.28E-04	1.25E-08	8.75E-03
	pCy	72	1.00E-02	1.00E-02	5.00E-04	1.00E-08	5.00E-03
	pCy	73	1.00E-03	1.00E-03	1.00E-04	1.25E-08	8.75E-03
	pCy	74	7.00E-04	7.00E-04	1.00E-03	1.28E-08	1.00E-02
	pCy	75	1.00E-03	1.00E-03	1.00E-03	1.25E-08	8.75E-03
	pCy	76	2.71E-04	2.71E-04	2.71E-04	1.25E-08	8.75E-03
	pCpi	80	1.00E-04	1.00E-04	1.00E-04	1.00E-08	6.00E-03
	Arnett	157	1.00E-03	1.00E-03	1.00E-03	1.00E-08	1.00E-04
	Concentrator	168	1.00E-04	1.00E-04	1.00E-04	1.00E-08	1.00E-04
	Conley Springs - Deep	176	3.61E-05	3.61E-05	3.61E-05	1.00E-08	1.00E-04
	Concentrator West	195	1.00E-03	1.00E-03	1.00E-03	1.00E-08	1.00E-04
	Devils Canyon	203	1.00E-01	1.00E-01	1.00E-01	1.00E-08	1.00E-04
	JI Ranch	218	1.00E-03	1.00E-03	1.00E-03	1.00E-08	1.00E-04
	Main	231	1.00E-04	1.00E-04	1.00E-04	1.00E-08	1.00E-04
	Mineral Creek	246	1.00E-02	1.00E-02	1.00E-02	1.00E-08	1.00E-04
	North Boundary	250	6.25E-04	6.25E-04	6.25E-04	1.00E-08	1.00E-04
	Rancho Rio	265	2.50E-04	2.50E-04	2.50E-04	1.00E-08	1.00E-04
	Roblas Woods	275	1.00E-03	1.00E-03	1.00E-03	1.00E-08	1.00E-04
	South	284	1.60E-05	1.60E-05	1.60E-05	1.00E-08	1.00E-04
	West	290	1.25E-05	1.25E-05	1.25E-05	1.00E-08	1.00E-04
	Laramide	325	1.00E-05	1.00E-05	1.00E-05	1.00E-08	1.00E-04
	Anxiety	330	5.00E-04	1.00E-02	5.00E-04	1.00E-08	1.00E-04

HGU Material Property Values – Elevation -1,150 ft amsl, Layer 32 (Plan View)

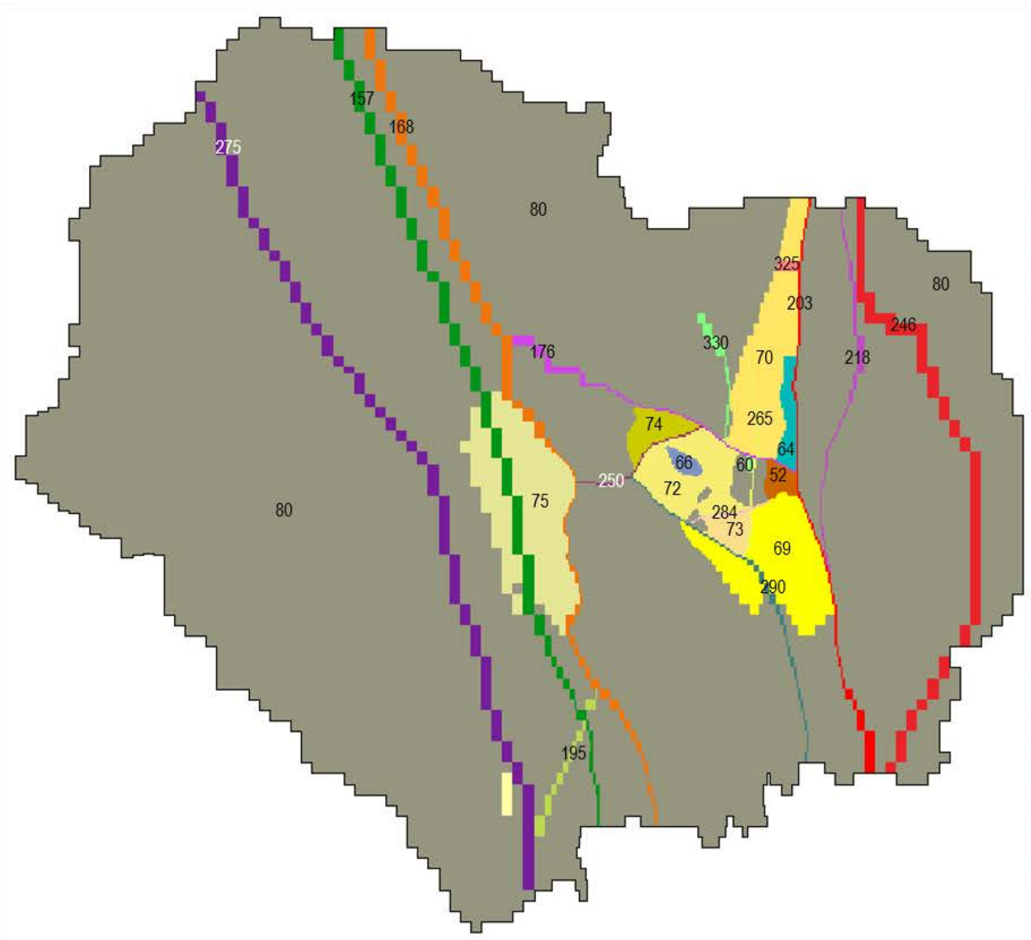
CLIENT:	Resolution Copper	PROJECT:	Regional Groundwater Model		
JOB:	31400968.001	DRAWN:	CP	CHECKED:	DO
DATE:	January 2019	FIGURE:	Appendix B		



Color	HGU	Zone	Kx (ft/d)	Ky (ft/d)	Kz (ft/d)	Ss (1/ft)	Sy
	Tw	52	1.25E-05	1.25E-05	1.25E-05	3.50E-08	1.00E-02
	KVS	59	1.00E-04	1.00E-04	1.00E-04	5.00E-08	7.07E-03
	KVS	60	2.85E-04	2.85E-04	1.00E-04	1.30E-08	5.00E-03
	Pz	63	5.00E-04	5.00E-04	5.00E-04	4.65E-08	1.00E-02
	Pz	64	1.48E-05	1.48E-05	1.48E-05	4.40E-08	8.75E-03
	Pz	66	1.00E-02	1.00E-02	1.00E-02	2.00E-08	5.00E-03
	pCy	69	1.00E-03	1.00E-03	1.00E-03	1.25E-08	8.75E-03
	pCy	70	1.28E-04	1.28E-04	1.28E-04	1.25E-08	8.75E-03
	pCy	72	1.00E-02	1.00E-02	5.00E-04	1.00E-08	5.00E-03
	pCy	73	1.00E-03	1.00E-03	1.00E-04	1.25E-08	8.75E-03
	pCy	74	7.00E-04	7.00E-04	1.00E-03	1.28E-08	1.00E-02
	pCy	75	1.00E-03	1.00E-03	1.00E-03	1.25E-08	8.75E-03
	pCy	76	2.71E-04	2.71E-04	2.71E-04	1.25E-08	8.75E-03
	pCpi	80	1.00E-04	1.00E-04	1.00E-04	1.00E-08	6.00E-03
	Arnett	157	1.00E-03	1.00E-03	1.00E-03	1.00E-08	1.00E-04
	Concentrator	168	1.00E-04	1.00E-04	1.00E-04	1.00E-08	1.00E-04
	Conley Springs - Deep	176	3.61E-05	3.61E-05	3.61E-05	1.00E-08	1.00E-04
	Concentrator West	195	1.00E-03	1.00E-03	1.00E-03	1.00E-08	1.00E-04
	Devils Canyon	203	1.00E-01	1.00E-01	1.00E-01	1.00E-08	1.00E-04
	JI Ranch	218	1.00E-03	1.00E-03	1.00E-03	1.00E-08	1.00E-04
	Main	231	1.00E-04	1.00E-04	1.00E-04	1.00E-08	1.00E-04
	Mineral Creek	246	1.00E-02	1.00E-02	1.00E-02	1.00E-08	1.00E-04
	North Boundary	250	6.25E-04	6.25E-04	6.25E-04	1.00E-08	1.00E-04
	Rancho Rio	265	2.50E-04	2.50E-04	2.50E-04	1.00E-08	1.00E-04
	Roblas Woods	275	1.00E-03	1.00E-03	1.00E-03	1.00E-08	1.00E-04
	South	284	1.60E-05	1.60E-05	1.60E-05	1.00E-08	1.00E-04
	West	290	1.25E-05	1.25E-05	1.25E-05	1.00E-08	1.00E-04
	Laramide	325	1.00E-05	1.00E-05	1.00E-05	1.00E-08	1.00E-04
	Anxiety	330	5.00E-04	1.00E-02	5.00E-04	1.00E-08	1.00E-04

HGU Material Property Values – Elevation -2,350 ft amsl, Layer 36 (Plan View)

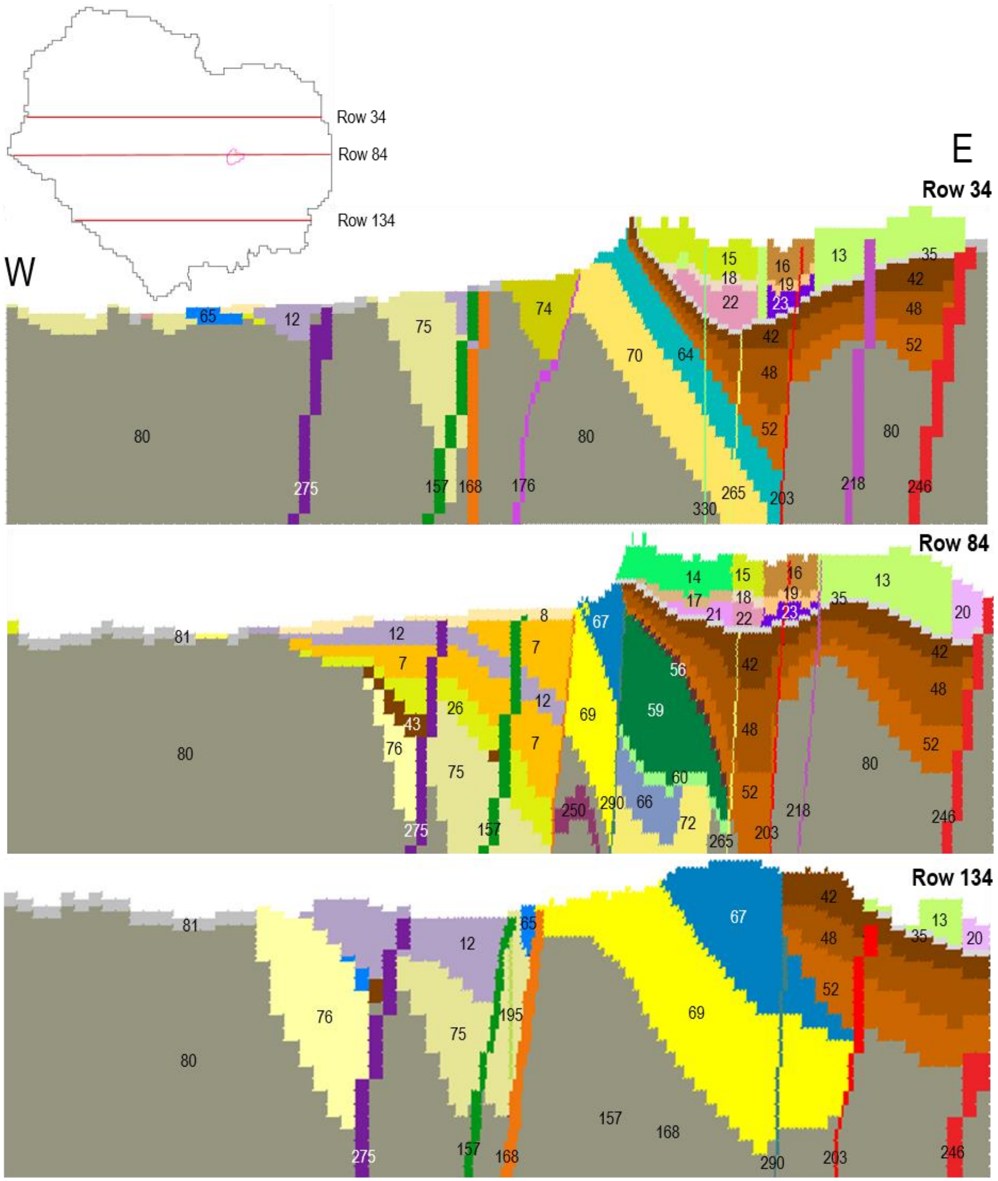
CLIENT:	Resolution Copper	PROJECT:	Regional Groundwater Model		
JOB:	31400968.001	DRAWN:	CP	CHECKED:	DO
DATE:	January 2019	FIGURE:	Appendix B		



Color	HGU	Zone	Kx (ft/d)	Ky (ft/d)	Kz (ft/d)	Ss (1/ft)	Sy
	Tw	52	1.25E-05	1.25E-05	1.25E-05	3.50E-08	1.00E-02
	KVS	60	2.85E-04	2.85E-04	1.00E-04	1.30E-08	5.00E-03
	Pz	64	1.48E-05	1.48E-05	1.48E-05	4.40E-08	8.75E-03
	Pz	66	1.00E-02	1.00E-02	1.00E-02	2.00E-08	5.00E-03
	pCy	69	1.00E-03	1.00E-03	1.00E-03	1.25E-08	8.75E-03
	pCy	70	1.28E-04	1.28E-04	1.28E-04	1.25E-08	8.75E-03
	pCy	72	1.00E-02	1.00E-02	5.00E-04	1.00E-08	5.00E-03
	pCy	73	1.00E-03	1.00E-03	1.00E-04	1.25E-08	8.75E-03
	pCy	74	7.00E-04	7.00E-04	1.00E-03	1.28E-08	1.00E-02
	pCy	75	1.00E-03	1.00E-03	1.00E-03	1.25E-08	8.75E-03
	pCpi	80	1.00E-04	1.00E-04	1.00E-04	1.00E-08	6.00E-03
	Arnett	157	1.00E-03	1.00E-03	1.00E-03	1.00E-08	1.00E-04
	Concentrator	168	1.00E-04	1.00E-04	1.00E-04	1.00E-08	1.00E-04
	Conley Springs - Deep	176	3.61E-05	3.61E-05	3.61E-05	1.00E-08	1.00E-04
	Concentrator West	195	1.00E-03	1.00E-03	1.00E-03	1.00E-08	1.00E-04
	Devils Canyon	203	1.00E-01	1.00E-01	1.00E-01	1.00E-08	1.00E-04
	JI Ranch	218	1.00E-03	1.00E-03	1.00E-03	1.00E-08	1.00E-04
	Main	231	1.00E-04	1.00E-04	1.00E-04	1.00E-08	1.00E-04
	Mineral Creek	246	1.00E-02	1.00E-02	1.00E-02	1.00E-08	1.00E-04
	North Boundary	250	6.25E-04	6.25E-04	6.25E-04	1.00E-08	1.00E-04
	Rancho Rio	265	2.50E-04	2.50E-04	2.50E-04	1.00E-08	1.00E-04
	Roblas Woods	275	1.00E-03	1.00E-03	1.00E-03	1.00E-08	1.00E-04
	South	284	1.60E-05	1.60E-05	1.60E-05	1.00E-08	1.00E-04
	West	290	1.25E-05	1.25E-05	1.25E-05	1.00E-08	1.00E-04
	Laramide	325	1.00E-05	1.00E-05	1.00E-05	1.00E-08	1.00E-04
	Anxiety	330	5.00E-04	1.00E-02	5.00E-04	1.00E-08	1.00E-04

HGU Material Property Values – Elevation -3,900 ft amsl, Layer 39 (Plan View)

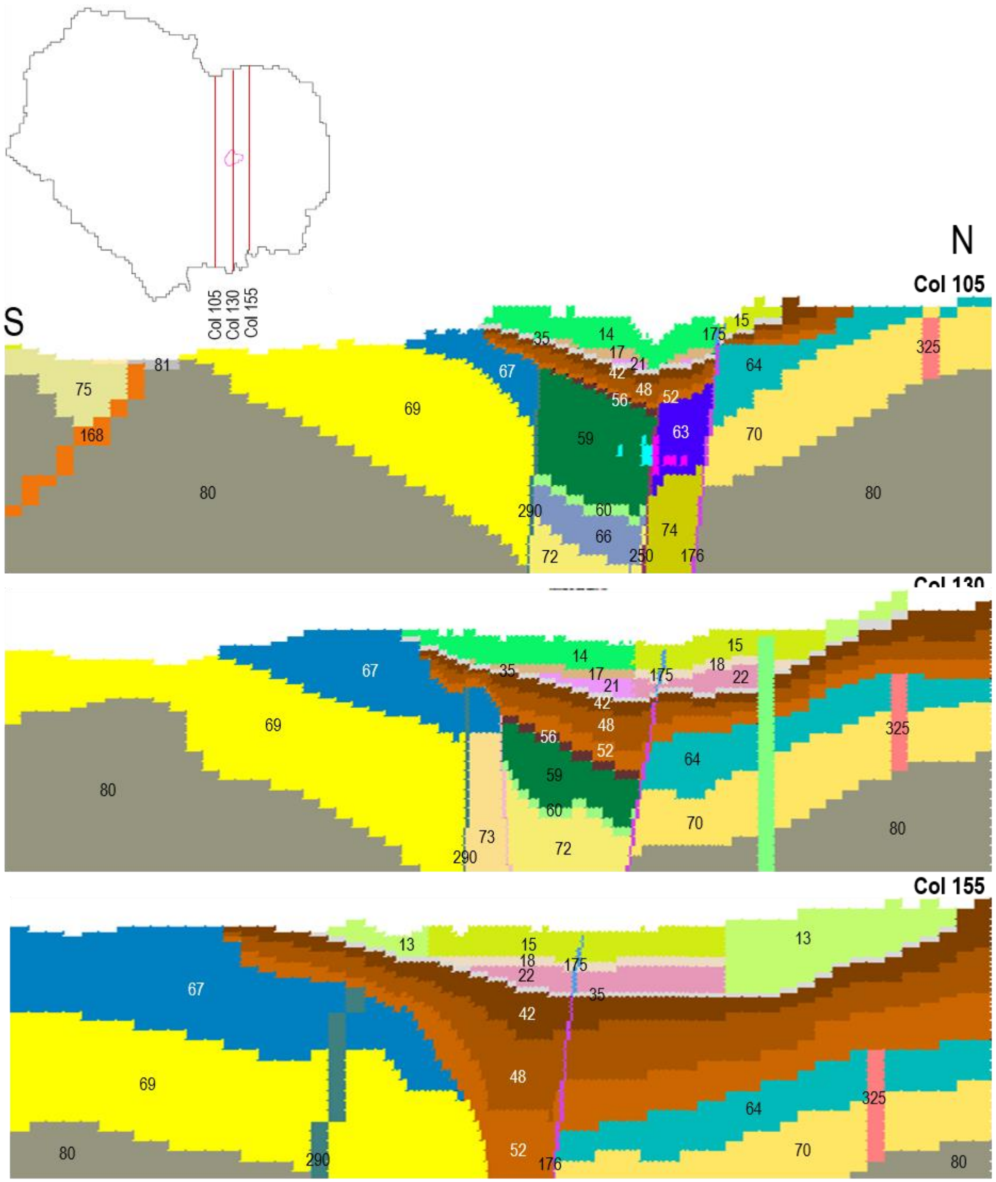
CLIENT:	Resolution Copper	PROJECT:	Regional Groundwater Model		
JOB:	31400968.001	DRAWN:	CP	CHECKED:	DO
DATE:	January 2019	FIGURE:	Appendix B		



Color	HGU	Zone	Kx (ft/d)	Ky (ft/d)	Kz (ft/d)	Ss (1/ft)	Sy
	Qal	4	1.92E+00	1.92E+00	1.92E-01	1.00E-05	2.00E-01
	QTg	7	2.54E-04	2.54E-04	2.54E-04	3.71E-08	1.00E-02
	QTg	8	2.03E-03	2.03E-03	2.03E-03	3.71E-08	1.00E-02
	Tvy	12	6.25E-03	6.25E-03	6.25E-03	5.00E-08	5.00E-03
	Tal	13	6.25E-02	6.25E-02	6.25E-02	5.00E-08	5.00E-03
	Tal	14	2.50E-01	2.50E-01	2.50E-01	5.00E-08	1.00E-03
	Tal	15	1.26E-02	1.26E-02	1.26E-02	5.00E-08	5.00E-03
	Tal	16	3.00E+00	3.00E+00	3.00E+00	5.00E-08	5.00E-03
	Tal	17	6.00E-02	6.00E-02	6.00E-02	5.00E-08	5.00E-03
	Tal	18	5.00E-03	5.00E-03	5.00E-03	5.00E-08	5.00E-03
	Tal	19	1.00E+00	1.00E+00	1.00E+00	5.00E-08	5.00E-03
	Tal	20	4.00E-01	4.00E-01	4.00E-01	5.00E-08	5.00E-03
	Tal	21	1.07E-02	1.07E-02	1.07E-02	5.00E-08	5.00E-03
	Tal	22	1.00E-03	1.00E-03	1.00E-03	5.00E-08	5.00E-03
	Tal	23	4.00E-01	4.00E-01	4.00E-01	5.00E-08	5.00E-03
	Tal	26	1.00E-03	1.00E-03	1.00E-03	5.00E-08	5.00E-03
	Talv	35	1.00E-03	1.00E-03	1.00E-03	5.00E-08	5.00E-03
	Tvo	38	2.17E-01	2.17E-01	2.17E-01	5.76E-07	5.00E-03
	Tvo	39	8.71E-02	8.71E-02	8.71E-02	5.76E-07	5.00E-03
	Tw	42	2.74E-03	2.74E-03	2.74E-03	3.50E-08	1.00E-02
	Tw	43	7.00E-04	7.00E-04	7.00E-04	3.50E-08	1.00E-02
	Tw	48	8.51E-05	8.51E-05	8.51E-05	3.50E-08	1.00E-02
	Tw	52	1.25E-05	1.25E-05	1.25E-05	3.50E-08	1.00E-02
	Tw	56	3.03E-06	3.03E-06	5.00E-07	4.01E-08	1.00E-02
	KVS	59	1.00E-04	1.00E-04	1.00E-04	5.00E-08	7.07E-03
	KVS	60	2.85E-04	2.85E-04	1.00E-04	1.30E-08	5.00E-03
	Pz	63	5.00E-04	5.00E-04	5.00E-04	4.65E-08	1.00E-02
	Pz	64	1.48E-05	1.48E-05	1.48E-05	4.40E-08	8.75E-03
	Pz	65	7.36E-04	7.36E-04	7.36E-04	4.40E-08	8.75E-03
	Pz	66	1.00E-02	1.00E-02	1.00E-02	2.00E-08	5.00E-03
	Pz	67	1.00E-04	1.00E-04	1.00E-04	4.40E-08	8.75E-03
	pCy	69	1.00E-03	1.00E-03	1.00E-03	1.25E-08	8.75E-03
	pCy	70	1.28E-04	1.28E-04	1.28E-04	1.25E-08	8.75E-03
	pCy	71	4.56E-05	4.56E-05	4.56E-05	1.00E-08	7.00E-03
	pCy	72	1.00E-02	1.00E-02	5.00E-04	1.00E-08	5.00E-03
	pCy	73	1.00E-03	1.00E-03	1.00E-04	1.25E-08	8.75E-03
	pCy	74	7.00E-04	7.00E-04	1.00E-03	1.28E-08	1.00E-02
	pCy	75	1.00E-03	1.00E-03	1.00E-03	1.25E-08	8.75E-03
	pCy	76	2.71E-04	2.71E-04	2.71E-04	1.25E-08	8.75E-03
	pCpi	80	1.00E-04	1.00E-04	1.00E-04	1.00E-08	6.00E-03
	pCpi	81	1.00E-03	1.00E-03	1.00E-03	1.00E-08	6.00E-03
	Arnett	157	1.00E-03	1.00E-03	1.00E-03	1.00E-08	1.00E-04
	Concentrator	168	1.00E-04	1.00E-04	1.00E-04	1.00E-08	1.00E-04
	Conley Springs - Shallow	175	1.00E-04	1.00E-04	1.00E-04	1.00E-08	1.00E-04
	Conley Springs - Deep	176	3.61E-05	3.61E-05	3.61E-05	1.00E-08	1.00E-04
	Concentrator West	195	1.00E-03	1.00E-03	1.00E-03	1.00E-08	1.00E-04
	Devils Canyon	203	1.00E-01	1.00E-01	1.00E-01	1.00E-08	1.00E-04
	JI Ranch	218	1.00E-03	1.00E-03	1.00E-03	1.00E-08	1.00E-04
	Main	231	1.00E-04	1.00E-04	1.00E-04	1.00E-08	1.00E-04
	Mineral Creek	246	1.00E-02	1.00E-02	1.00E-02	1.00E-08	1.00E-04
	North Boundary	250	6.25E-04	6.25E-04	6.25E-04	1.00E-08	1.00E-04
	Rancho Rio	265	2.50E-04	2.50E-04	2.50E-04	1.00E-08	1.00E-04
	Roblas Woods	275	1.00E-03	1.00E-03	1.00E-03	1.00E-08	1.00E-04
	South	284	1.60E-05	1.60E-05	1.60E-05	1.00E-08	1.00E-04
	West	290	1.25E-05	1.25E-05	1.25E-05	1.00E-08	1.00E-04
	Laramide	325	1.00E-05	1.00E-05	1.00E-05	1.00E-08	1.00E-04
	Anxiety	330	5.00E-04	1.00E-02	5.00E-04	1.00E-08	1.00E-04

HGU Material Property Values – Rows 34, 84, & 134 (X-Section View)

CLIENT:	Resolution Copper	PROJECT:	Regional Groundwater Model
JOB:	31400968.001	DRAWN:	CP CHECKED: DO
DATE:	January 2019	FIGURE:	Appendix B

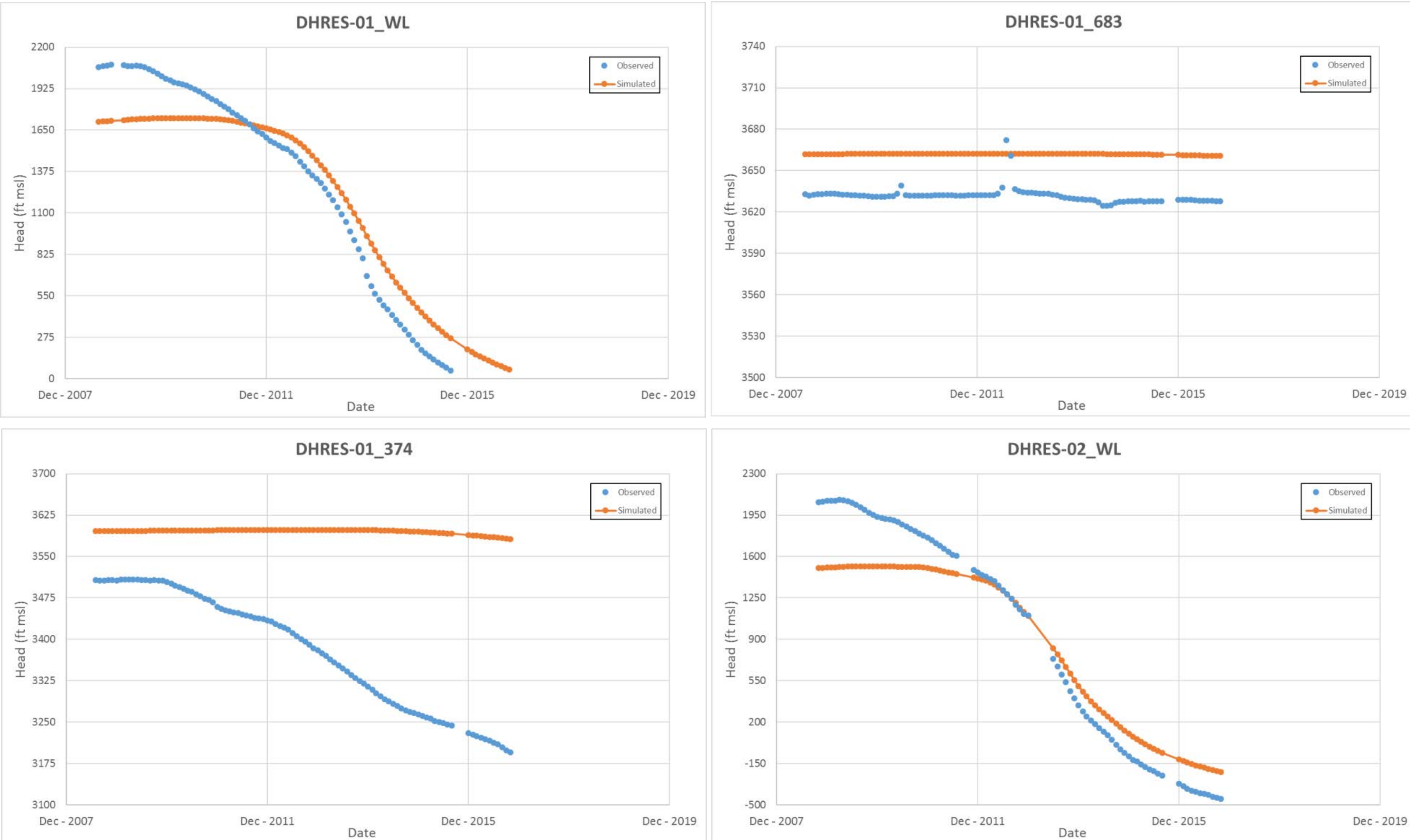


Color	HGU	Zone	Kx (ft/d)	Ky (ft/d)	Kz (ft/d)	Ss (1/ft)	Sy
	Qal	4	1.92E+00	1.92E+00	1.92E-01	1.00E-05	2.00E-01
	QTg	7	2.54E-04	2.54E-04	2.54E-04	3.71E-08	1.00E-02
	QTg	8	2.03E-03	2.03E-03	2.03E-03	3.71E-08	1.00E-02
	Tvy	12	6.25E-03	6.25E-03	6.25E-03	5.00E-08	5.00E-03
	Tal	13	6.25E-02	6.25E-02	6.25E-02	5.00E-08	5.00E-03
	Tal	14	2.50E-01	2.50E-01	2.50E-01	5.00E-08	1.00E-03
	Tal	15	1.26E-02	1.26E-02	1.26E-02	5.00E-08	5.00E-03
	Tal	16	3.00E+00	3.00E+00	3.00E+00	5.00E-08	5.00E-03
	Tal	17	6.00E-02	6.00E-02	6.00E-02	5.00E-08	5.00E-03
	Tal	18	5.00E-03	5.00E-03	5.00E-03	5.00E-08	5.00E-03
	Tal	19	1.00E+00	1.00E+00	1.00E+00	5.00E-08	5.00E-03
	Tal	20	4.00E-01	4.00E-01	4.00E-01	5.00E-08	5.00E-03
	Tal	21	1.07E-02	1.07E-02	1.07E-02	5.00E-08	5.00E-03
	Tal	22	1.00E-03	1.00E-03	1.00E-03	5.00E-08	5.00E-03
	Tal	23	4.00E-01	4.00E-01	4.00E-01	5.00E-08	5.00E-03
	Tal	26	1.00E-03	1.00E-03	1.00E-03	5.00E-08	5.00E-03
	Talv	35	1.00E-03	1.00E-03	1.00E-03	5.00E-08	5.00E-03
	Tvo	38	2.17E-01	2.17E-01	2.17E-01	5.76E-07	5.00E-03
	Tvo	39	8.71E-02	8.71E-02	8.71E-02	5.76E-07	5.00E-03
	Tw	42	2.74E-03	2.74E-03	2.74E-03	3.50E-08	1.00E-02
	Tw	43	7.00E-04	7.00E-04	7.00E-04	3.50E-08	1.00E-02
	Tw	48	8.51E-05	8.51E-05	8.51E-05	3.50E-08	1.00E-02
	Tw	52	1.25E-05	1.25E-05	1.25E-05	3.50E-08	1.00E-02
	Tw	56	1.00E-06	1.00E-06	5.00E-07	3.50E-08	1.00E-02
	KVS	59	4.86E-04	4.86E-04	2.77E-05	1.45E-08	6.25E-03
	KVS	60	1.40E-03	1.40E-03	2.67E-04	1.45E-08	3.00E-03
	Pz	63	1.51E-03	1.51E-03	1.51E-03	4.40E-08	8.75E-03
	Pz	64	1.48E-05	1.48E-05	1.48E-05	4.40E-08	8.75E-03
	Pz	65	7.36E-04	7.36E-04	7.36E-04	4.40E-08	8.75E-03
	Pz	66	1.03E-02	1.03E-02	3.84E-02	4.40E-08	1.00E-03
	pCy	69	1.00E-02	1.00E-02	1.00E-02	1.25E-08	8.75E-03
	pCy	70	1.28E-04	1.28E-04	1.28E-04	1.25E-08	8.75E-03
	pCy	71	4.56E-05	4.56E-05	4.56E-05	1.00E-08	7.00E-03
	pCy	72	4.52E-03	4.52E-03	8.00E-04	1.25E-08	1.00E-03
	pCy	73	1.00E-03	1.00E-03	1.00E-04	1.25E-08	8.75E-03
	pCy	74	1.02E-04	1.02E-04	1.02E-04	1.25E-08	8.75E-03
	pCy	75	1.00E-03	1.00E-03	1.00E-03	1.25E-08	8.75E-03
	pCy	76	2.71E-04	2.71E-04	2.71E-04	1.25E-08	8.75E-03
	pCpi	80	1.00E-04	1.00E-04	1.00E-04	1.00E-08	6.00E-03
	pCpi	81	1.00E-03	1.00E-03	1.00E-03	1.00E-08	6.00E-03
	Arnett	157	1.00E-03	1.00E-03	1.00E-03	1.00E-08	1.00E-04
	Concentrator	168	1.00E-04	1.00E-04	1.00E-04	1.00E-08	1.00E-04
	Conley Springs - Shallow	175	1.00E-04	1.00E-04	1.00E-04	1.00E-08	1.00E-04
	Conley Springs - Deep	176	3.61E-05	3.61E-05	3.61E-05	1.00E-08	1.00E-04
	Concentrator West	195	1.00E-03	1.00E-03	1.00E-03	1.00E-08	1.00E-04
	Devils Canyon	203	1.00E-01	1.00E-01	1.00E-01	1.00E-08	1.00E-04
	JI Ranch	218	1.00E-03	1.00E-03	1.00E-03	1.00E-08	1.00E-04
	Main	231	1.00E-04	1.00E-04	1.00E-04	1.00E-08	1.00E-04
	Mineral Creek	246	1.00E-02	1.00E-02	1.00E-02	1.00E-08	1.00E-04
	North Boundary	250	6.25E-04	6.25E-04	6.25E-04	1.00E-08	1.00E-04
	Rancho Rio	265	2.50E-04	2.50E-04	2.50E-04	1.00E-08	1.00E-04
	Roblas Woods	275	1.00E-03	1.00E-03	1.00E-03	1.00E-08	1.00E-04
	South	284	1.60E-05	1.60E-05	1.60E-05	1.00E-08	1.00E-04
	West	290	1.25E-05	1.25E-05	1.25E-05	1.00E-08	1.00E-04
	Laramide	325	1.00E-05	1.00E-05	1.00E-05	1.00E-08	1.00E-04
	Anxiety	330	5.00E-04	1.00E-02	5.00E-04	1.00E-08	1.00E-04

wsp

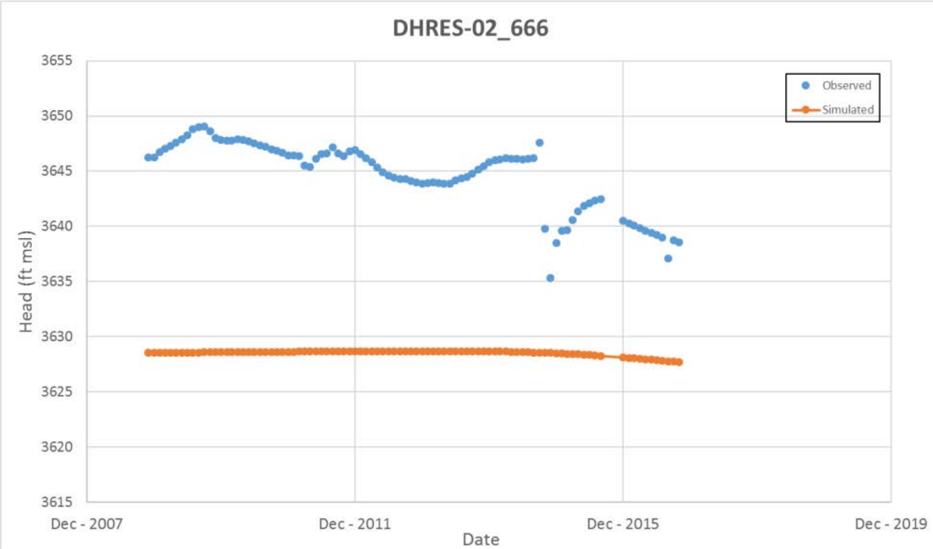
HGU Material Property Values – Rows 105, 130, & 155 (X-Section View)

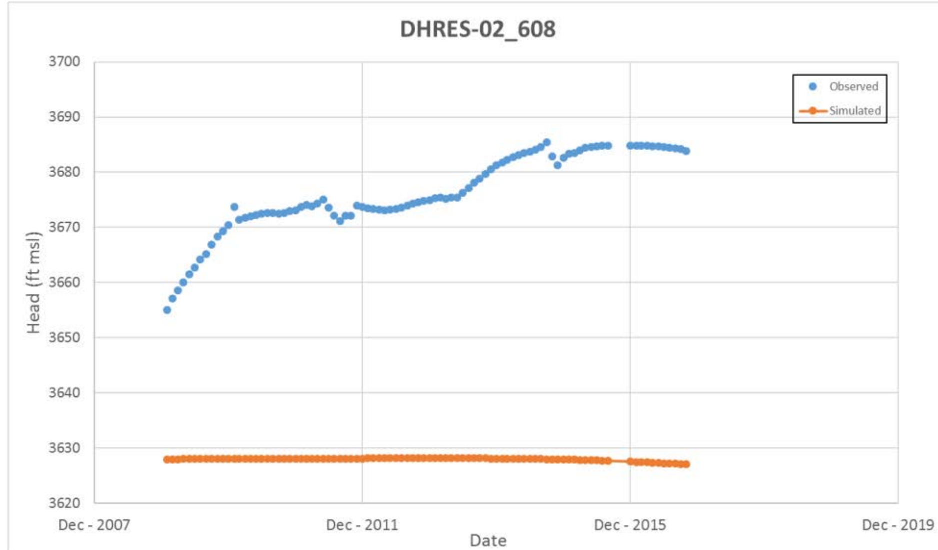
CLIENT:	Resolution Copper	PROJECT:	Regional Groundwater Model		
JOB:	31400968.001	DRAWN:	CP	CHECKED:	DO
DATE:	January 2019	FIGURE:	Appendix B		

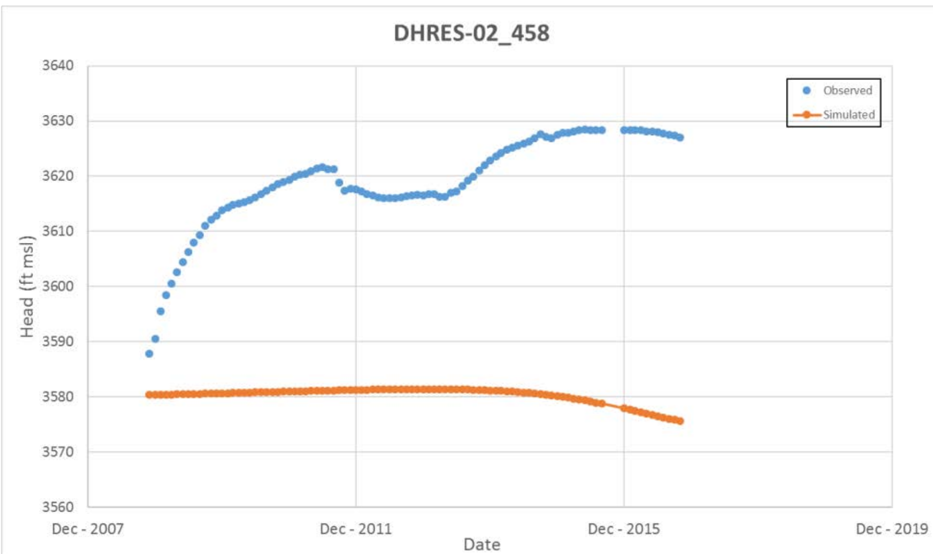


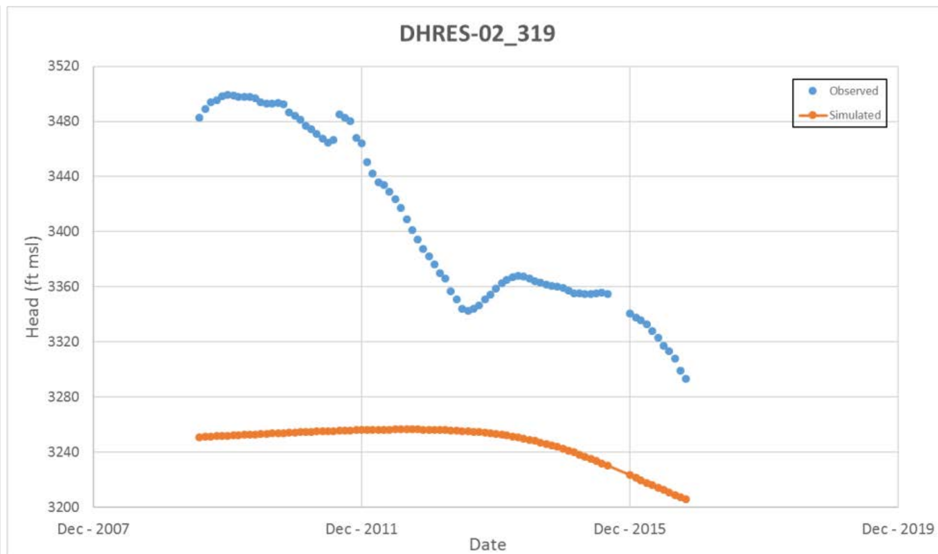
Model Calibration Hydrographs

PROJECT: Regional Groundwater Model		FIGURE #:	Appendix C
CLIENT: Resolution Copper		PROJECT #:	31400680
DRAWN: CP	CHECKED: DO	DATE:	January 2019



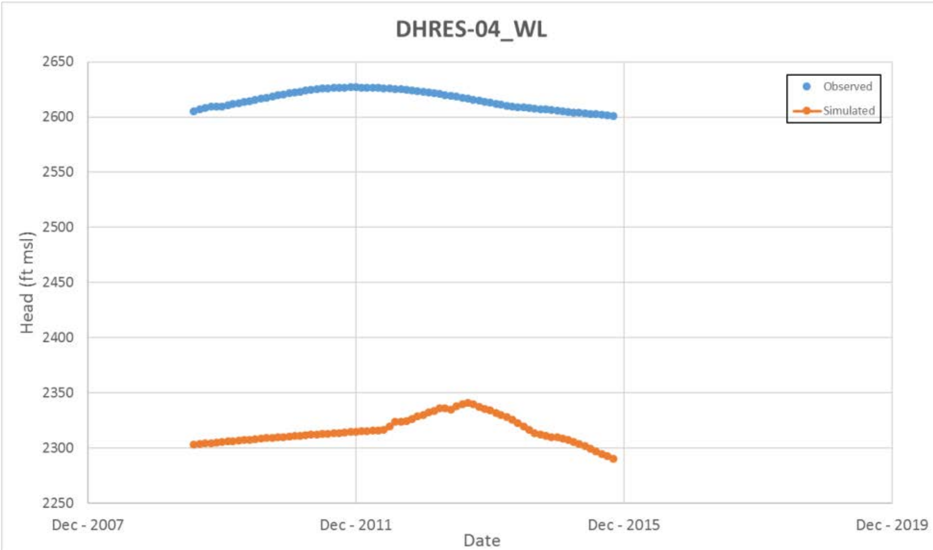


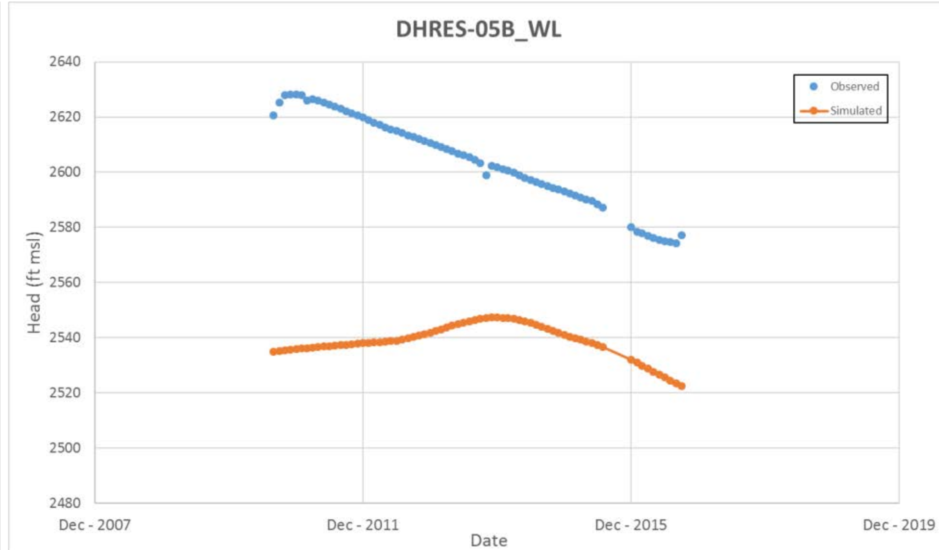


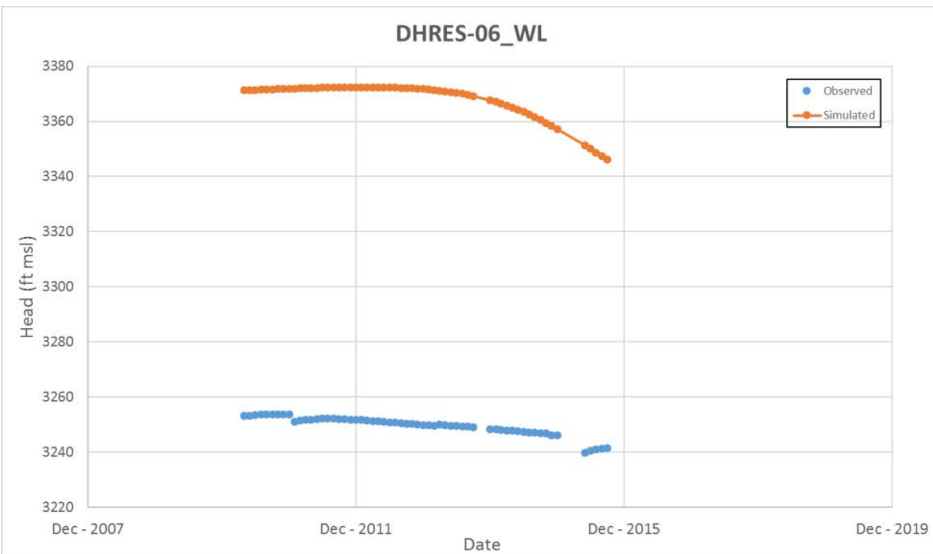


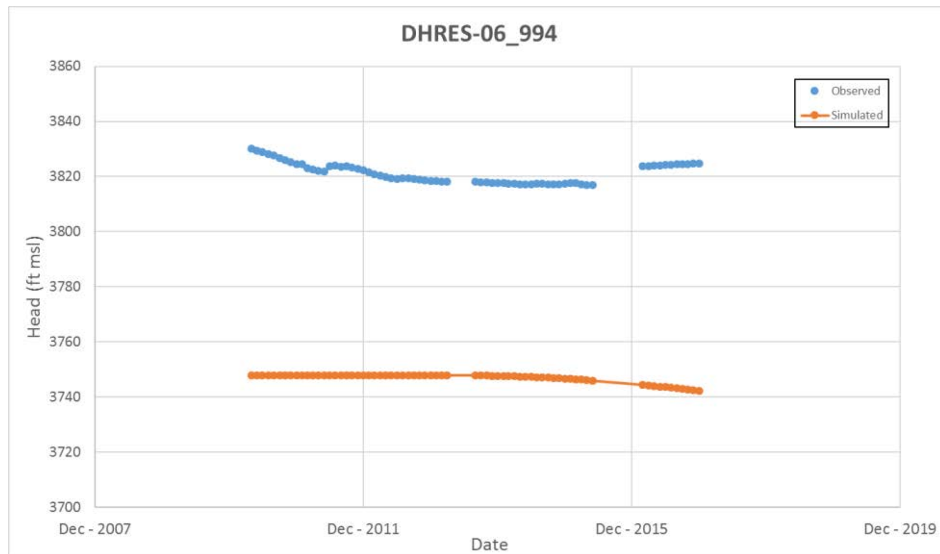
Model Calibration Hydrographs

PROJECT:	Regional Groundwater Model	FIGURE #:	Appendix C
CLIENT:	Resolution Copper	PROJECT #:	31400680
DRAWN: CP	CHECKED: DO	DATE:	January 2019



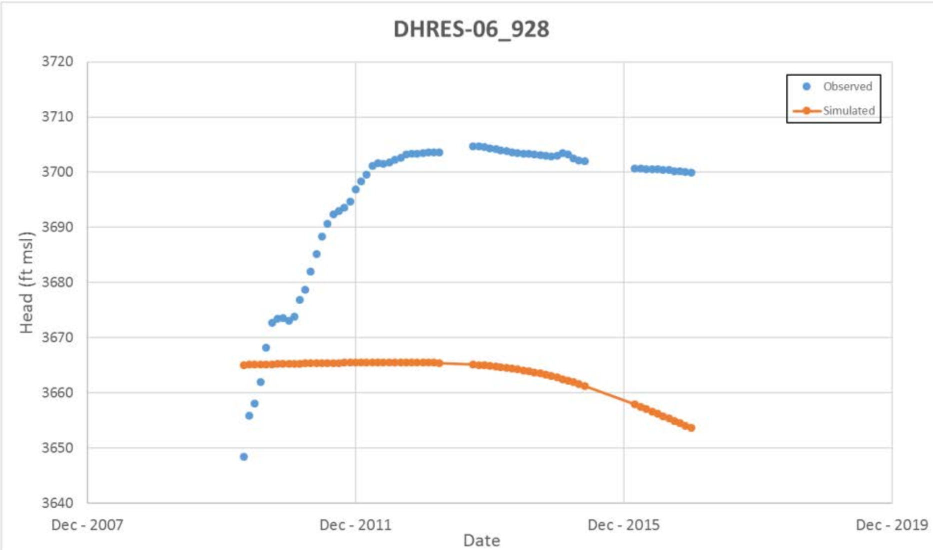


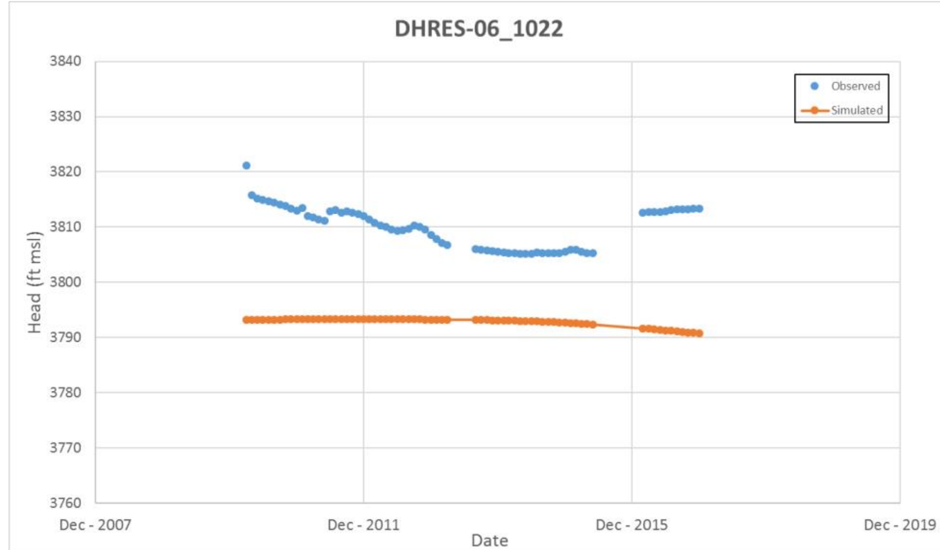


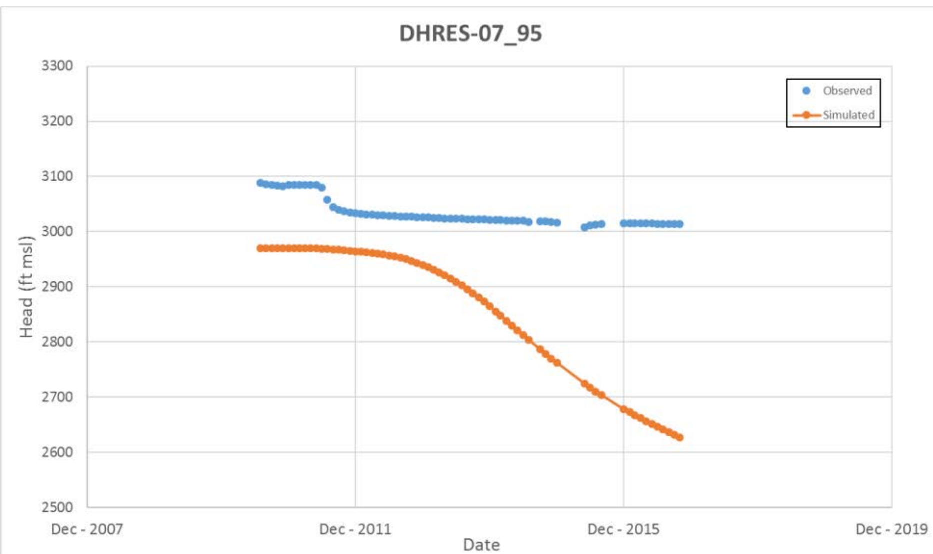


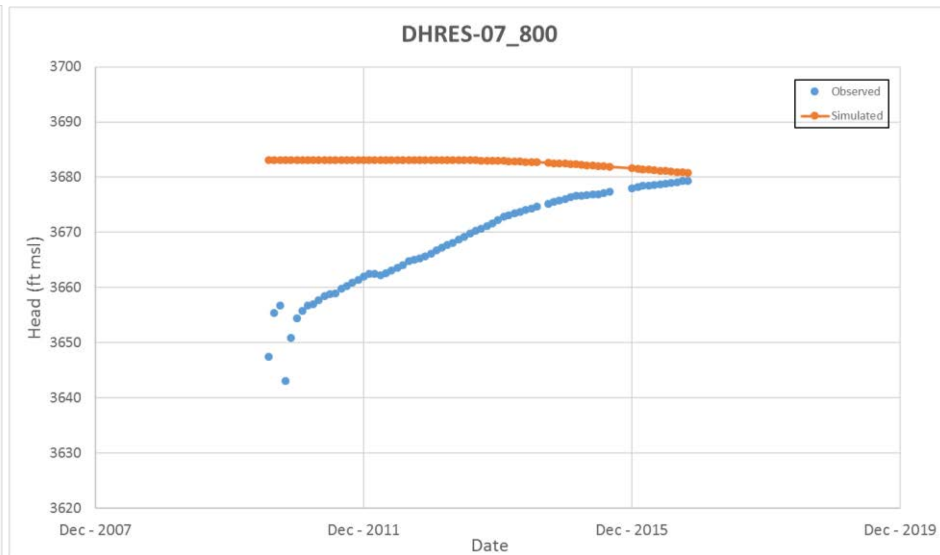
Model Calibration Hydrographs

PROJECT: Regional Groundwater Model		FIGURE #: Appendix C	
CLIENT: Resolution Copper		PROJECT #: 31400680	
DRAWN: CP	CHECKED: DO	DATE: January 2019	









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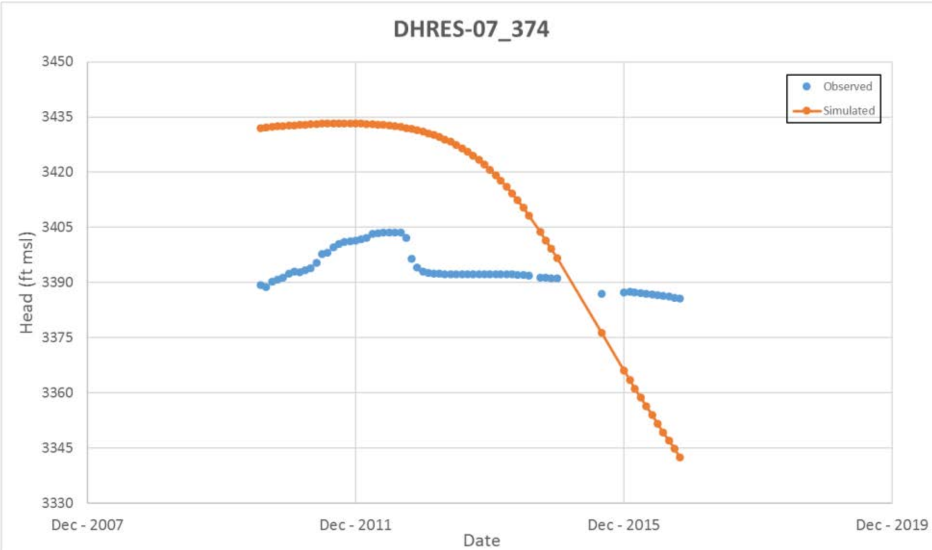
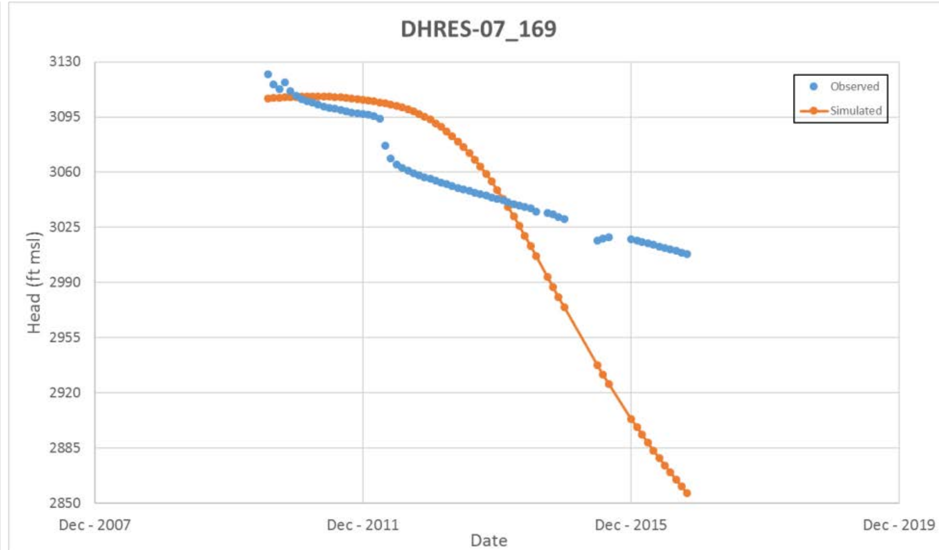
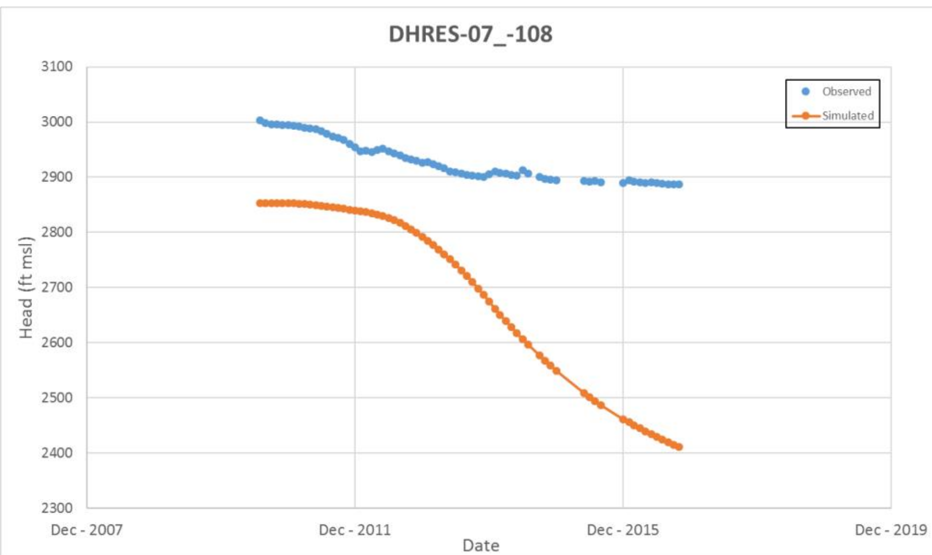
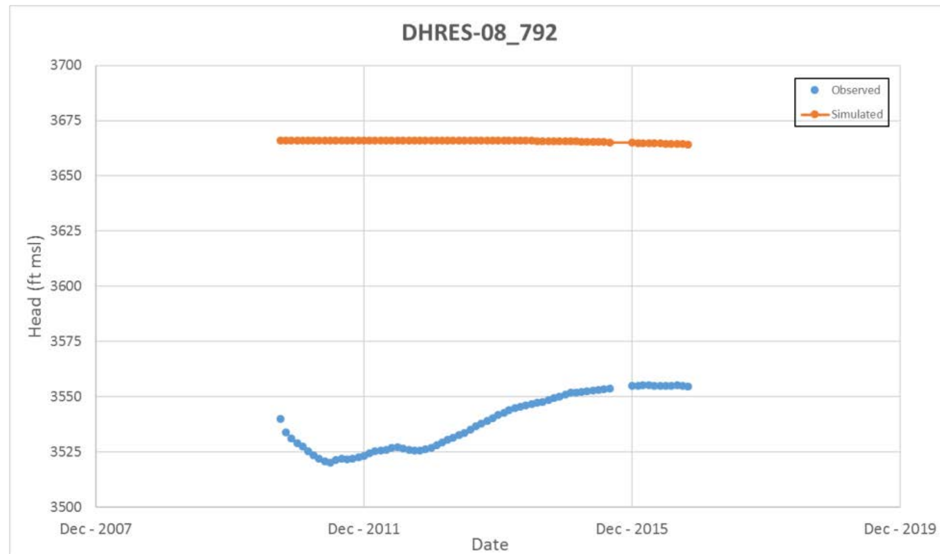
Model Calibration Hydrographs

PROJECT: Regional Groundwater Model		FIGURE #:	Appendix C
CLIENT: Resolution Copper		PROJECT #:	31400680
DRAWN: CP	CHECKED: DO	DATE:	January 2019



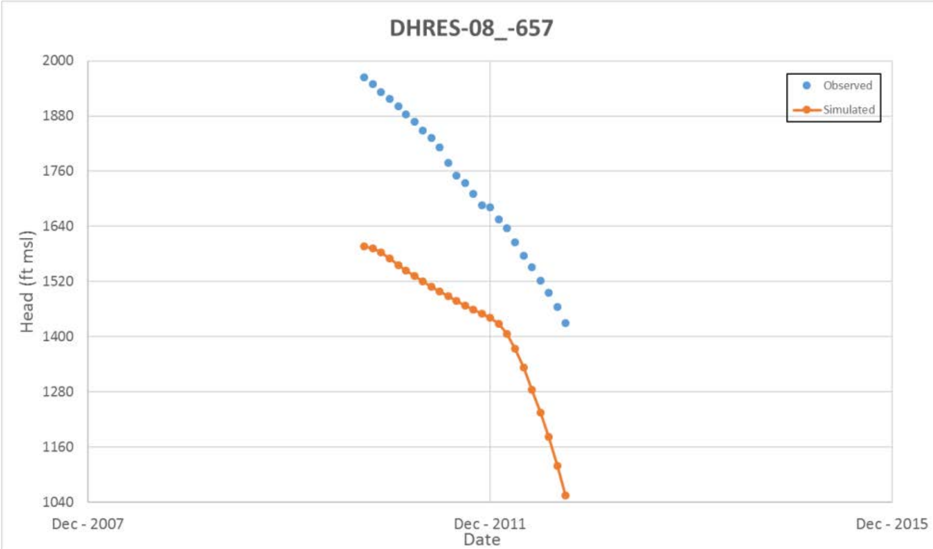


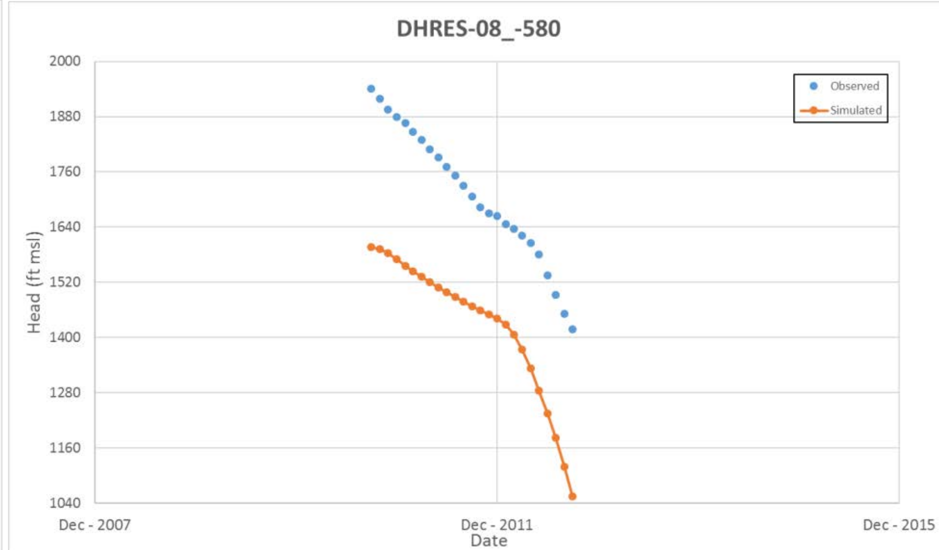


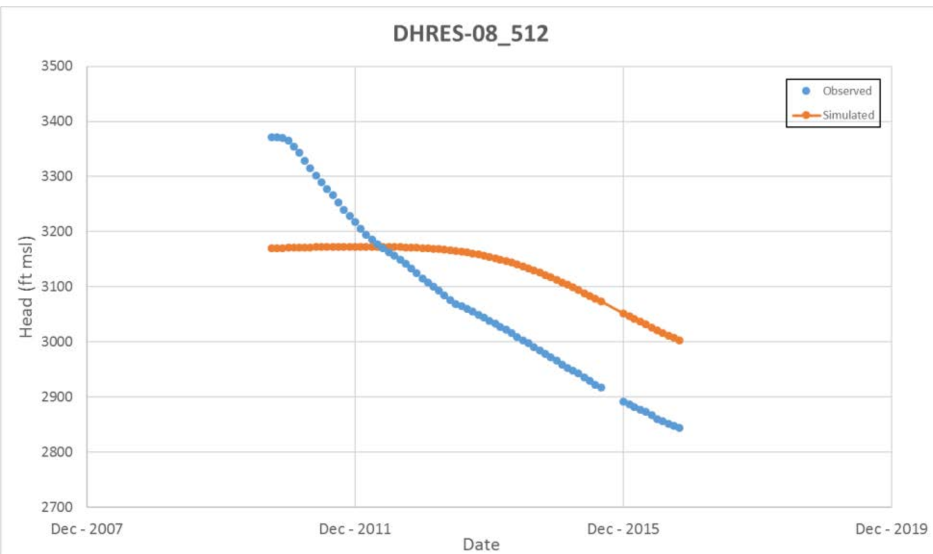


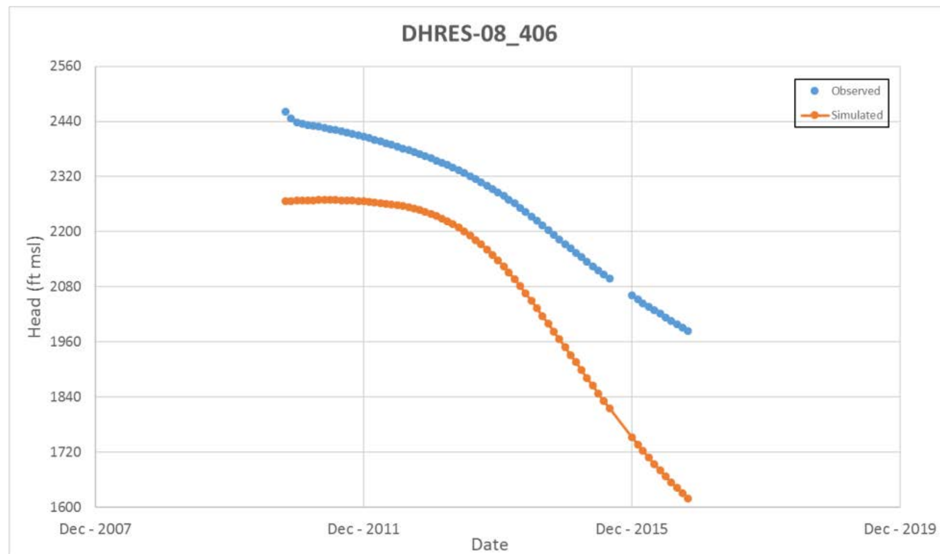
Model Calibration Hydrographs

PROJECT:	Regional Groundwater Model	FIGURE #:	Appendix C
CLIENT:	Resolution Copper	PROJECT #:	31400680
DRAWN: CP	CHECKED: DO	DATE:	January 2019









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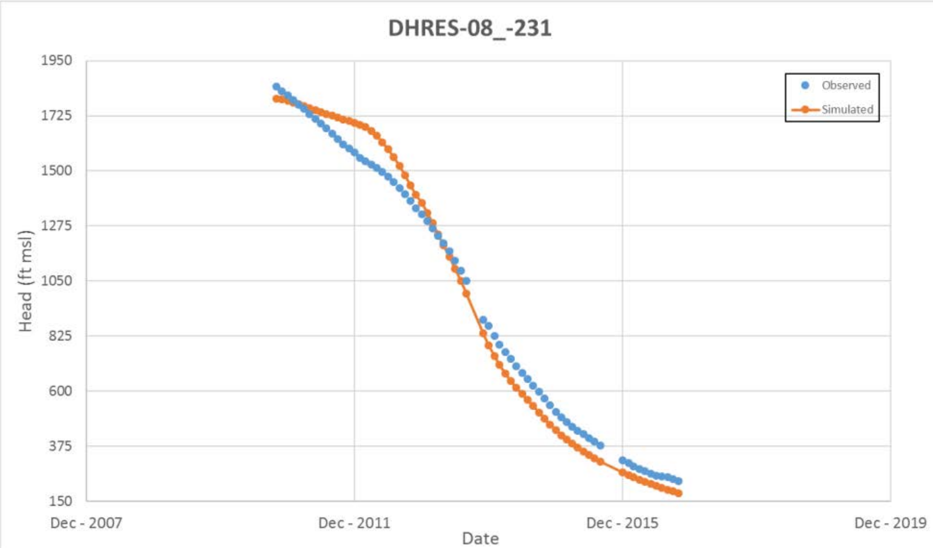
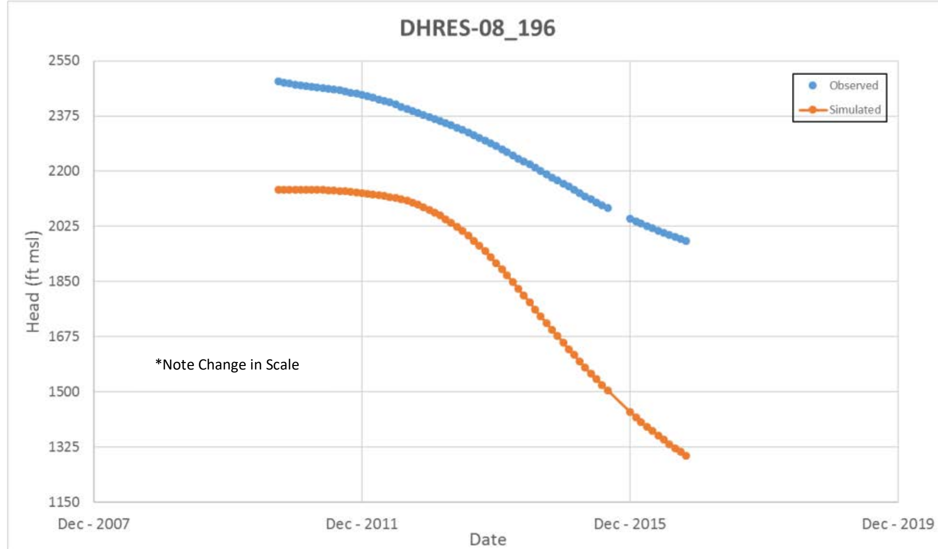
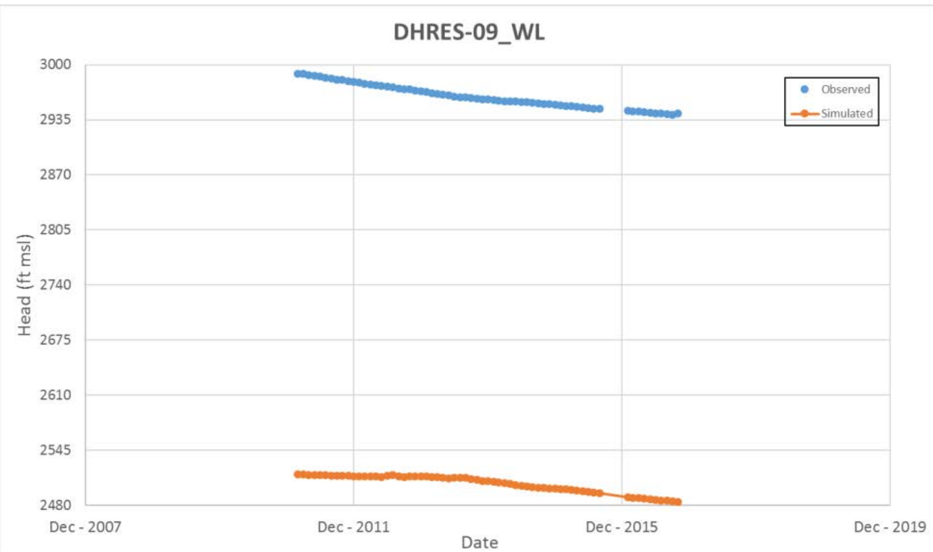
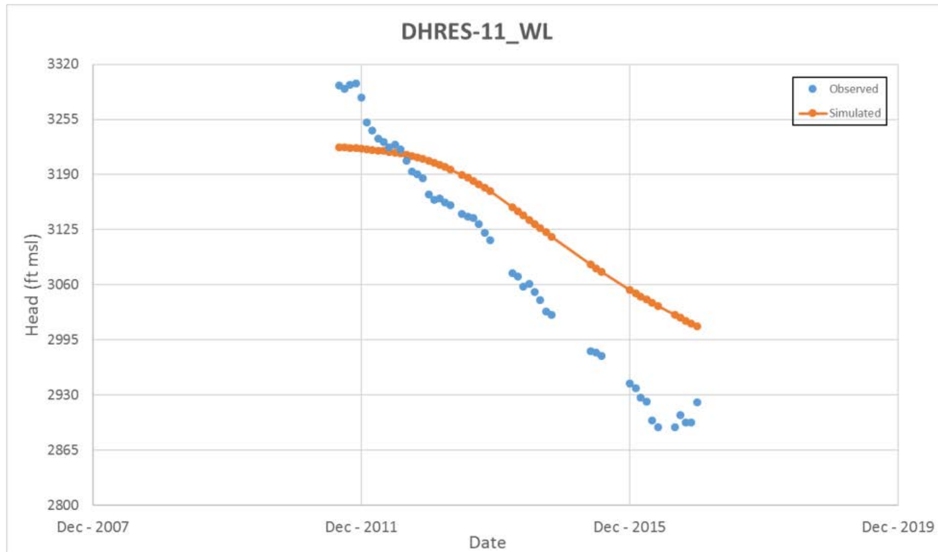
Model Calibration Hydrographs

PROJECT: Regional Groundwater Model		FIGURE #:	Appendix C
CLIENT: Resolution Copper		PROJECT #:	31400680
DRAWN: CP	CHECKED: DO	DATE:	January 2019



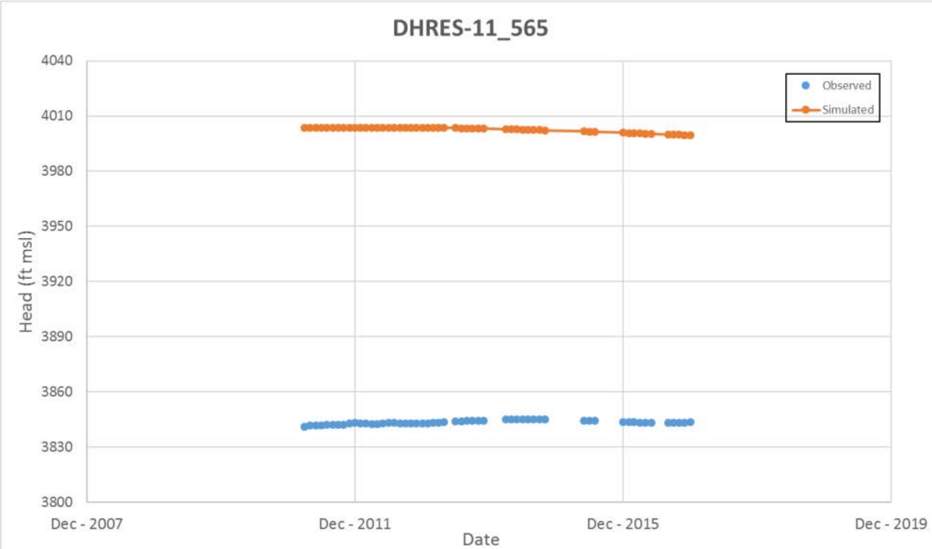


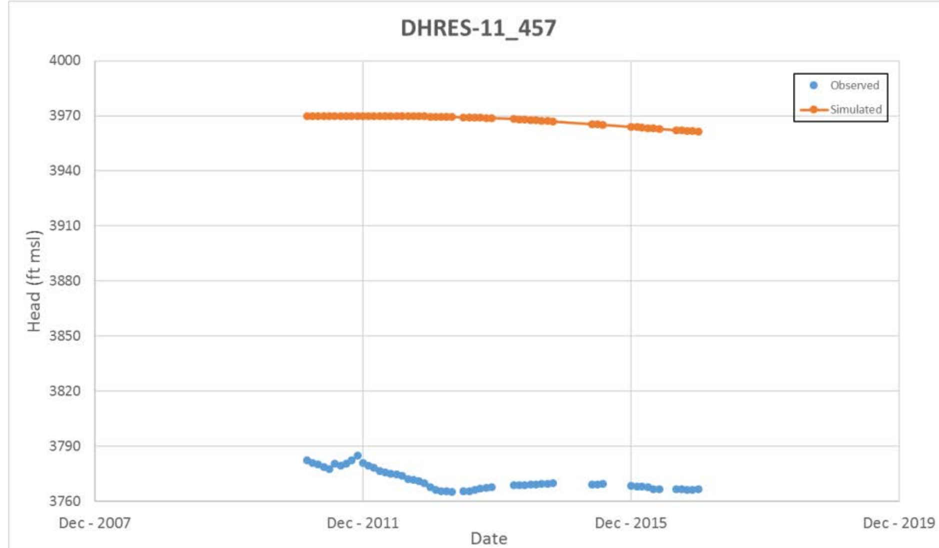


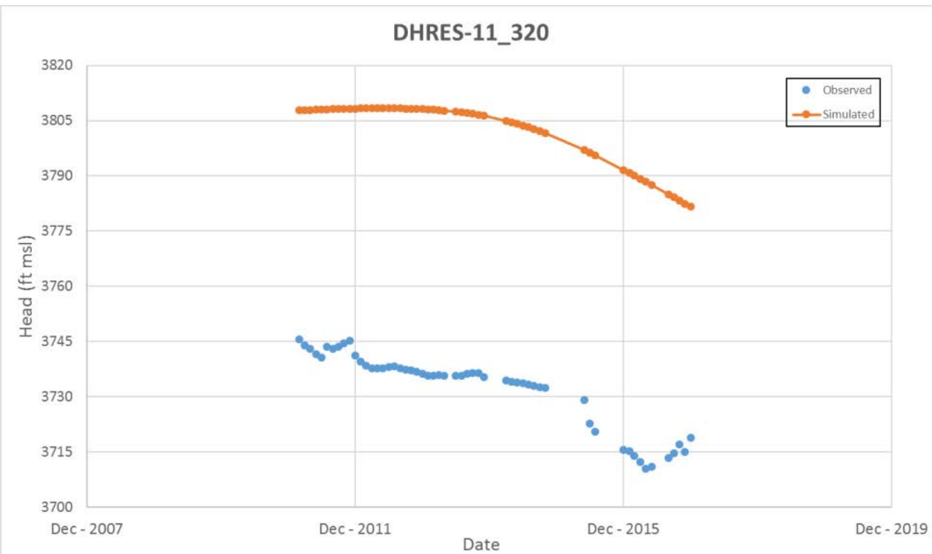


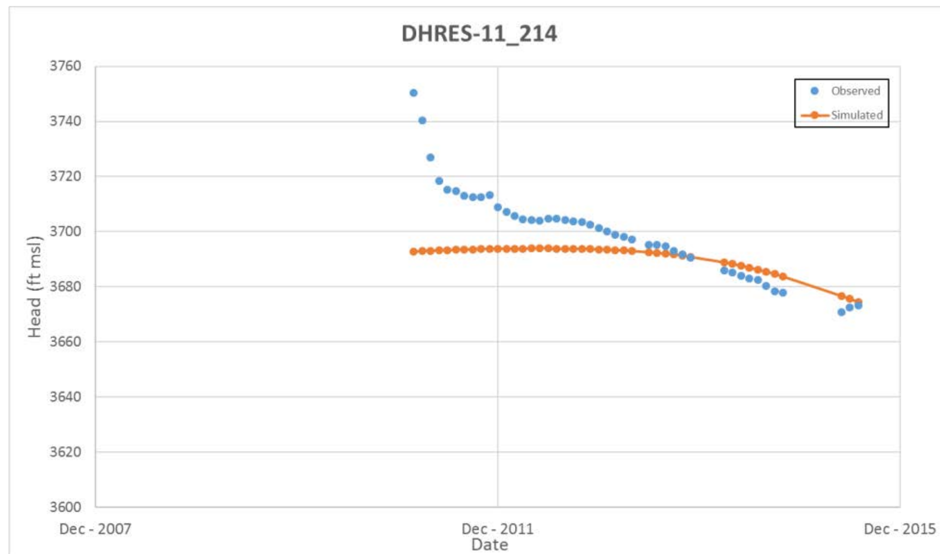
Model Calibration Hydrographs

PROJECT: Regional Groundwater Model		FIGURE #:	Appendix C
CLIENT: Resolution Copper		PROJECT #:	31400680
DRAWN: CP	CHECKED: DO	DATE:	January 2019









Model Calibration Hydrographs

PROJECT: Regional Groundwater Model		FIGURE #:	Appendix C
CLIENT: Resolution Copper		PROJECT #:	31400680
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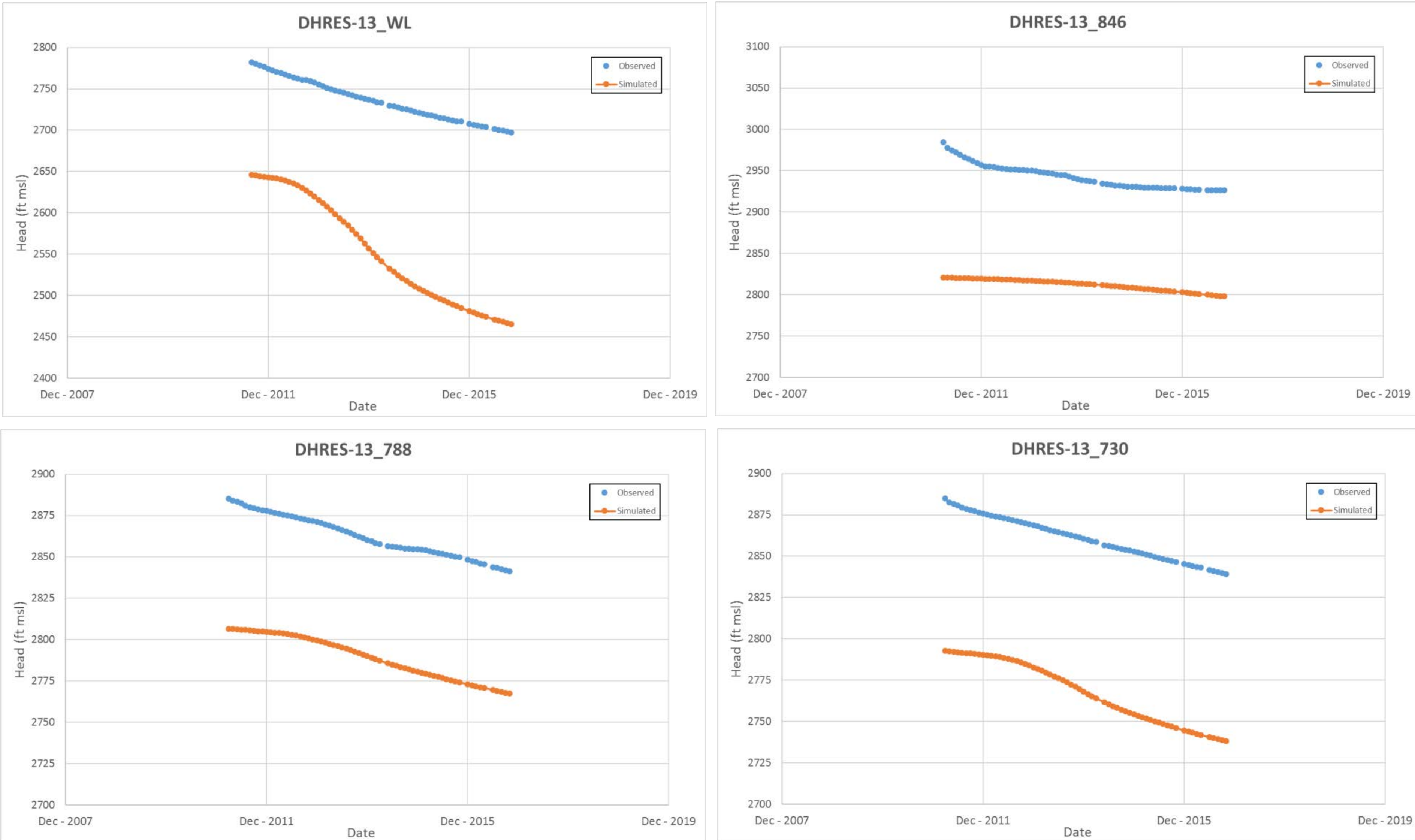

Model Calibration Hydrographs

PROJECT:	Regional Groundwater Model	FIGURE #:	Appendix C
CLIENT:	Resolution Copper	PROJECT #:	31400680
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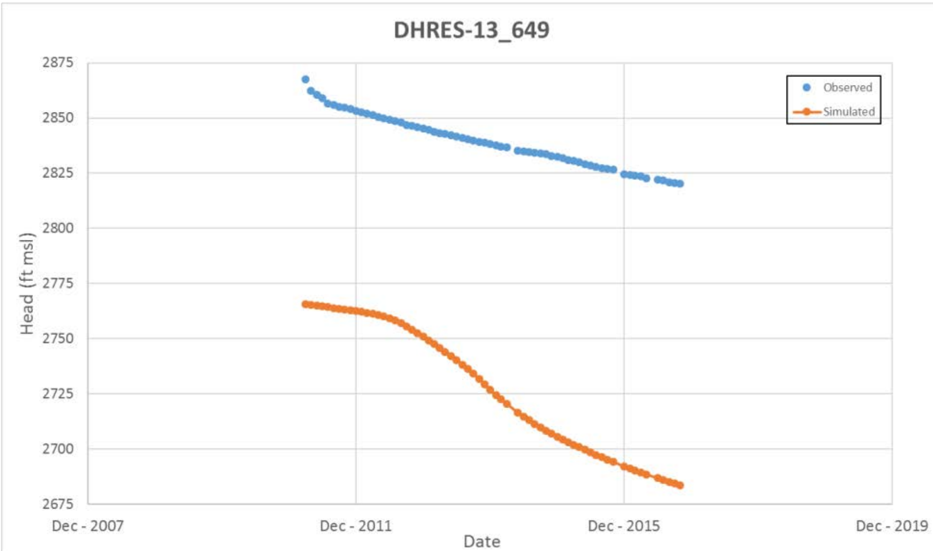

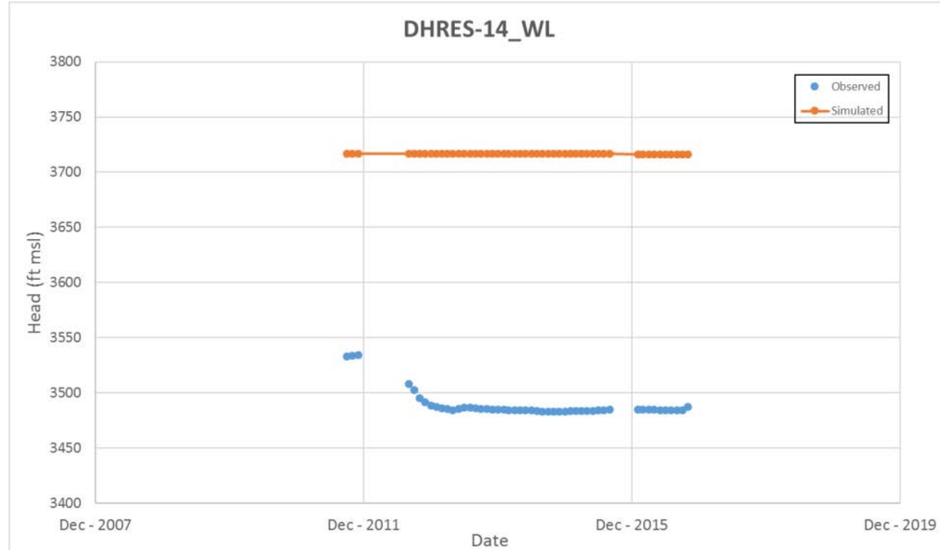

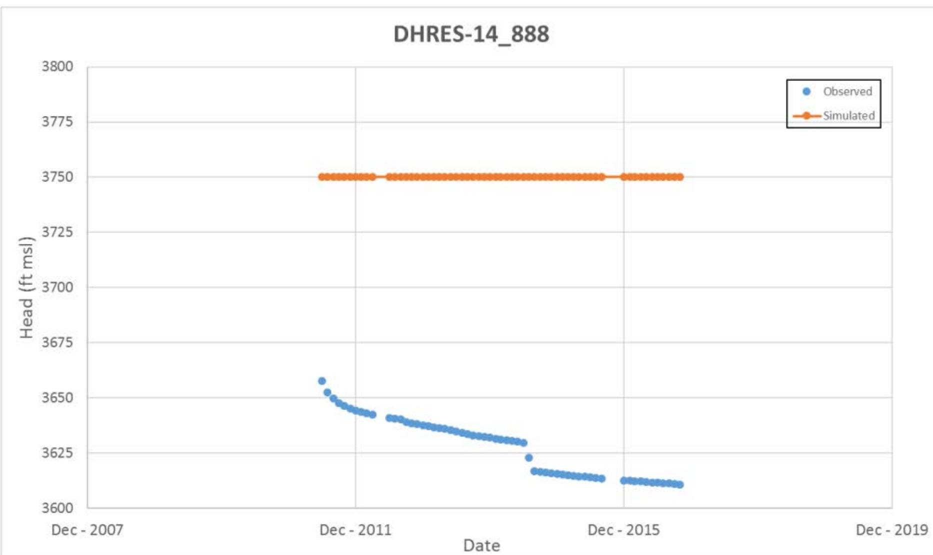

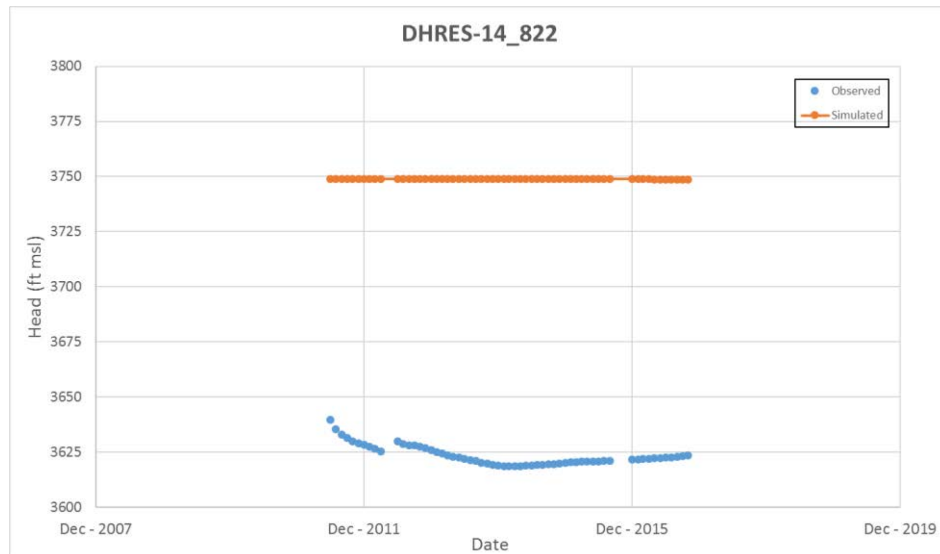

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Model Calibration Hydrographs

PROJECT:	Regional Groundwater Model	FIGURE #:	Appendix C
CLIENT:	Resolution Copper	PROJECT #:	31400680
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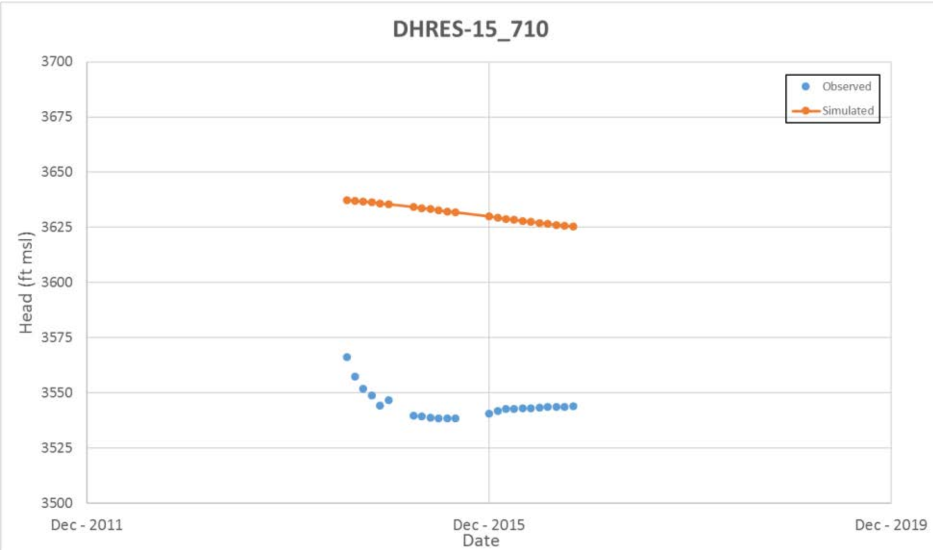

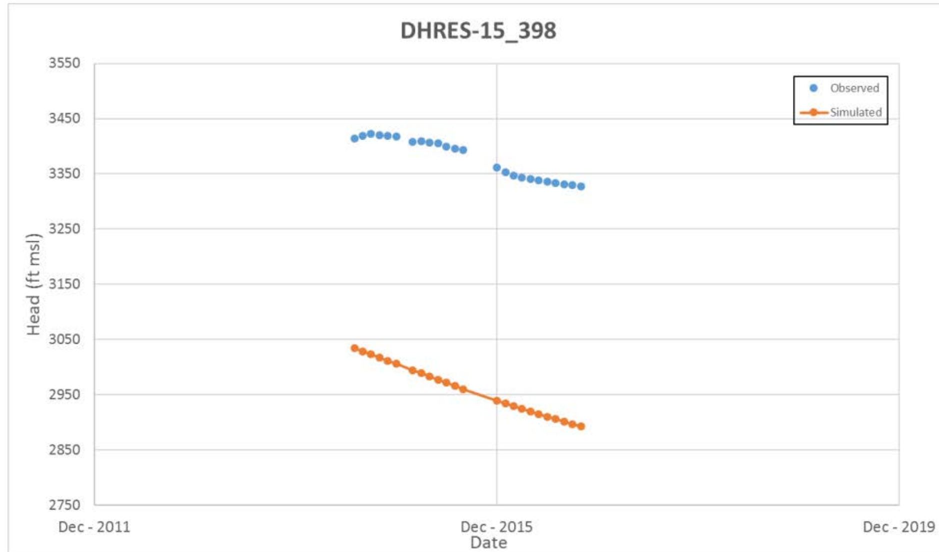

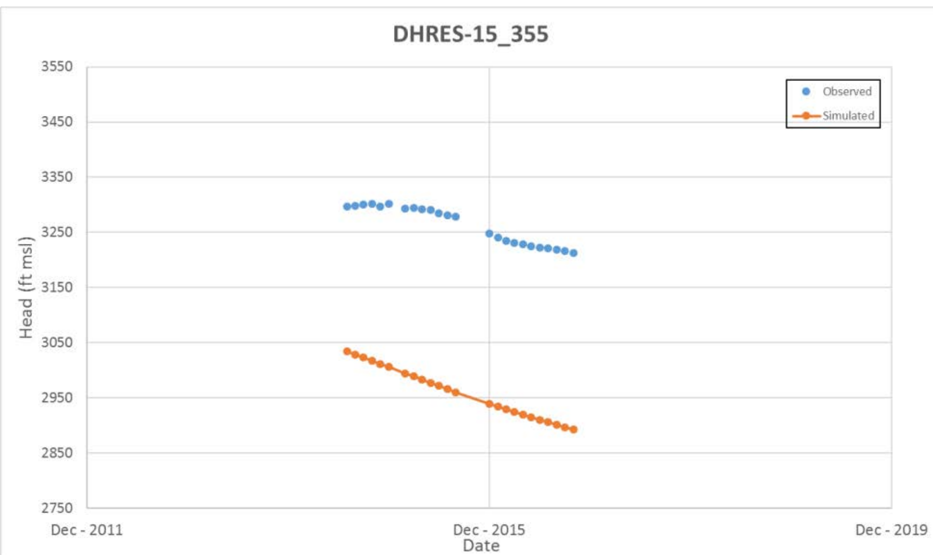

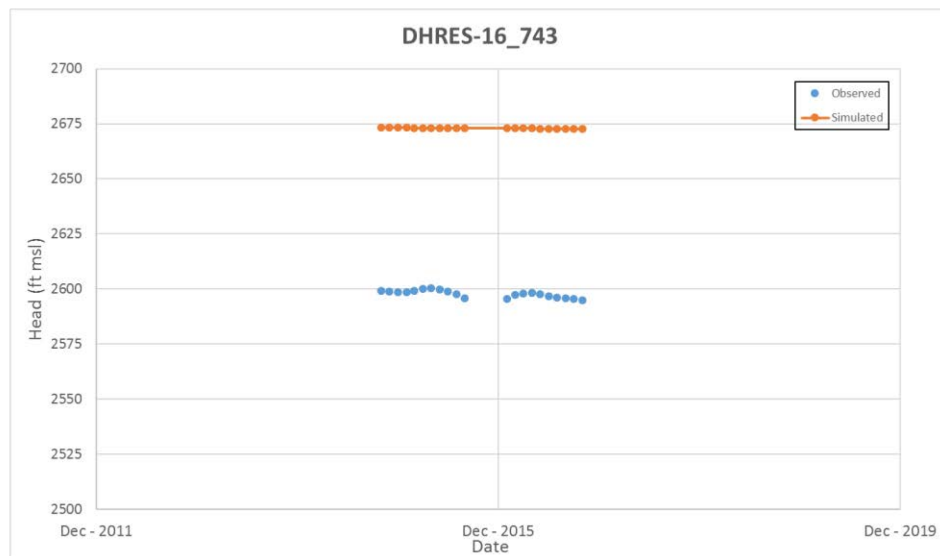

Model Calibration Hydrographs

PROJECT:	Regional Groundwater Model	FIGURE #:	Appendix C
CLIENT:	Resolution Copper	PROJECT #:	31400680
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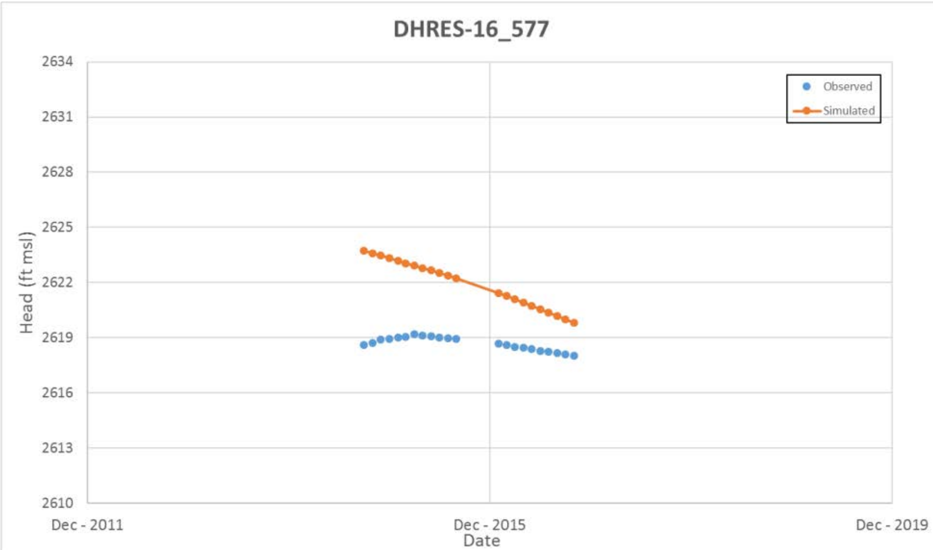

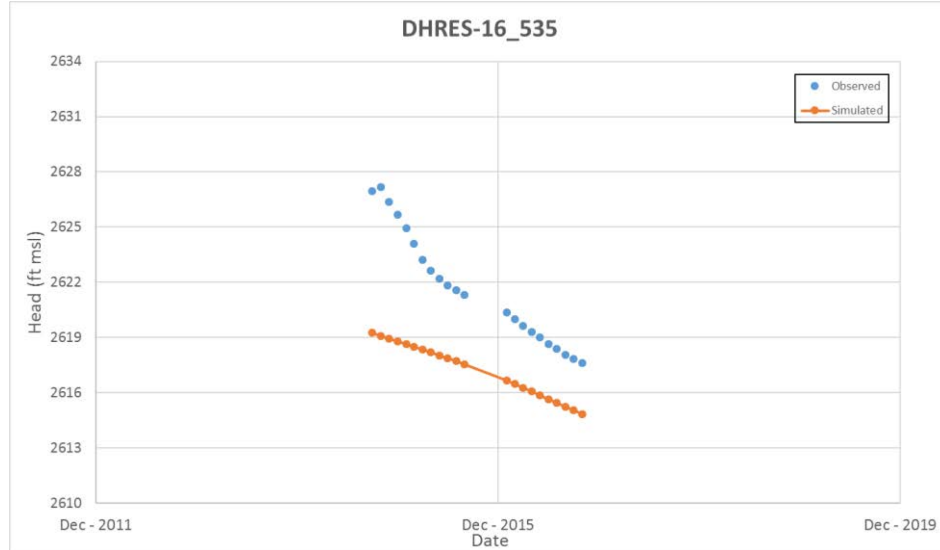

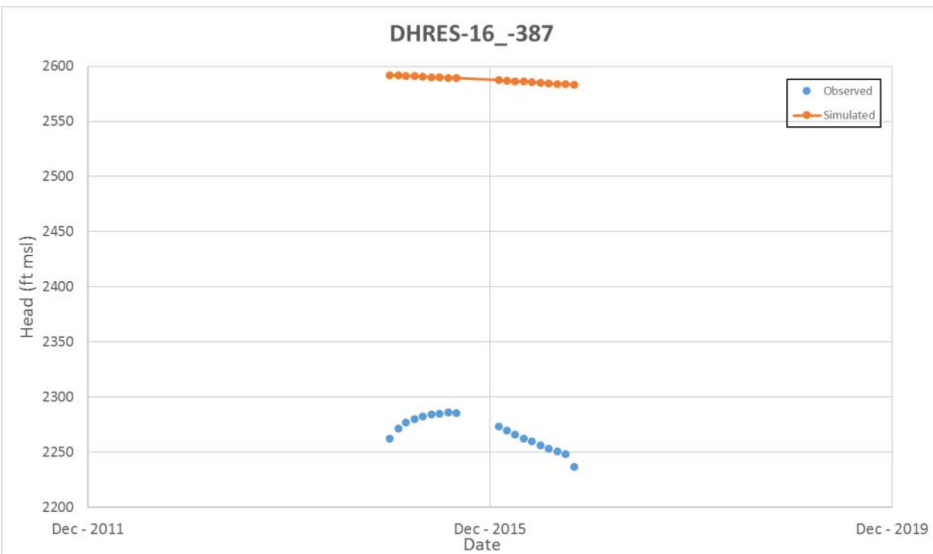

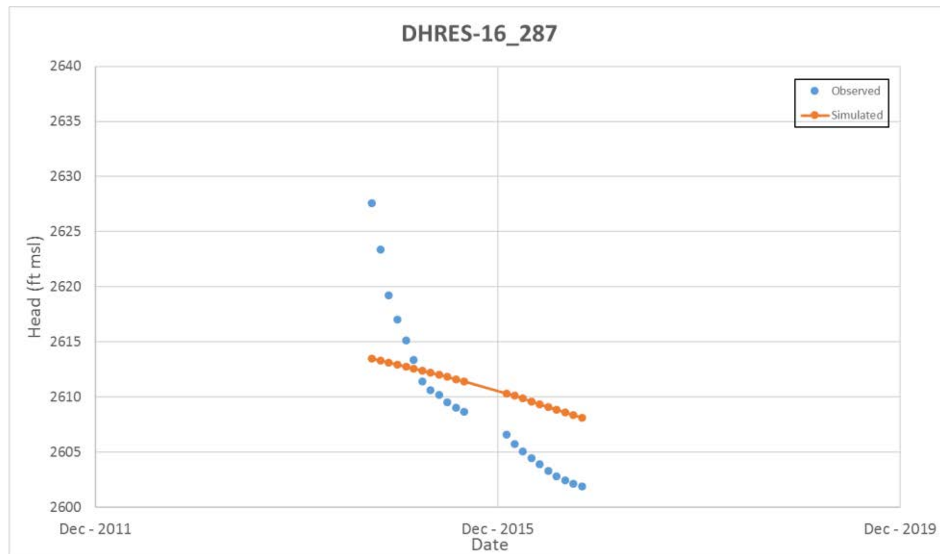

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Model Calibration Hydrographs

PROJECT: Regional Groundwater Model		FIGURE #:	Appendix C
CLIENT: Resolution Copper		PROJECT #:	31400680
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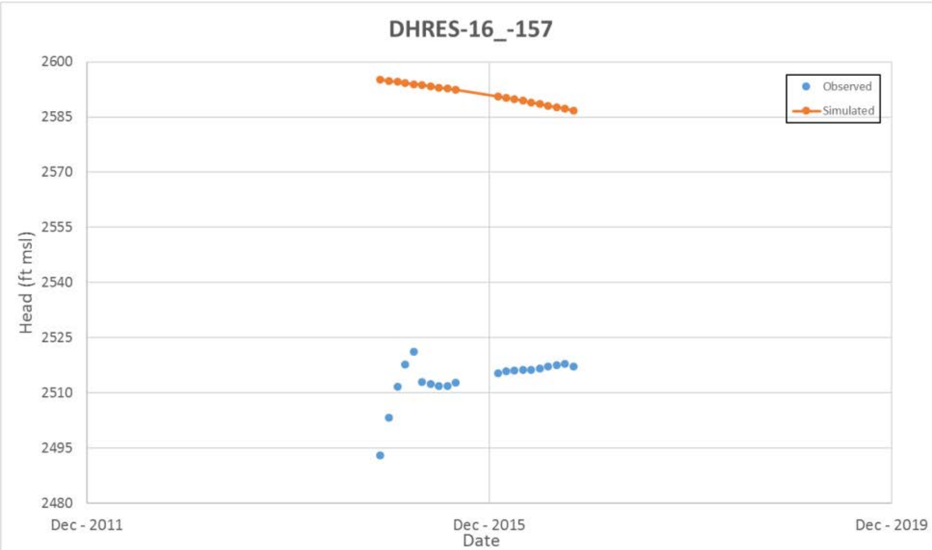

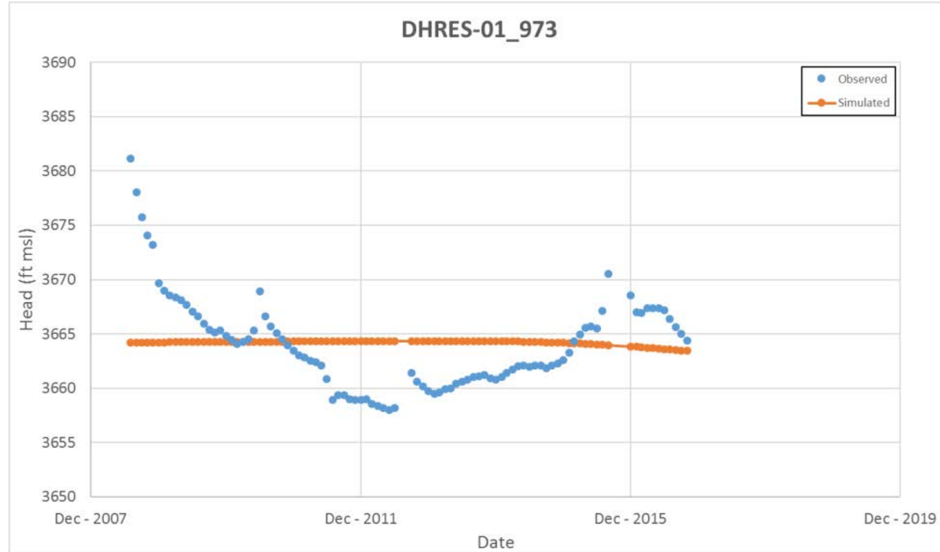

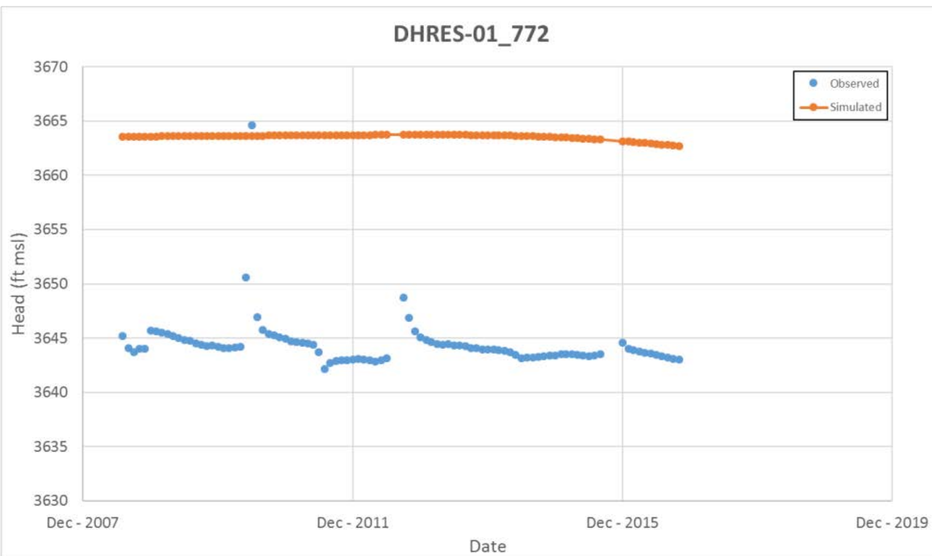

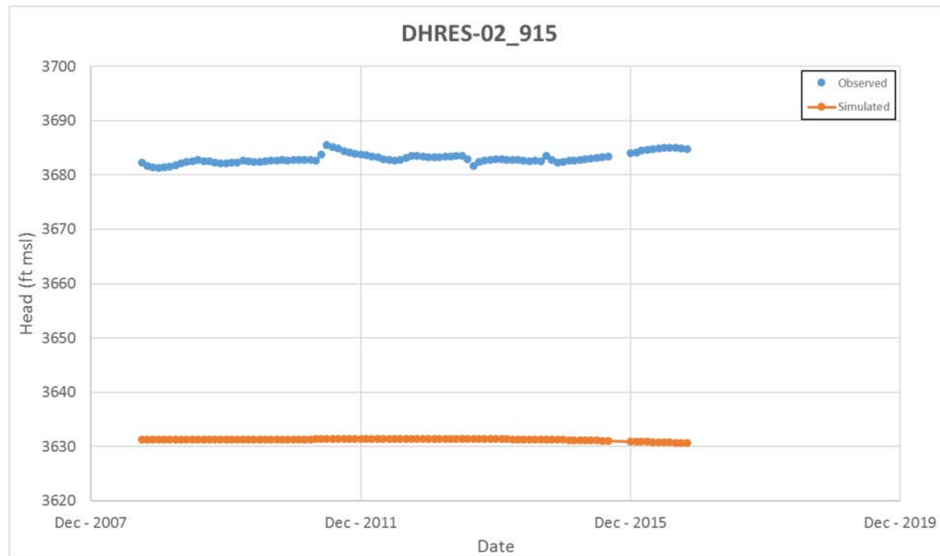

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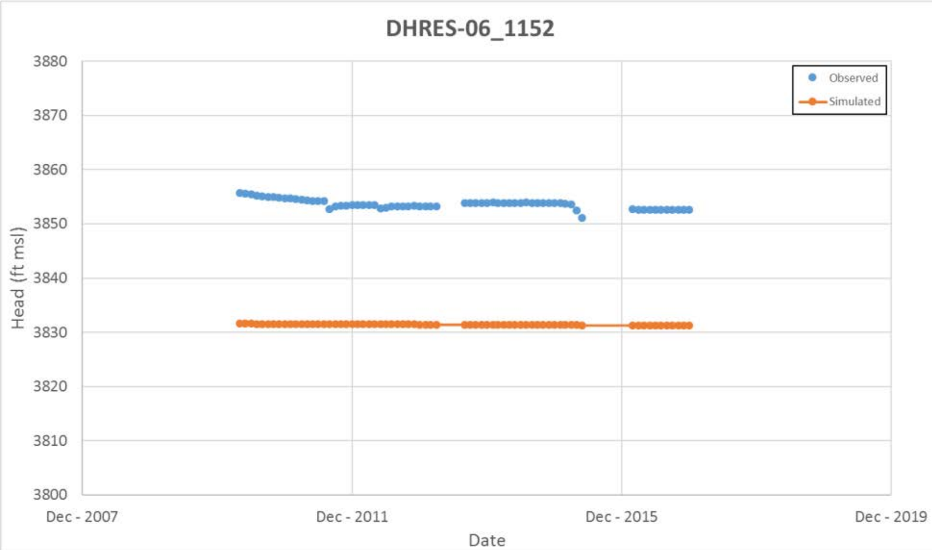
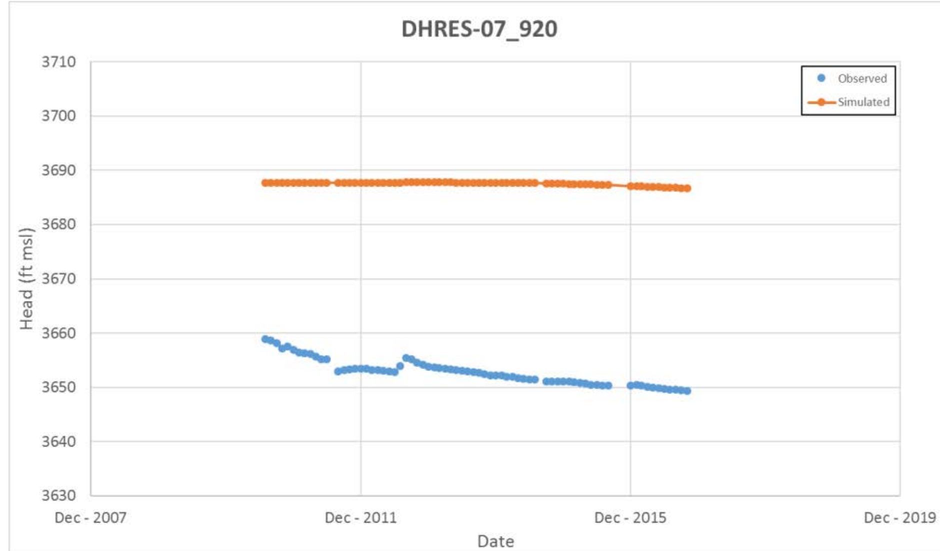
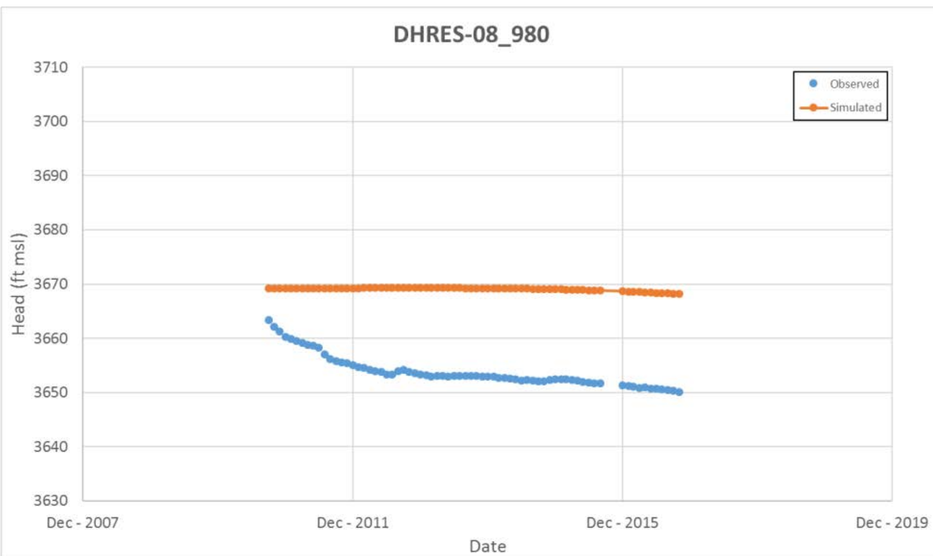
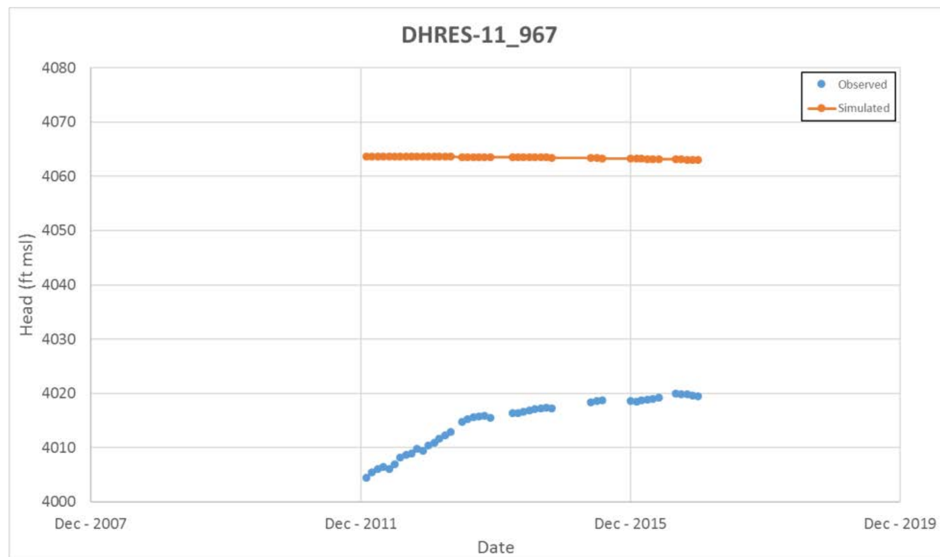
Model Calibration Hydrographs

PROJECT: Regional Groundwater Model		FIGURE #:	Appendix C
CLIENT: Resolution Copper		PROJECT #:	31400680
DRAWN: CP	CHECKED: DO	DATE:	January 2019









Model Calibration Hydrographs

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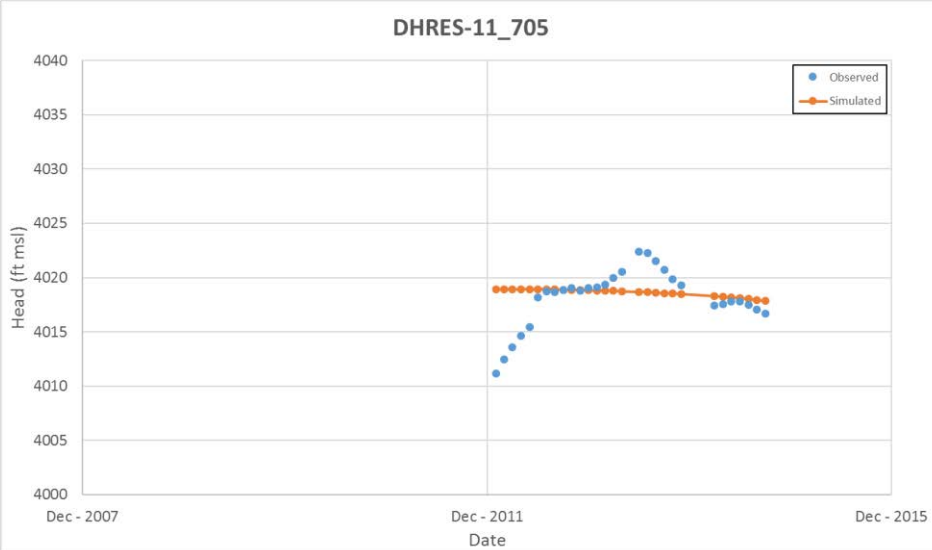
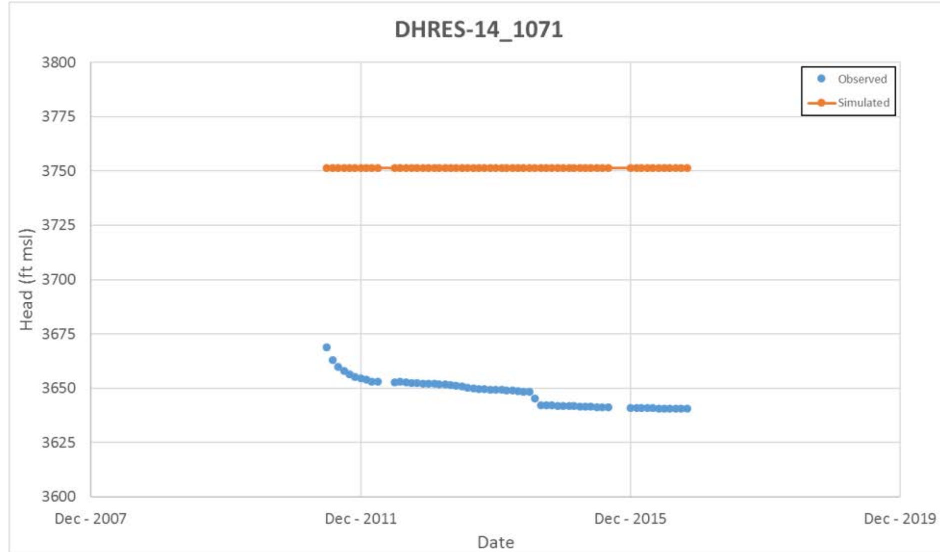
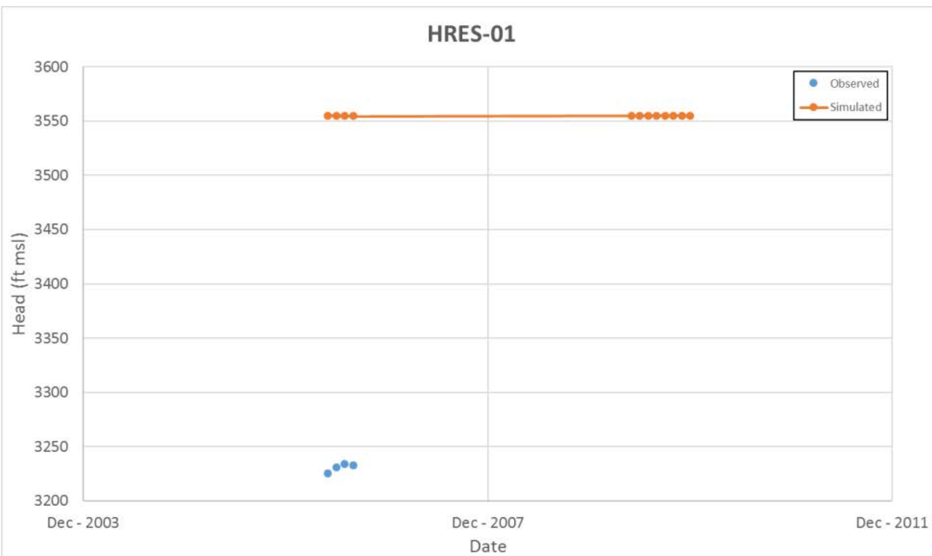
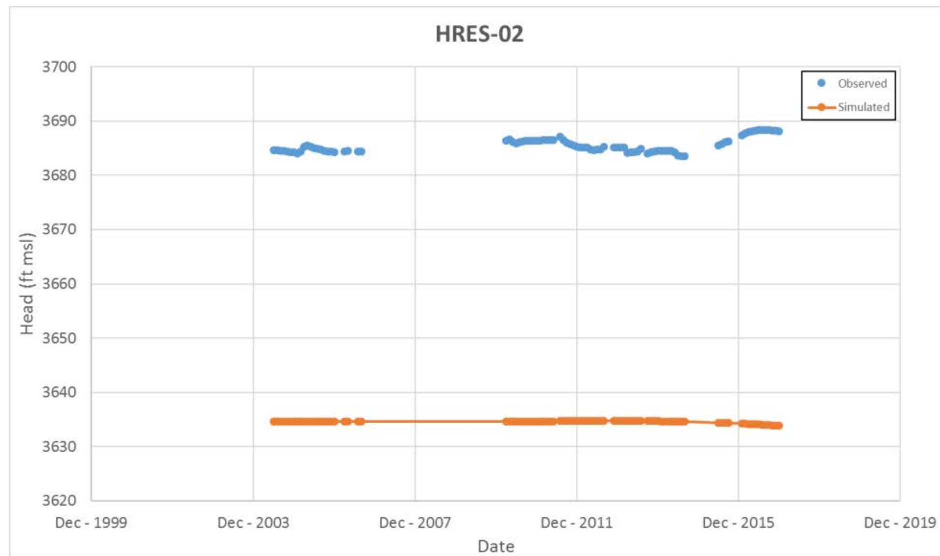
CLIENT: Resolution Copper		PROJECT #: 31400680	
DRAWN: CP	CHECKED: DO	DATE: January 2019	









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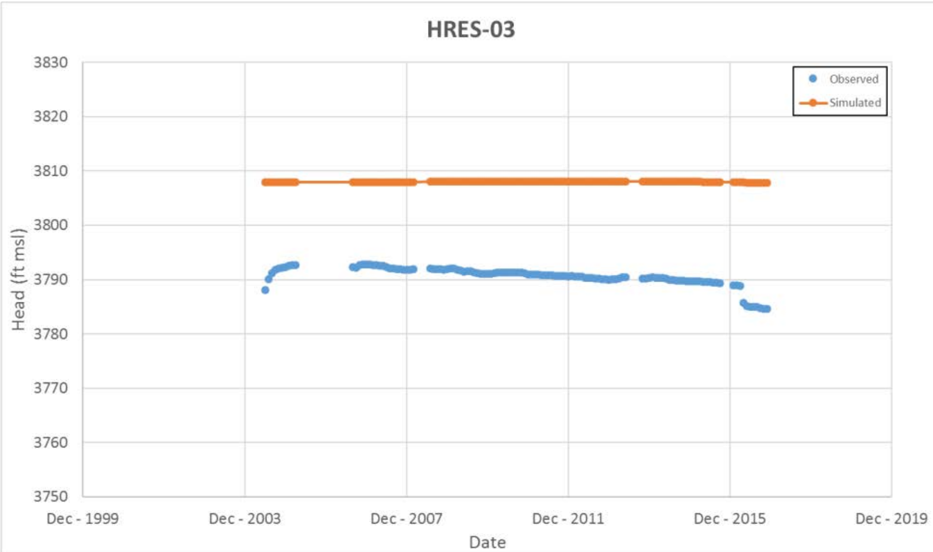
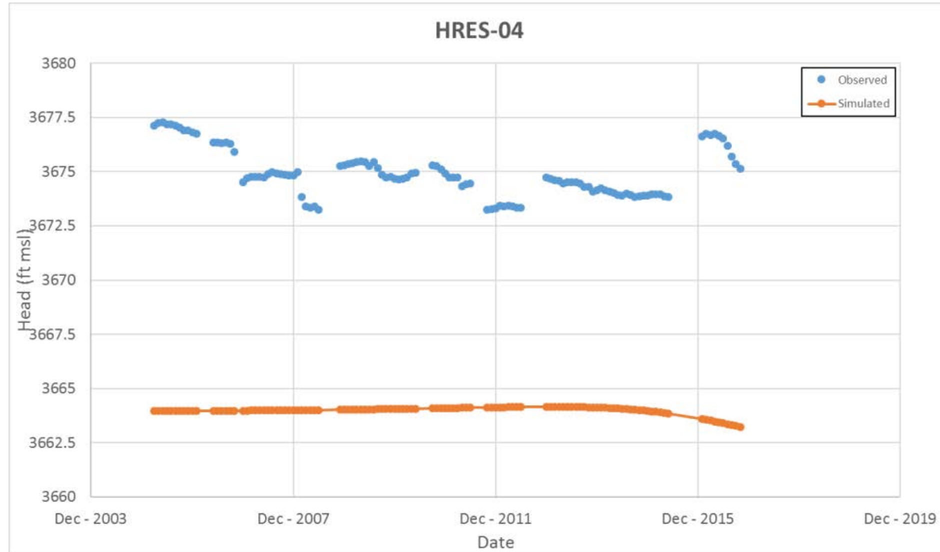
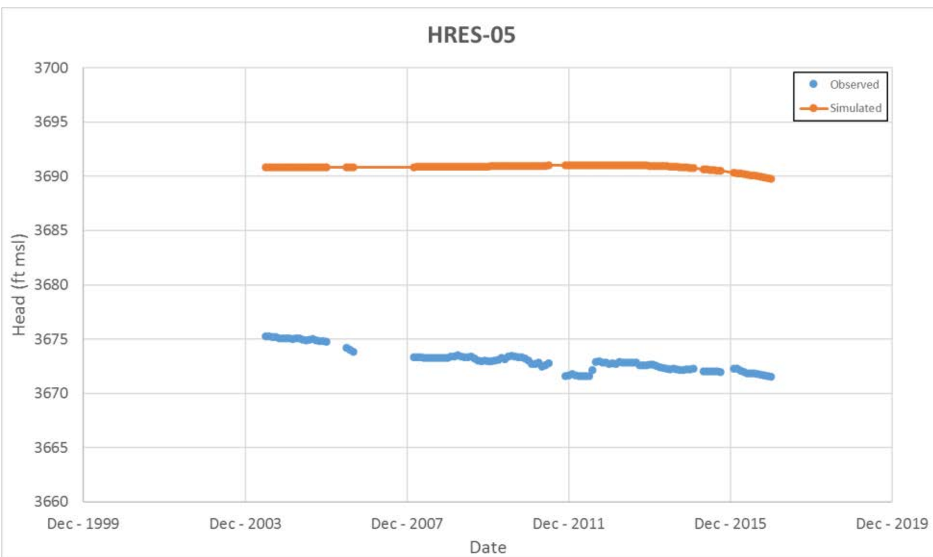
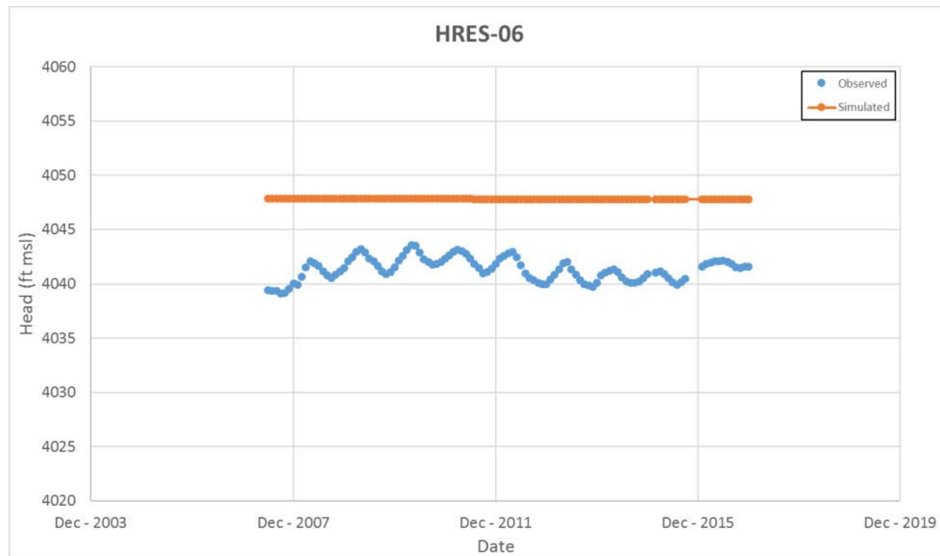
Model Calibration Hydrographs

PROJECT: Regional Groundwater Model		FIGURE #:	Appendix C
CLIENT: Resolution Copper		PROJECT #:	31400680
DRAWN: CP	CHECKED: DO	DATE:	January 2019



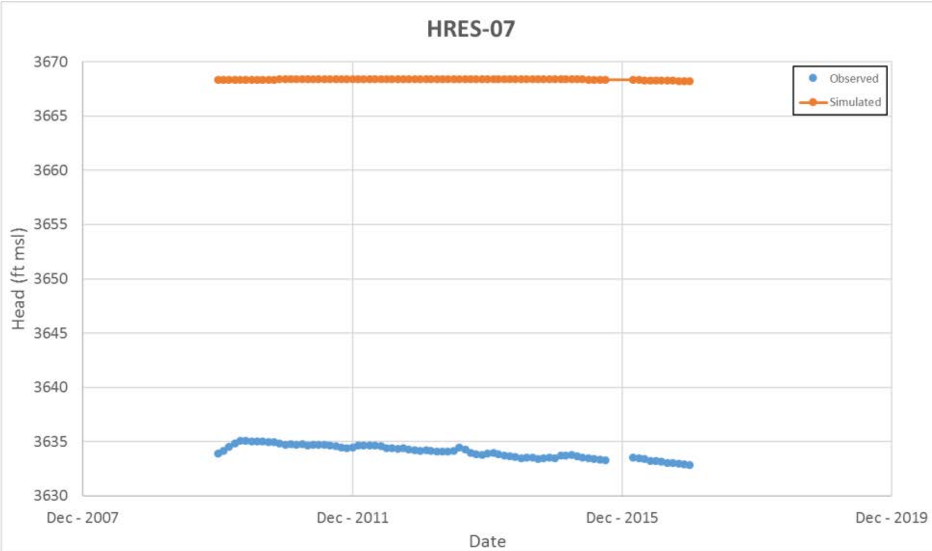


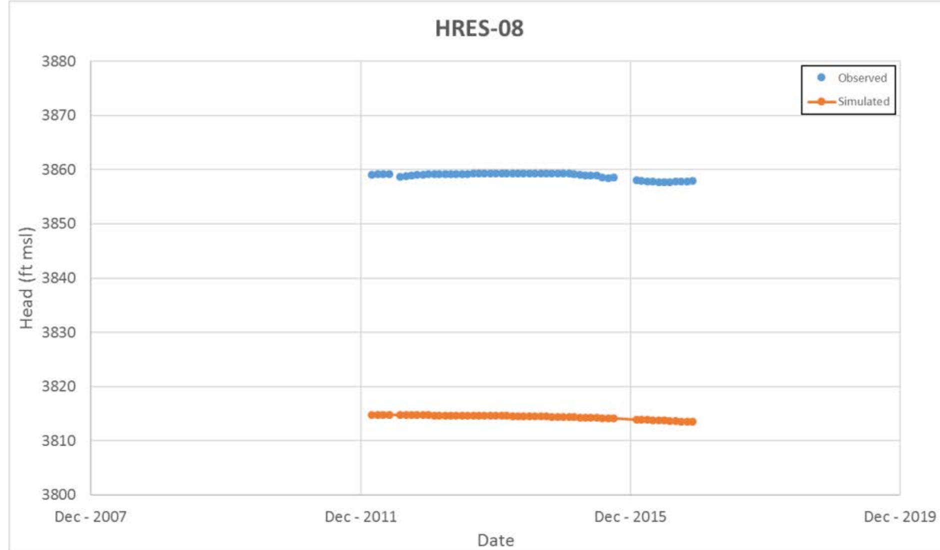


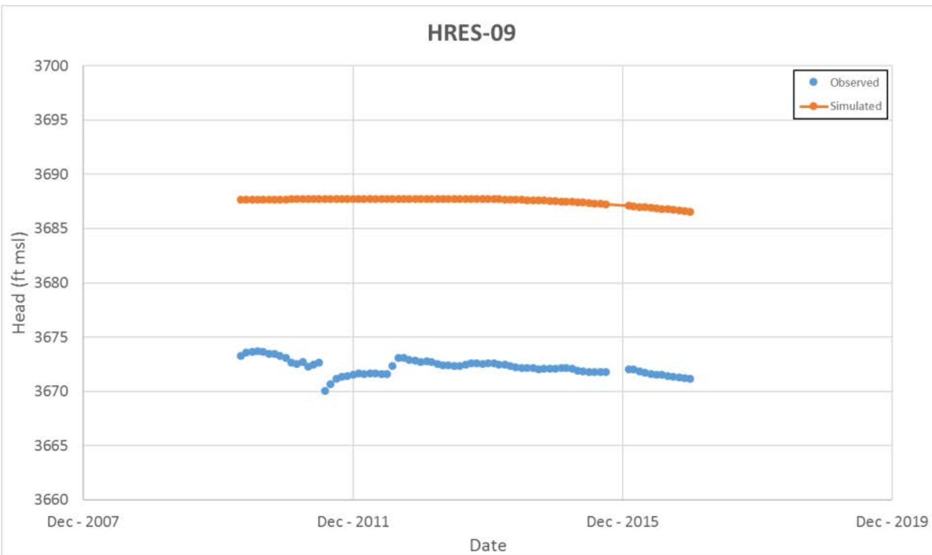


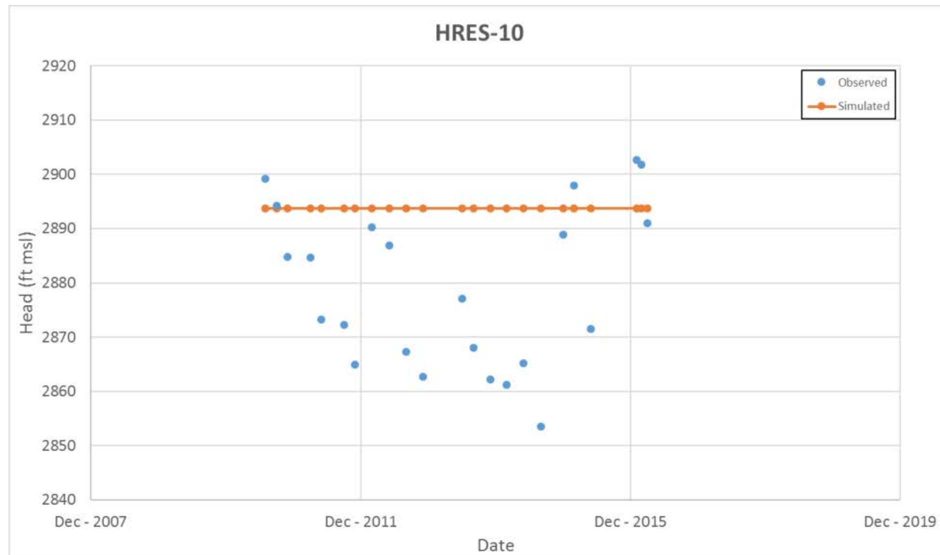
Model Calibration Hydrographs

PROJECT:	Regional Groundwater Model	FIGURE #:	Appendix C
CLIENT:	Resolution Copper	PROJECT #:	31400680
DRAWN: CP	CHECKED: DO	DATE:	January 2019





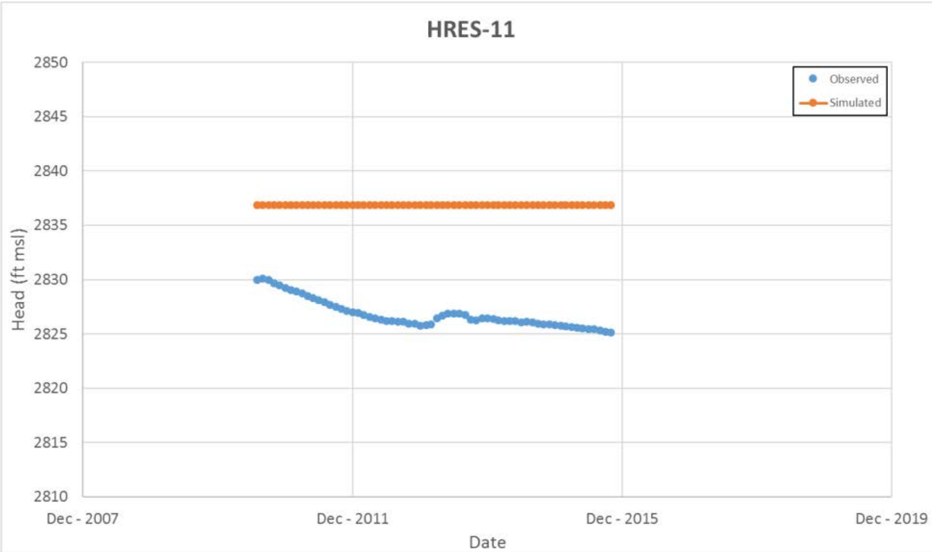


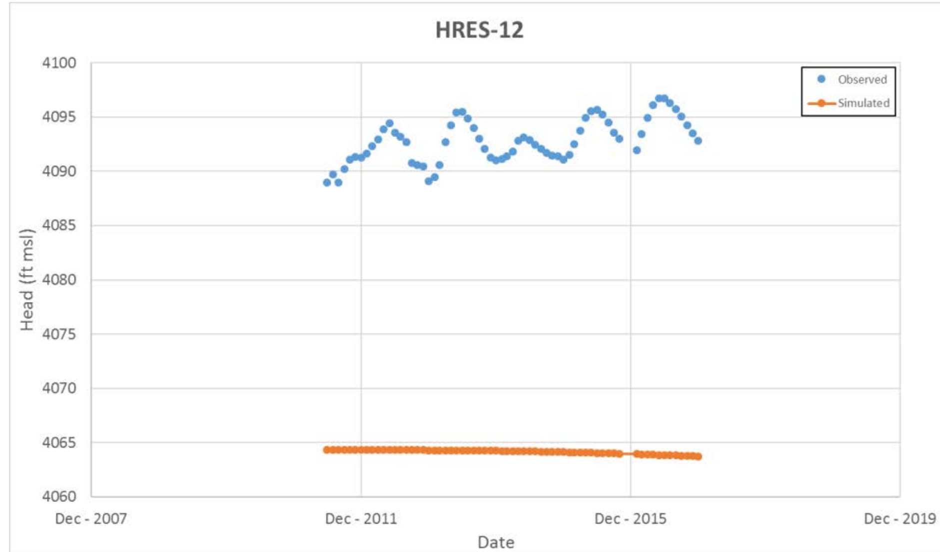


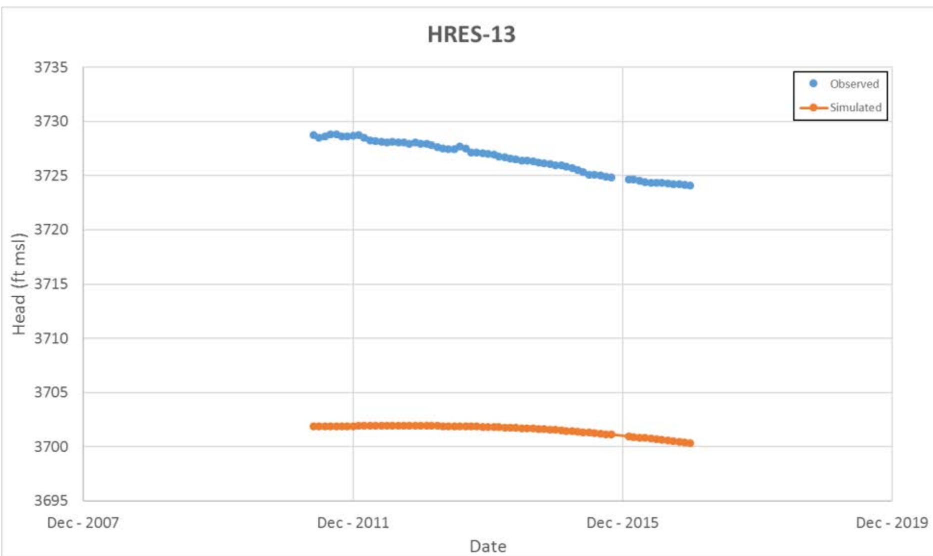
wsp

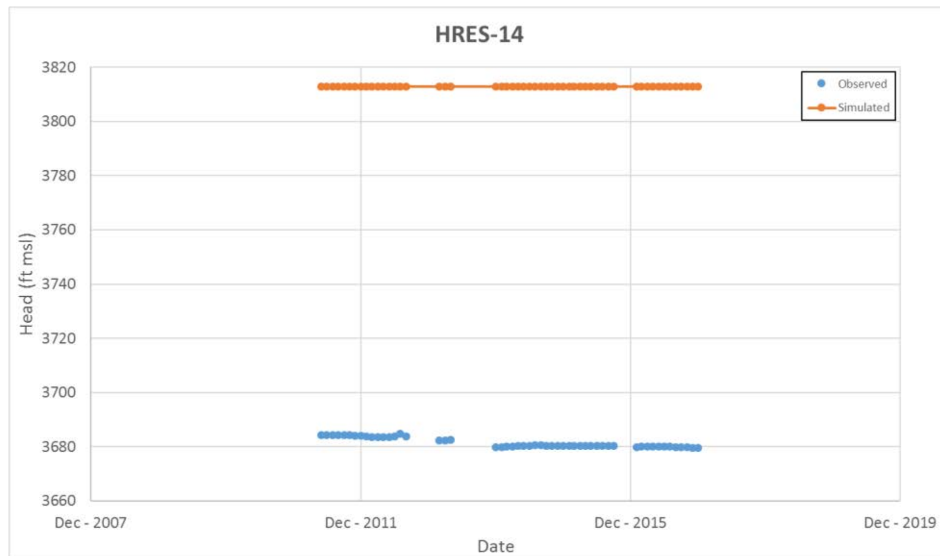
Model Calibration Hydrographs

PROJECT:	Regional Groundwater Model	FIGURE #:	Appendix C
CLIENT:	Resolution Copper	PROJECT #:	31400680
DRAWN: CP	CHECKED: DO	DATE:	January 2019



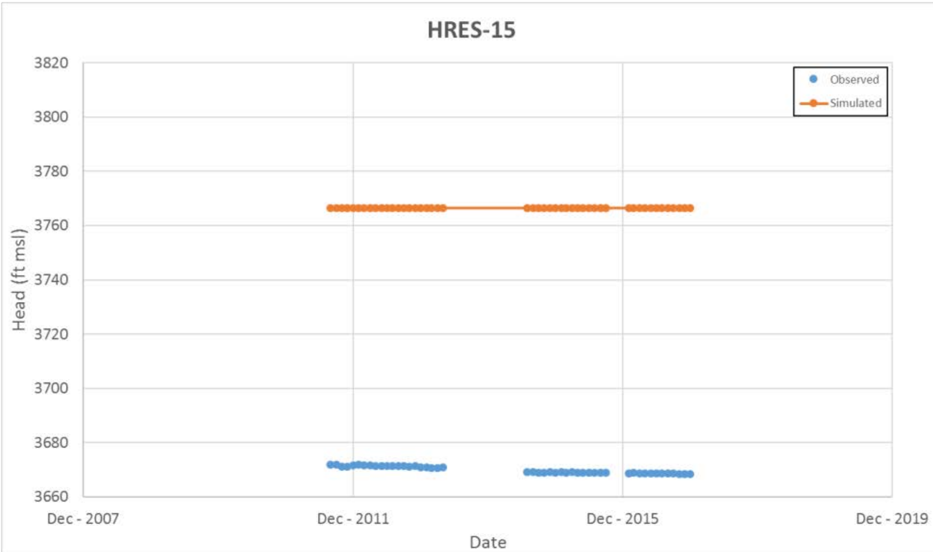


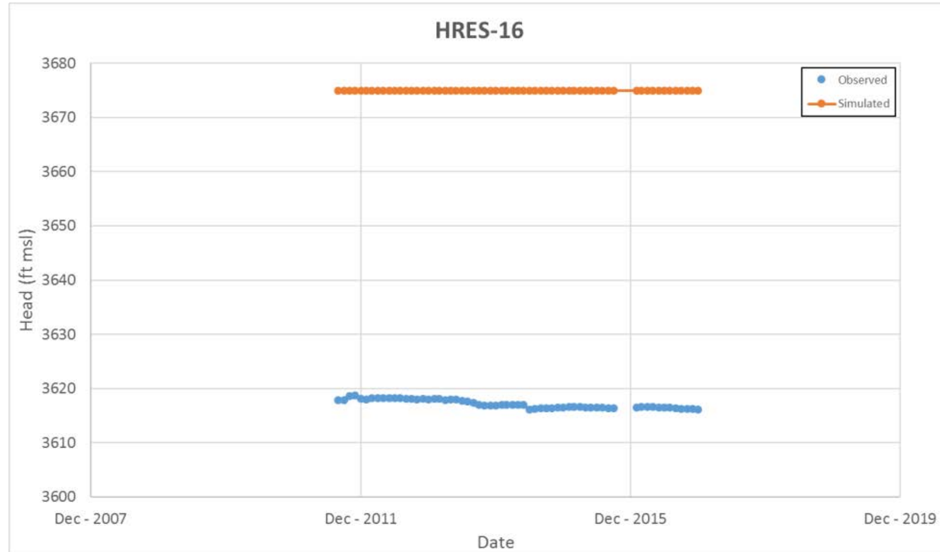


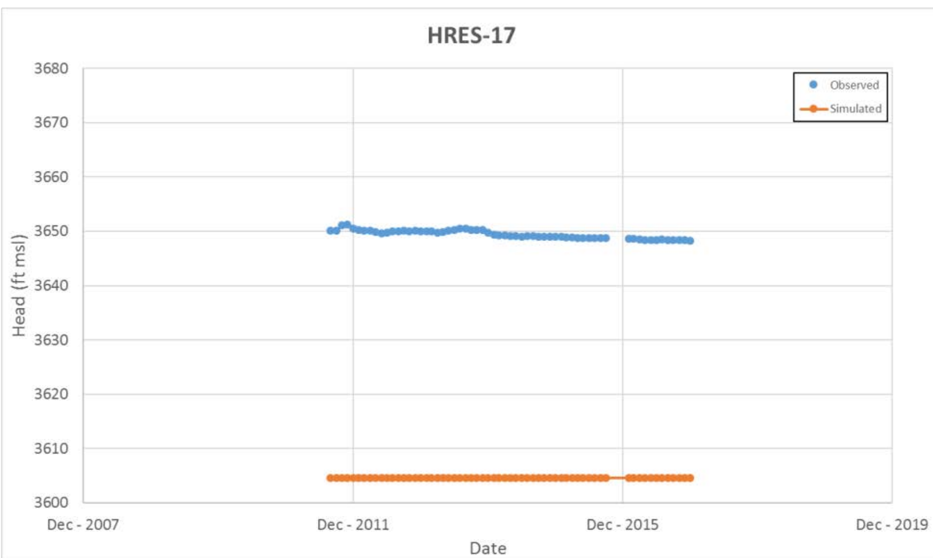


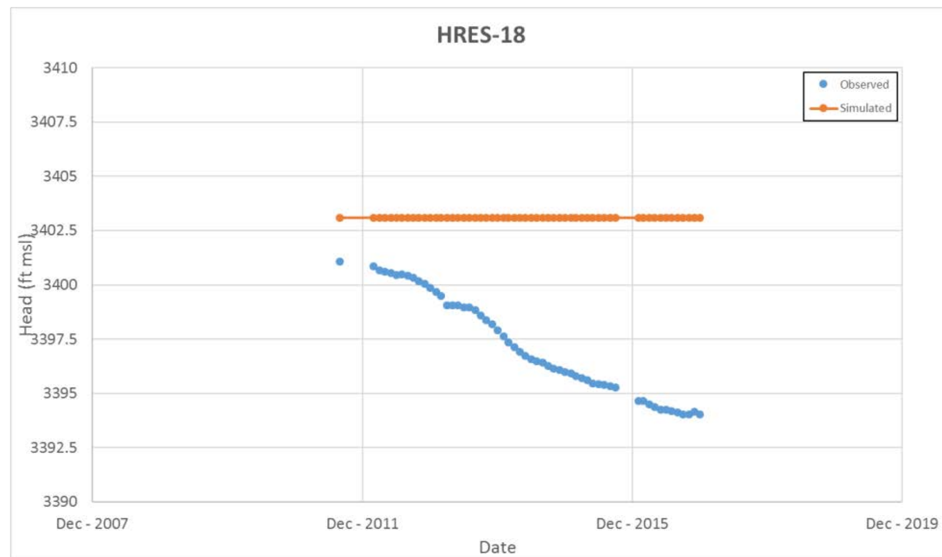
Model Calibration Hydrographs

PROJECT: Regional Groundwater Model		FIGURE #:	Appendix C
CLIENT: Resolution Copper		PROJECT #:	31400680
DRAWN: CP	CHECKED: DO	DATE:	January 2019





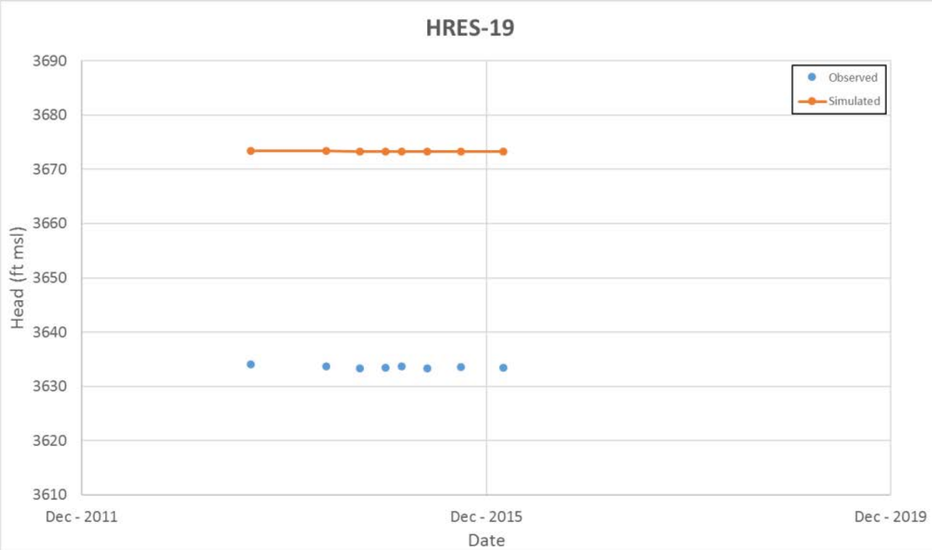


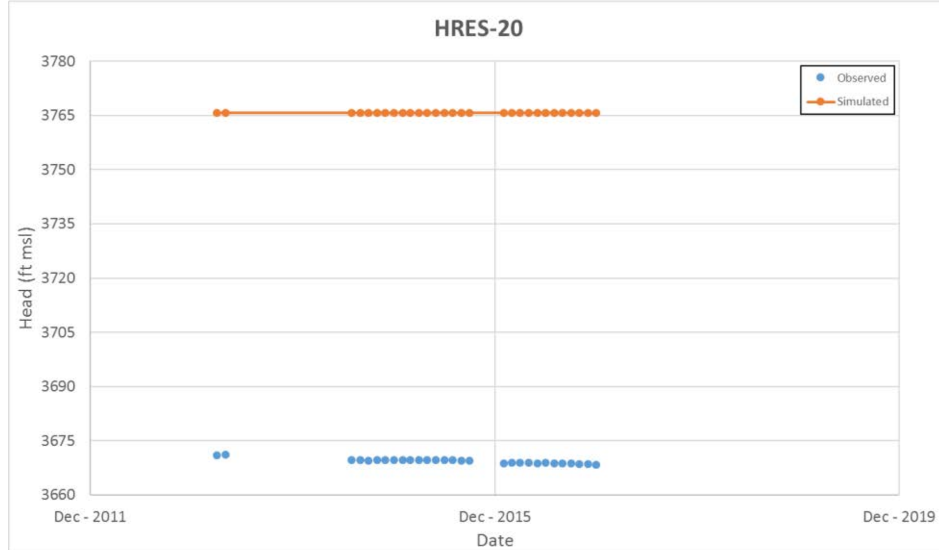


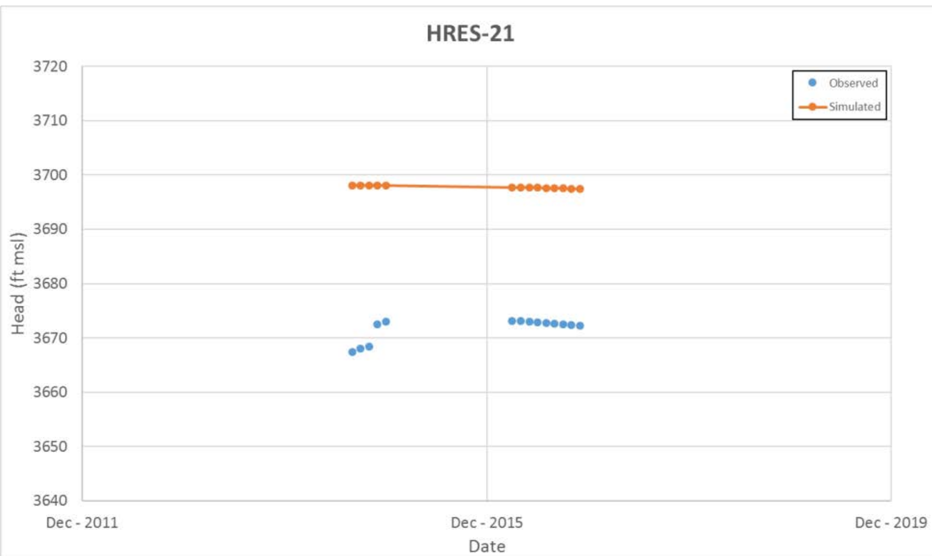
wsp

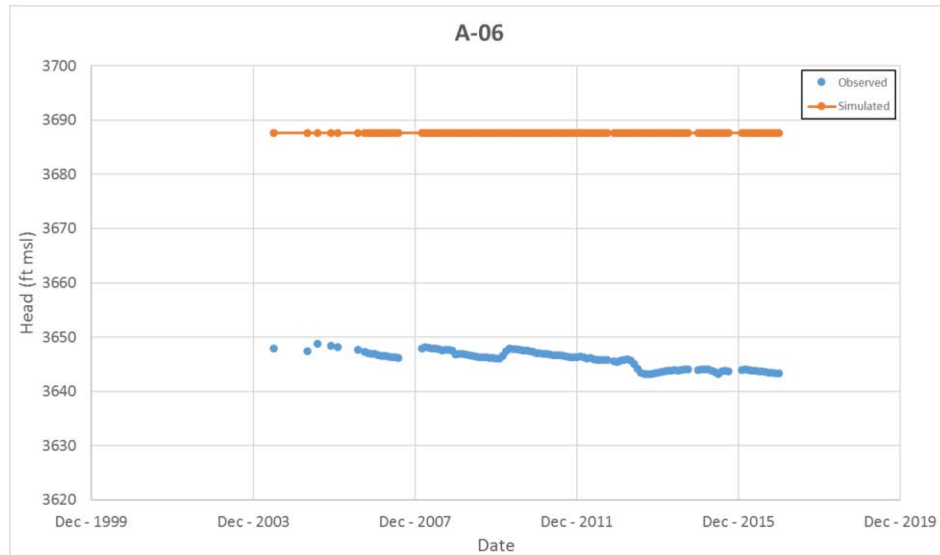
Model Calibration Hydrographs

PROJECT:	Regional Groundwater Model	FIGURE #:	Appendix C
CLIENT:	Resolution Copper	PROJECT #:	31400680
DRAWN: CP	CHECKED: DO	DATE:	January 2019



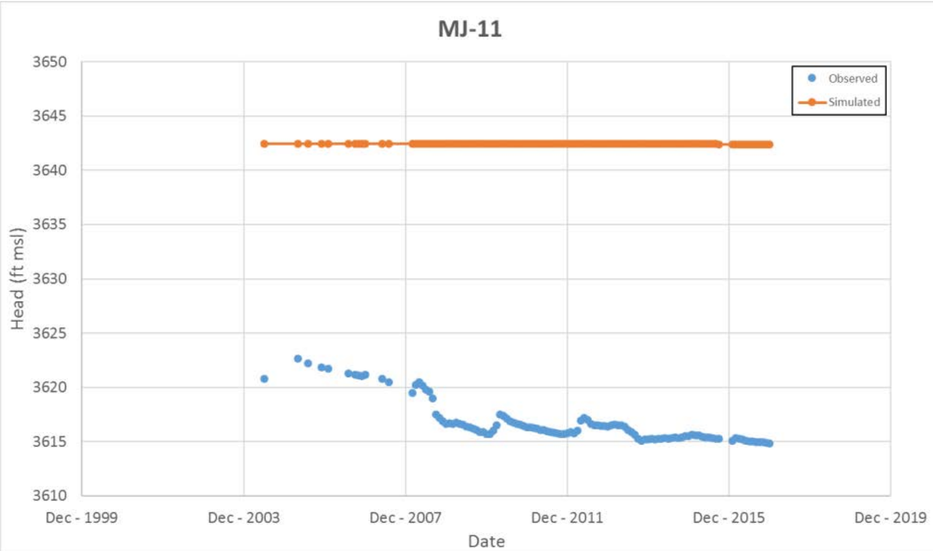


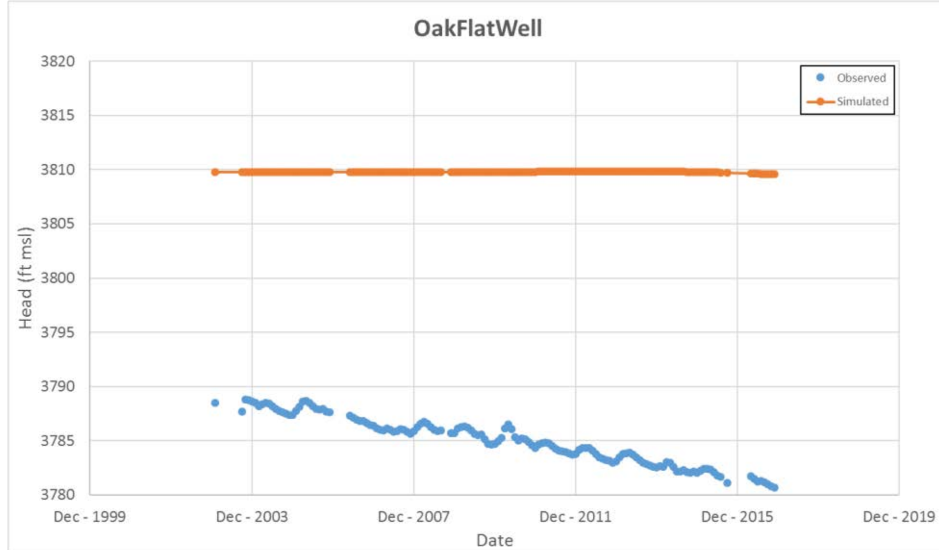


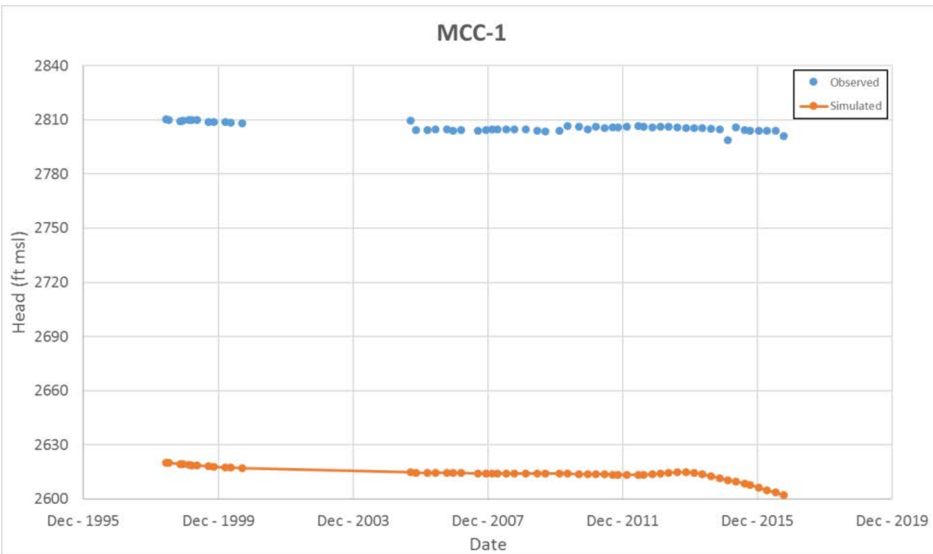


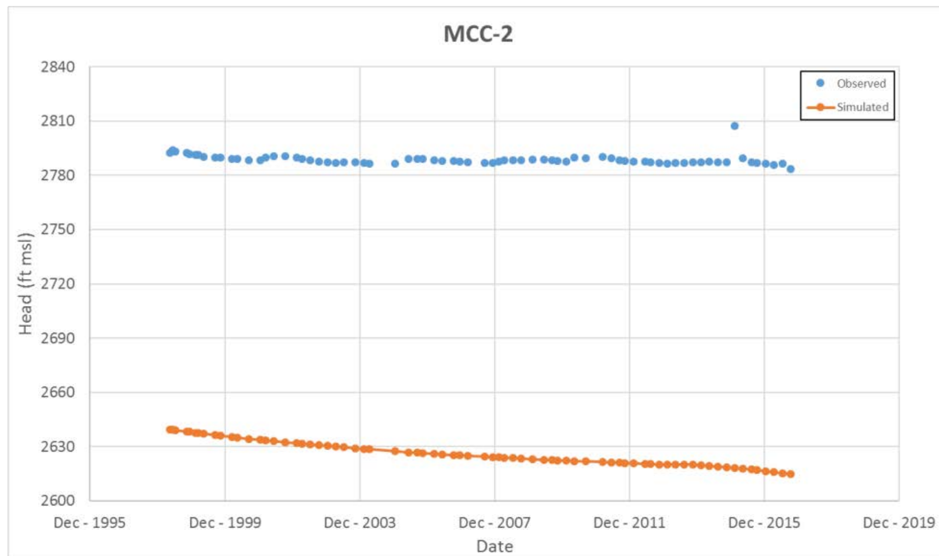
Model Calibration Hydrographs

PROJECT:	Regional Groundwater Model	FIGURE #:	Appendix C
CLIENT:	Resolution Copper	PROJECT #:	31400680
DRAWN: CP	CHECKED: DO	DATE:	January 2019





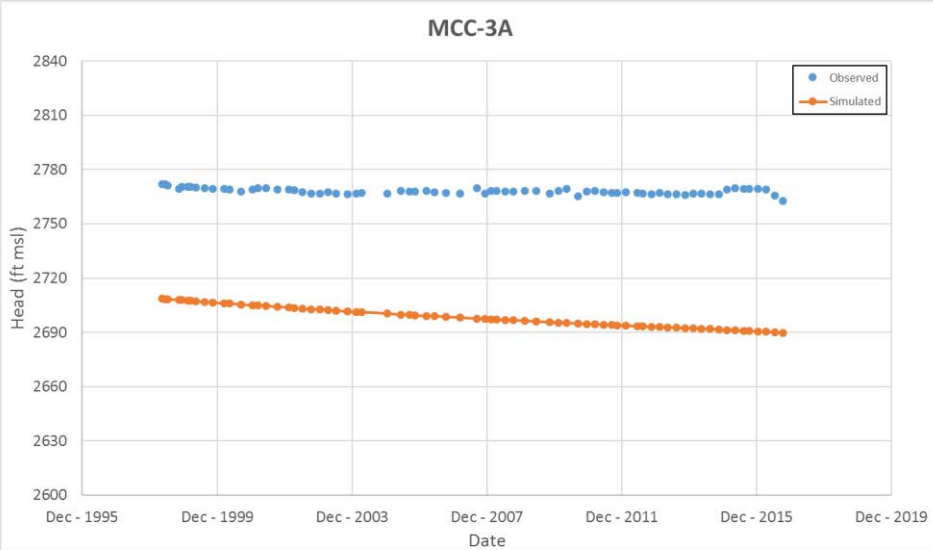


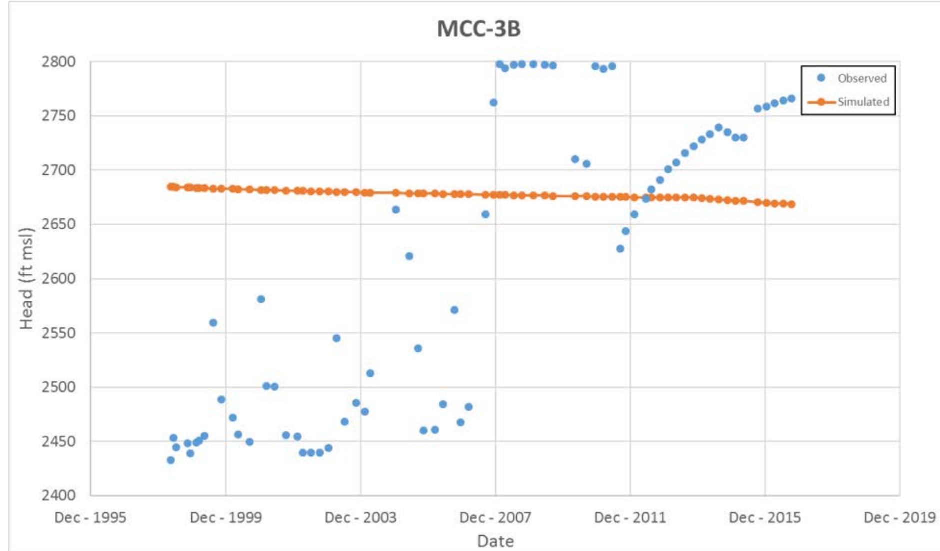


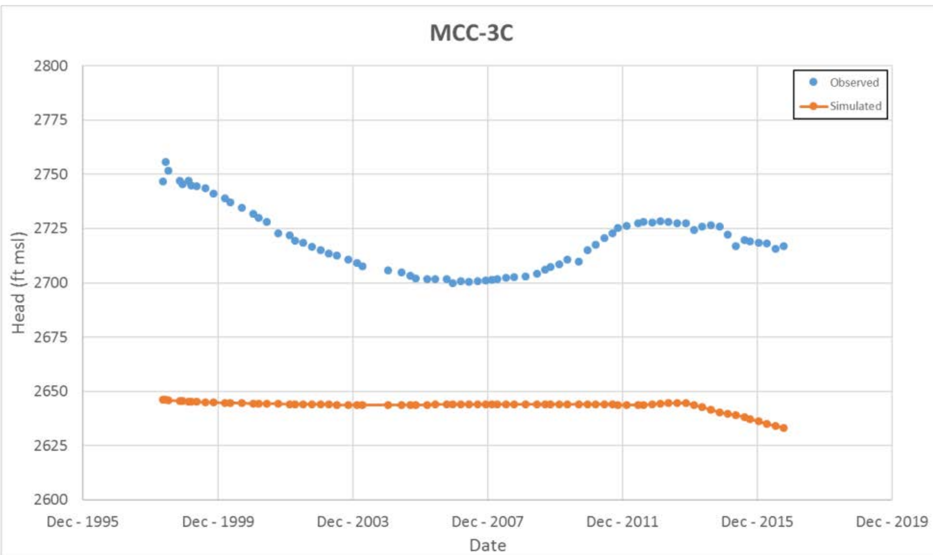
wsp

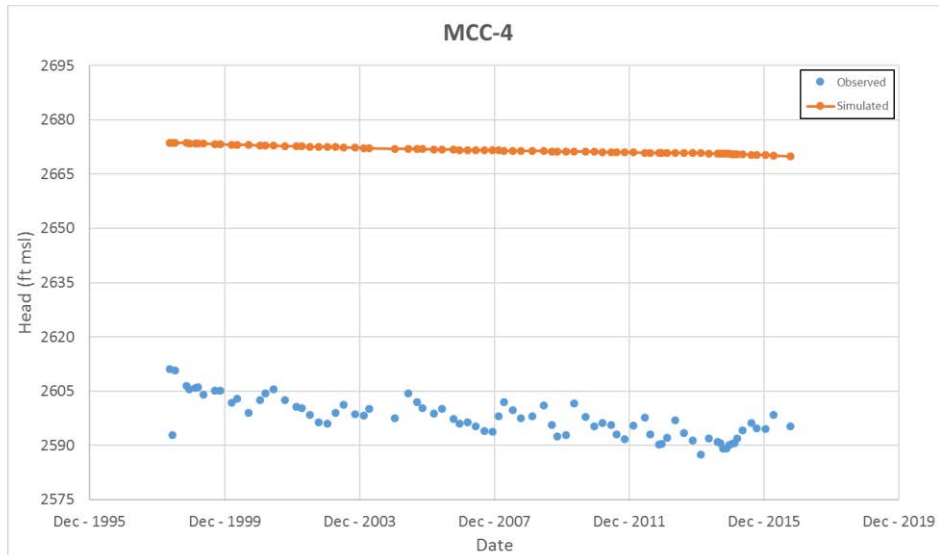
Model Calibration Hydrographs

PROJECT: Regional Groundwater Model		FIGURE #:	Appendix C
CLIENT: Resolution Copper		PROJECT #:	31400680
DRAWN: CP	CHECKED: DO	DATE:	January 2019









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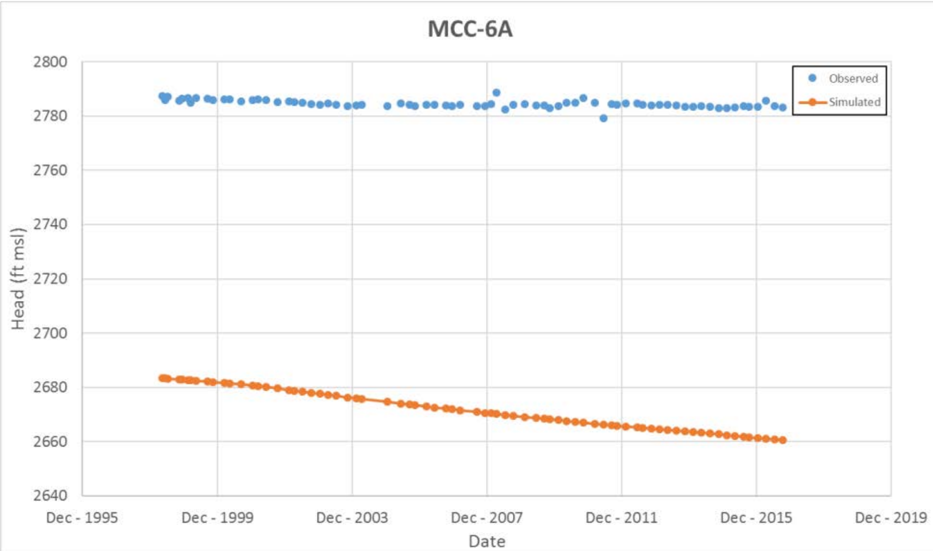
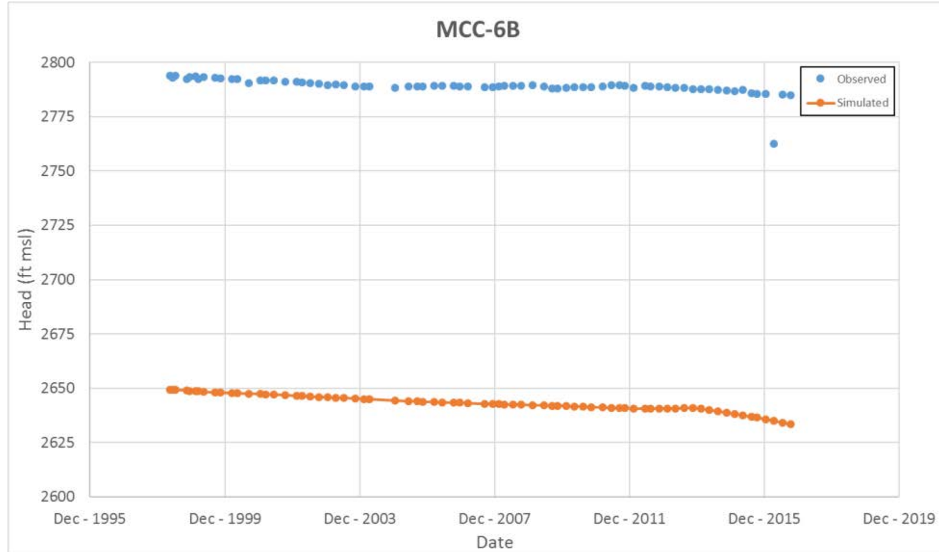
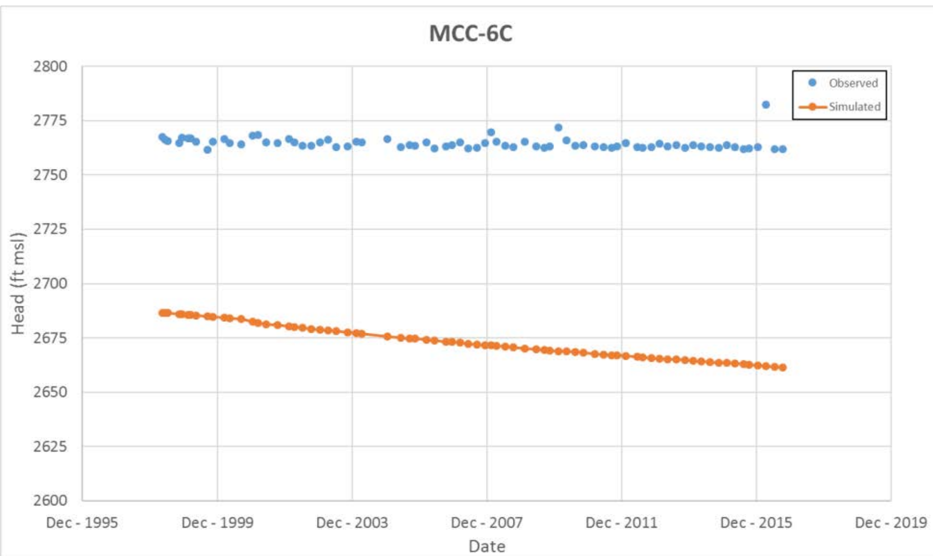
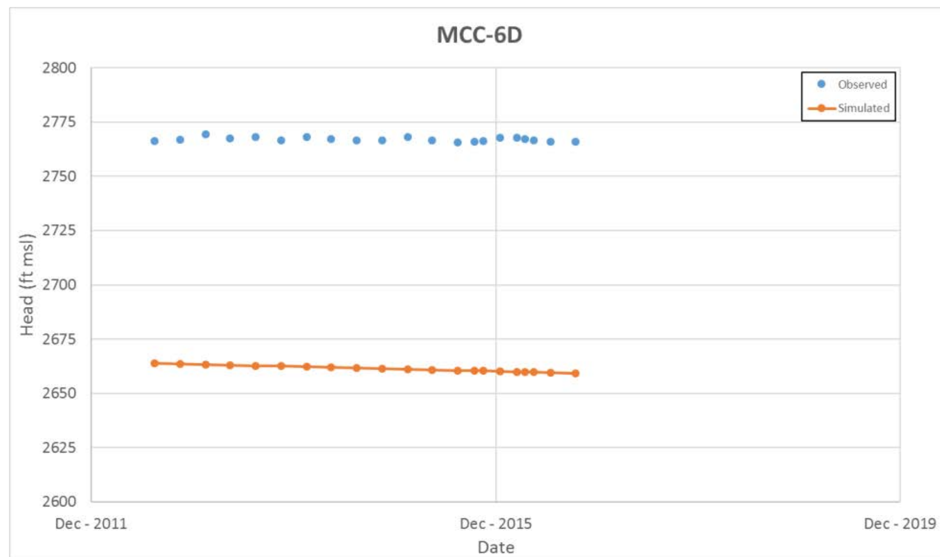
Model Calibration Hydrographs

PROJECT:	Regional Groundwater Model	FIGURE #:	Appendix C
CLIENT:	Resolution Copper	PROJECT #:	31400680
DRAWN: CP	CHECKED: DO	DATE:	January 2019



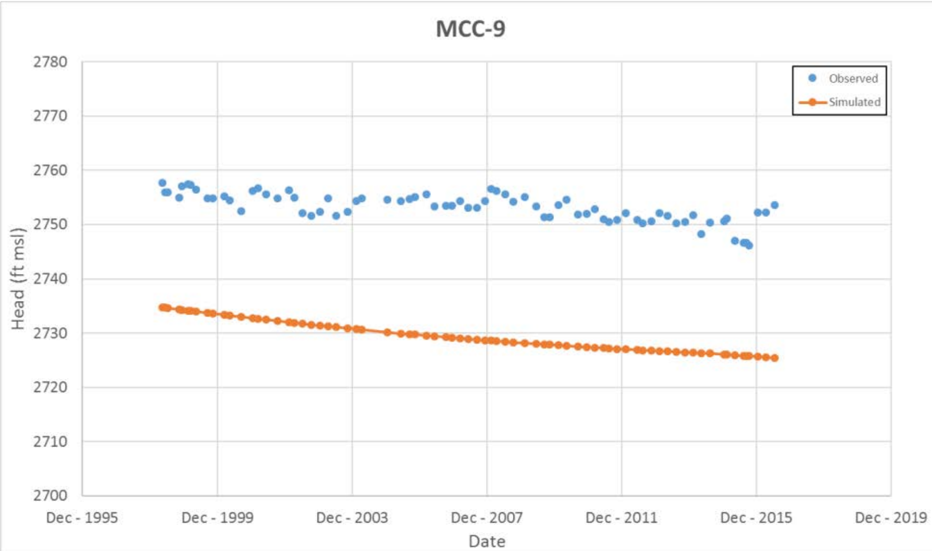


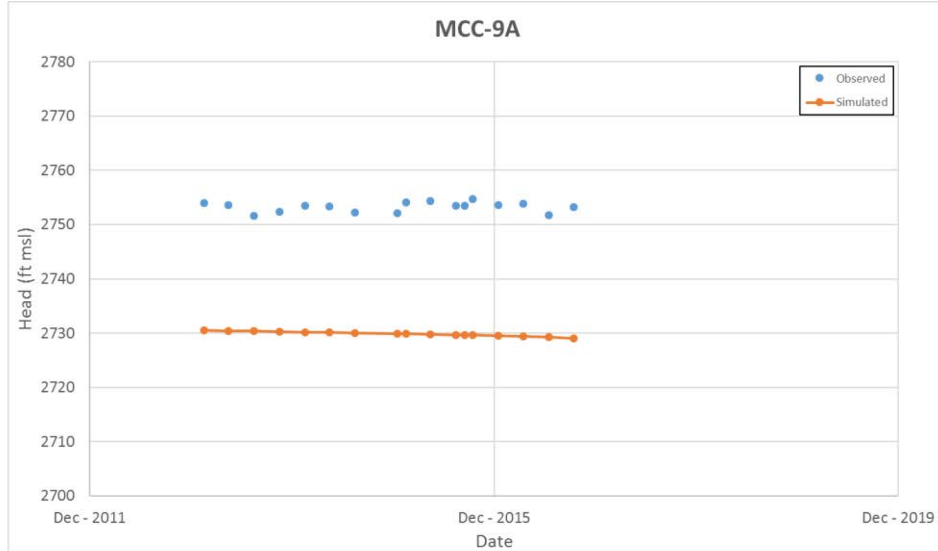




Model Calibration Hydrographs

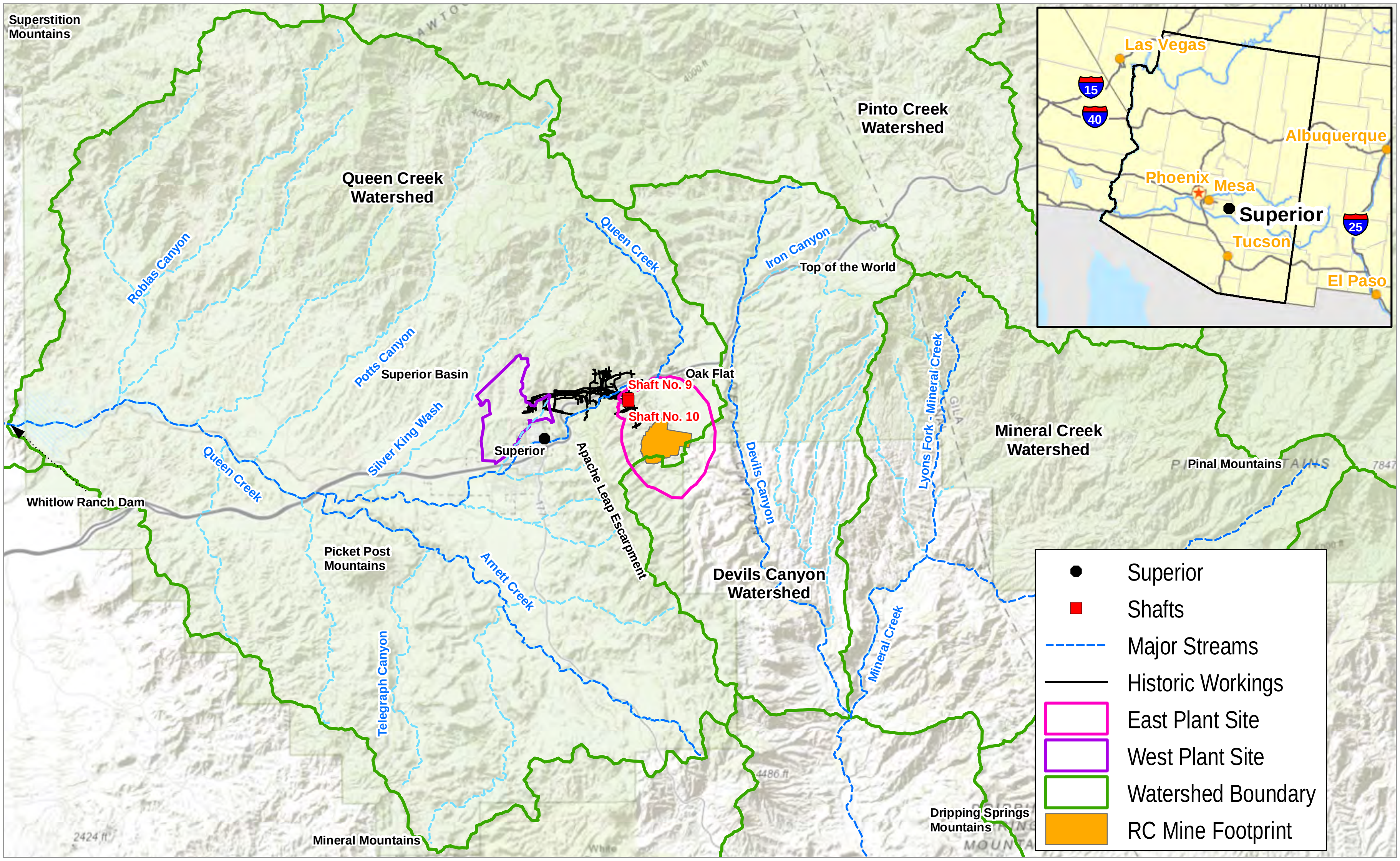
PROJECT:	Regional Groundwater Model	FIGURE #:	Appendix C
CLIENT:	Resolution Copper	PROJECT #:	31400680
DRAWN: CP	CHECKED: DO	DATE:	January 2019





Model Calibration Hydrographs

PROJECT:	Regional Groundwater Model	FIGURE #:	Appendix C
CLIENT:	Resolution Copper	PROJECT #:	31400680
DRAWN: CP	CHECKED: DO	DATE:	January 2019



1:180,000

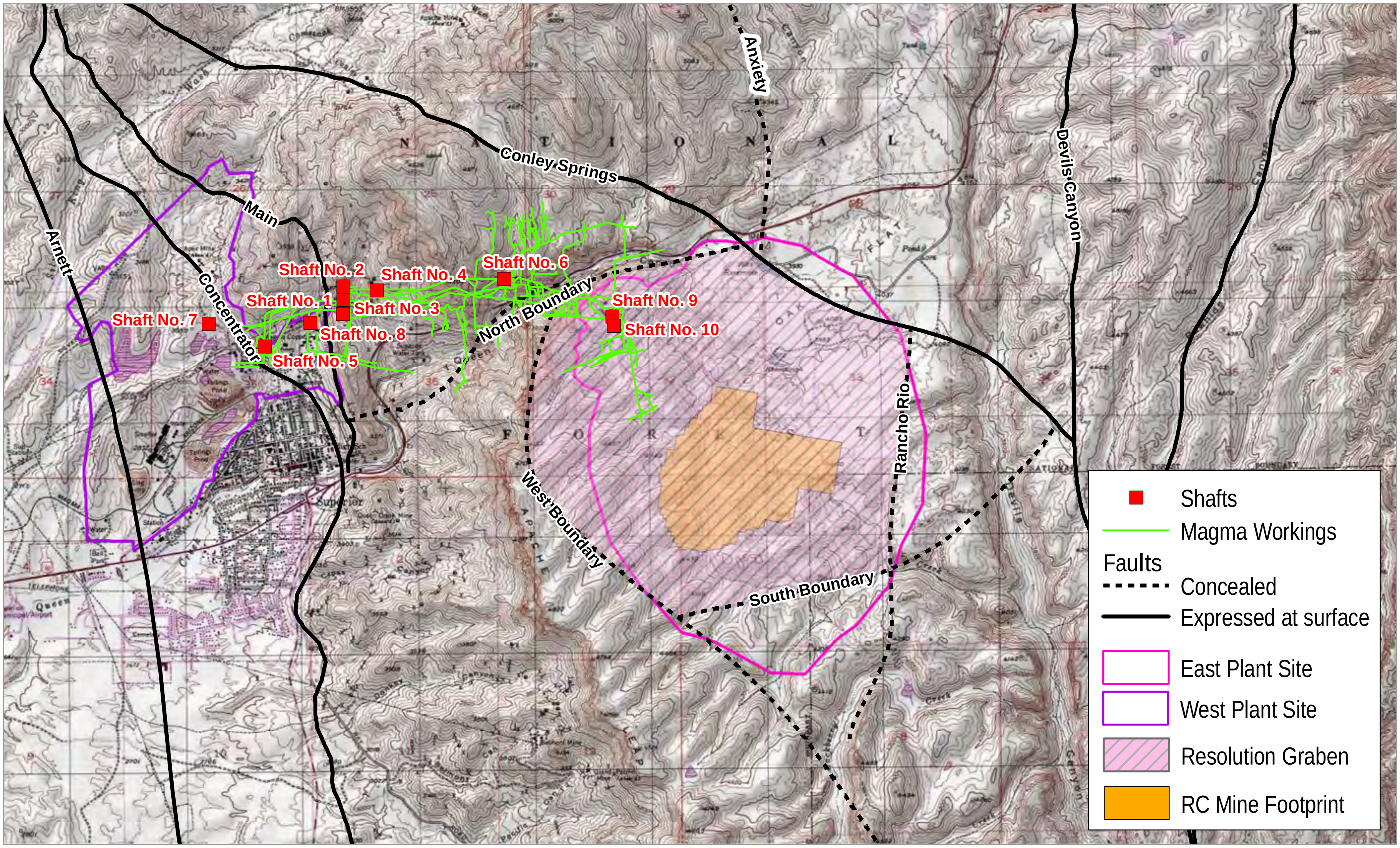
Coordinate System: NAD83 / Arizona Central (ft)

Site Location Map

PROJECT:	Regional Groundwater Model	FIGURE #:	1.1
CLIENT:	Resolution Copper	PROJECT #:	31400680
DRAWN: GM	CHECKED: DO	DATE:	January 2019

Document Path: C:\Users\USGM02889\Projects\Resolution\2019\GW Model Report\Figures\Figure 1.1 - Site Location Map.mxd

Service Layer Credits: Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community



0 2,500 5,000 10,000 Feet

1:50,000

Coordinate System: NAD83 / Arizona Central (ft)

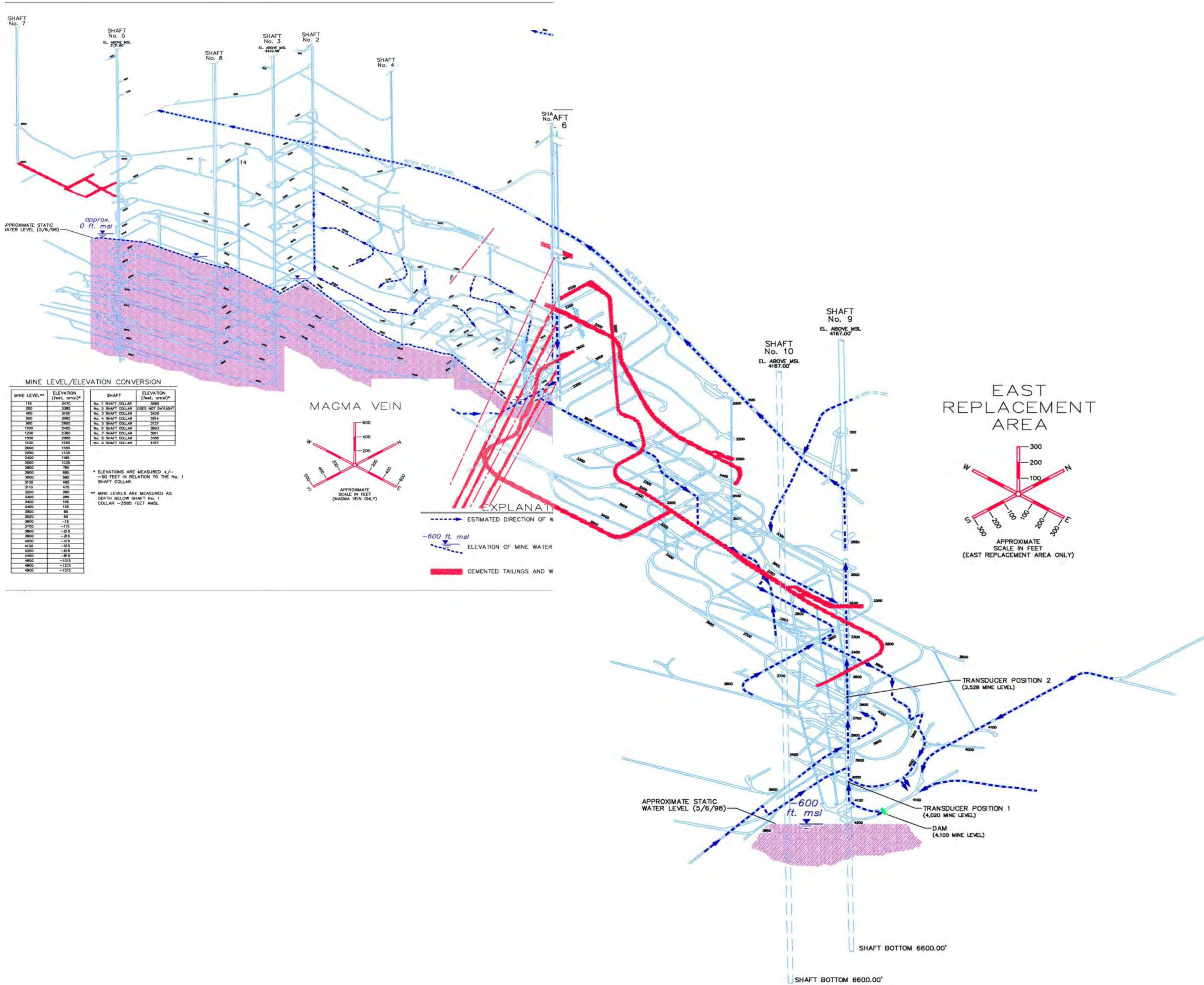
N

Mine Area Map

PROJECT: Regional Groundwater Model		FIGURE #:	1.2
CLIENT: Resolution Copper		PROJECT #:	31400680
DRAWN: CP	CHECKED: DO	DATE:	January 2019

Document Path: C:\Users\USGM02889\Projects\Resolution\2019\GW Model Report\Figures\Figure 1.2 - Mine Area Map.mxd

Service Layer Credits: Copyright:© 2013 National Geographic Society, i-cubed



MINE LEVEL/ELEVATION CONVERSION

MINE LEVEL**	ELEVATION (feet, amsl)*
115	3470
200	3385
400	3185
500	3085
900	2685
1100	2485
1200	2385
1500	2085
1600	1985
2000	1585
2250	1335
2400	1185
2550	1035
2800	785
2900	685
3000	585
3100	485
3110	475
3200	385
3300	285
3400	185
3450	135
3500	85
3520	65
3600	−15
3700	−115
3800	−215
3900	−315
4000	−415
4100	−515
4200	−615
4400	−815
4600	−1015
4800	−1215
4900	−1315

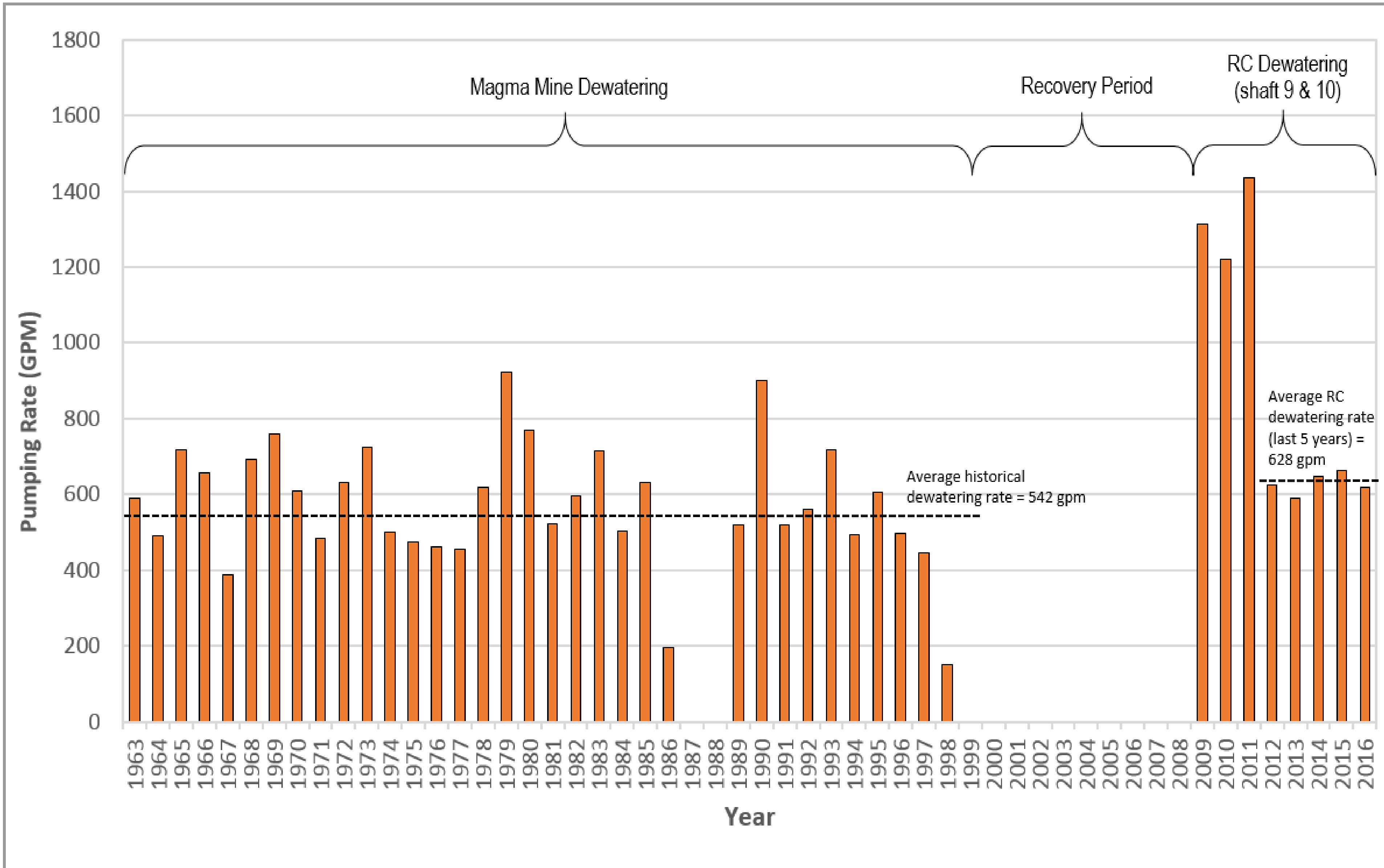
SHAFT	ELEVATION (feet, amsl)*
No. 1 SHAFT COLLAR	3585
No. 2 SHAFT COLLAR	DOES NOT DAYLIGHT
No. 3 SHAFT COLLAR	3435
No. 4 SHAFT COLLAR	3514
No. 5 SHAFT COLLAR	3137
No. 6 SHAFT COLLAR	3663
No. 7 SHAFT COLLAR	3011
No. 8 SHAFT COLLAR	3168
No. 9 SHAFT COLLAR	4167

* ELEVATIONS ARE MEASURED +/− ~50 FEET IN RELATION TO THE No. 1 SHAFT COLLAR

** MINE LEVELS ARE MEASURED AS DEPTH BELOW SHAFT No. 1 COLLAR ~3585 FEET AMSL

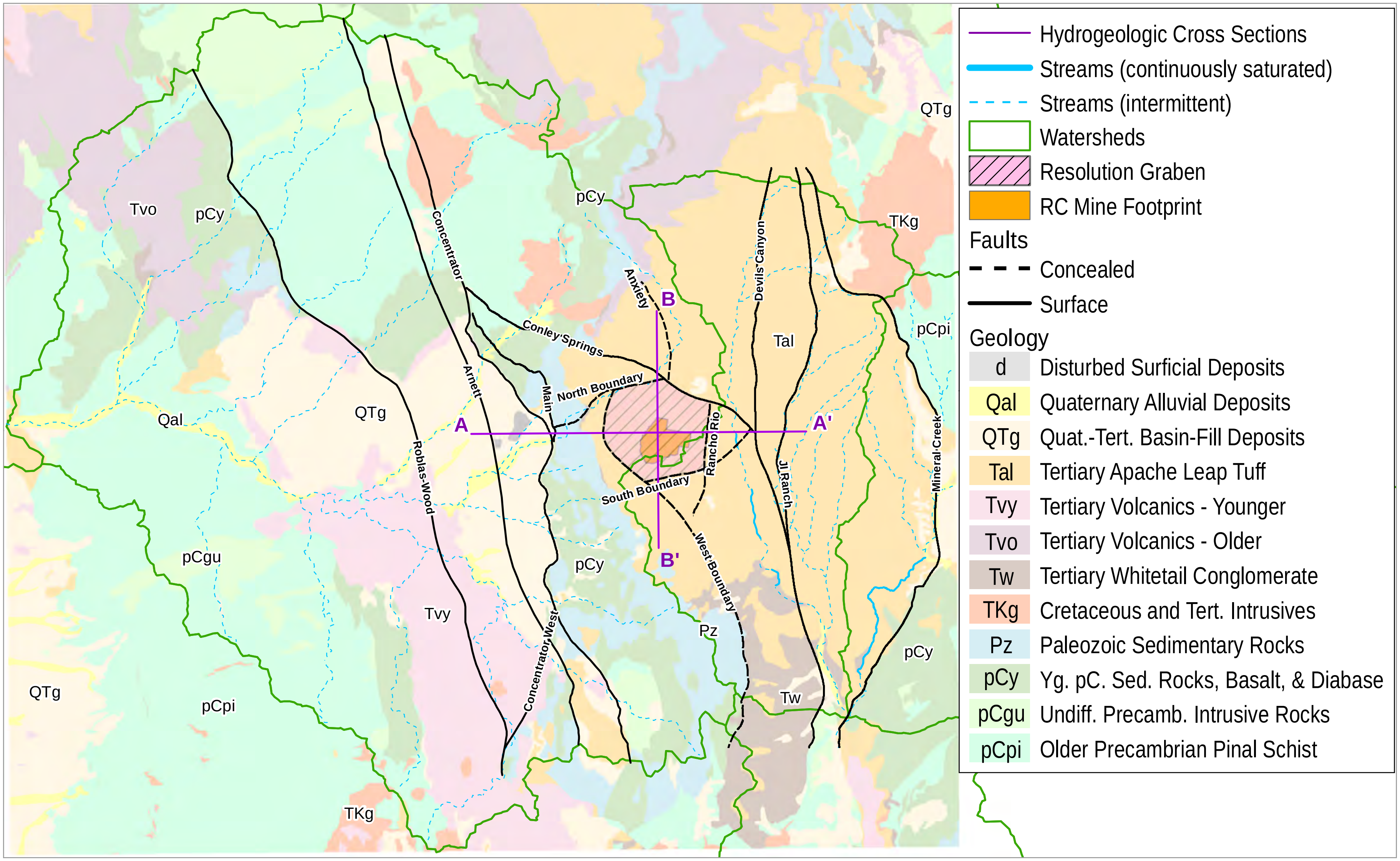
Magma Mine Workings

PROJECT:	Regional Groundwater Model	FIGURE:	1.3
CLIENT:	Resolution Copper	PROJECT #:	31400968
DRAWN: GM	CHECKED: DO	DATE:	January 2019



Historical and RC Dewatering Rates

PROJECT: Regional Groundwater Model		FIGURE #: 1.4	
CLIENT: Resolution Copper		PROJECT #: 31400680	
DRAWN: GM	CHECKED: DO	DATE: January 2019	



0 1.5 3 6

Miles

1:180,000

N

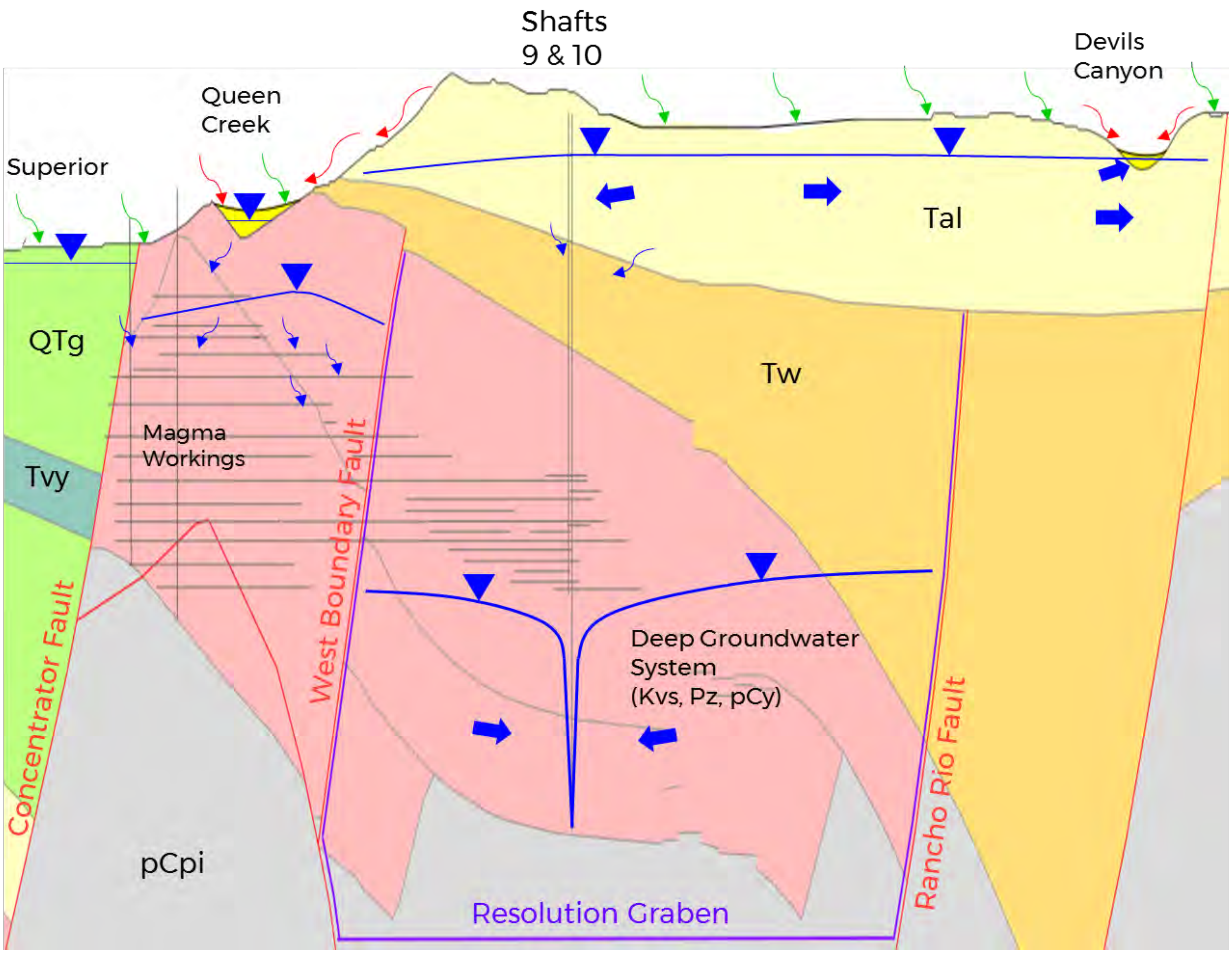
Coordinate System: NAD83 / Arizona Central (ft)

wsp

Surface Geology Map

PROJECT: Regional Groundwater Model		FIGURE #:	2.1
CLIENT: Resolution Copper		PROJECT #:	31400680
DRAWN: CP	CHECKED: DO	DATE:	January 2019

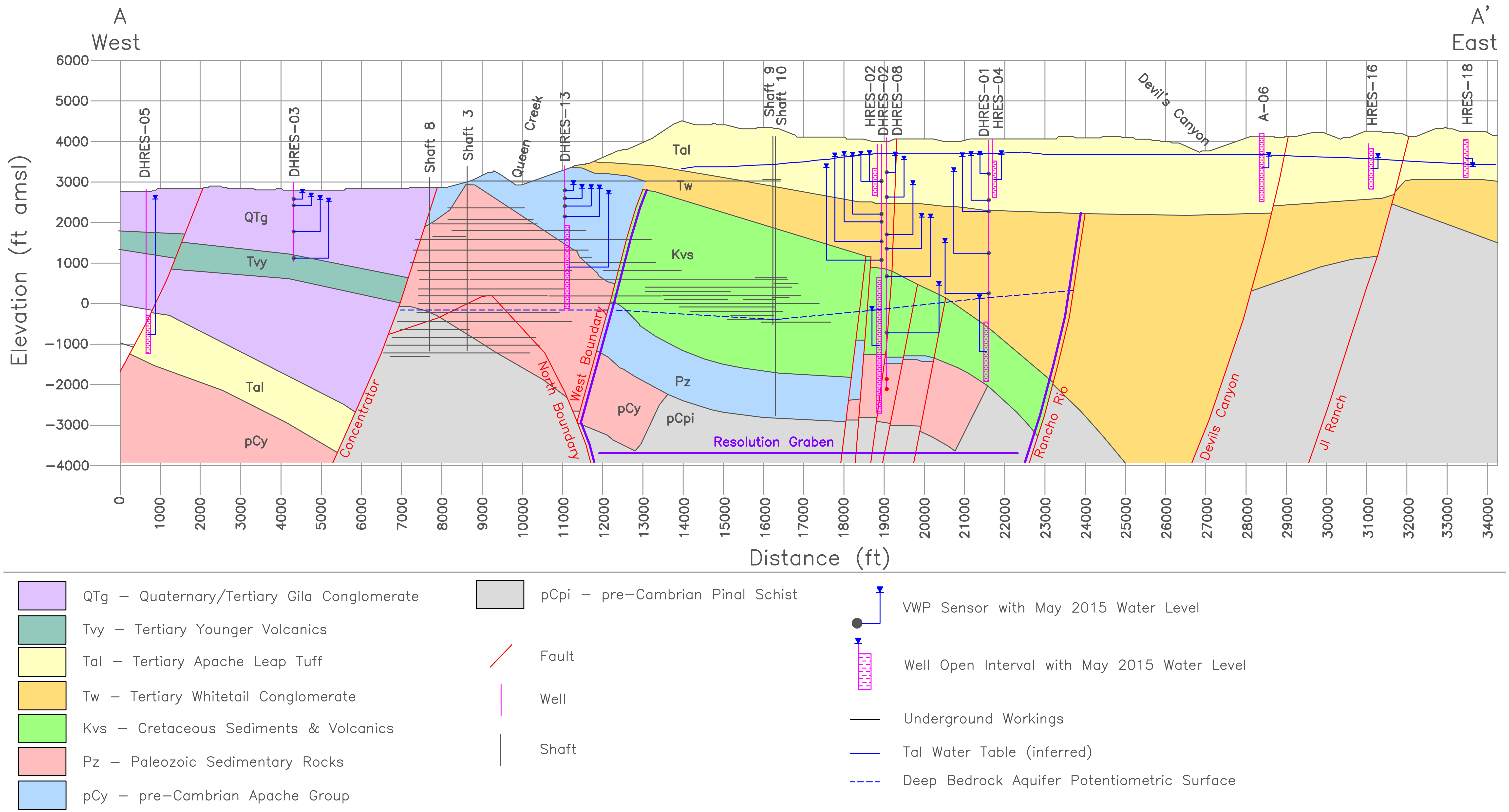
Document Path: C:\Users\USGM02889\Projects\Resolution\2019\GW Model Report\Figures\Figure 2.1 - Surface Geology Map.mxd



- Recharge
- Surface Runoff
- Minor GW Flow
- Primary GW Flow

Hydrogeological Conceptual Model

PROJECT: Regional Groundwater Model		FIGURE #:	2.2
CLIENT: Resolution Copper		PROJECT #:	31400680
DRAWN: CP	CHECKED: DO	DATE:	January 2019



N

0 1000 2000 3000 4000 5000 Feet

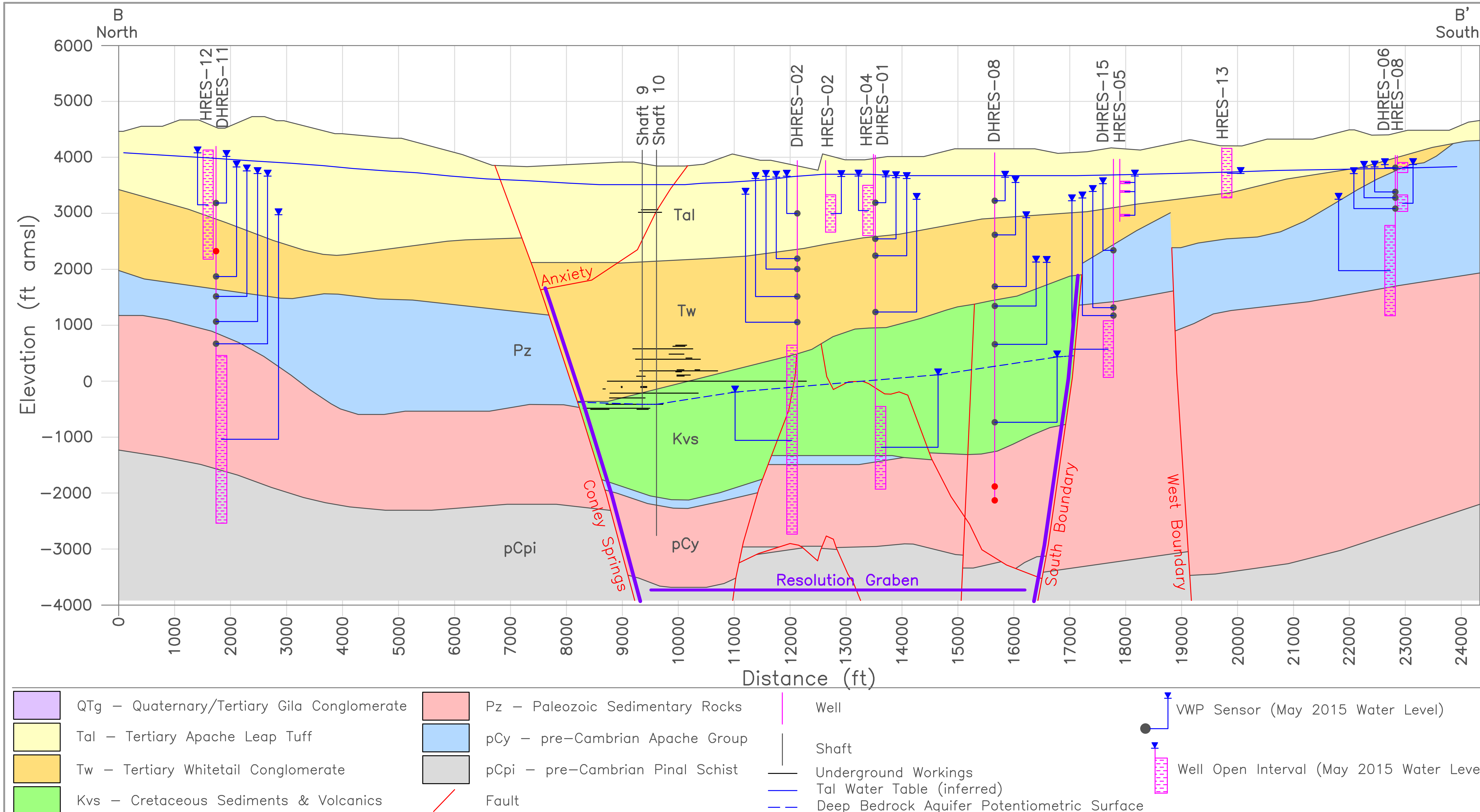
SCALE: 1:2350

* Wells and shafts projected onto section
Projected up to 4000 feet
Shown as true elevations

wsp

Hydrogeologic cross section A-A'

PROJECT: Regional Groundwater Model		FIGURE: 2.3	
CLIENT: Resolution Copper		PROJECT #: 31400680	
DRAWN: CP	CHECKED: DO	DATE: January 2019	



N

0 1000 2000 3000 4000 5000 Feet

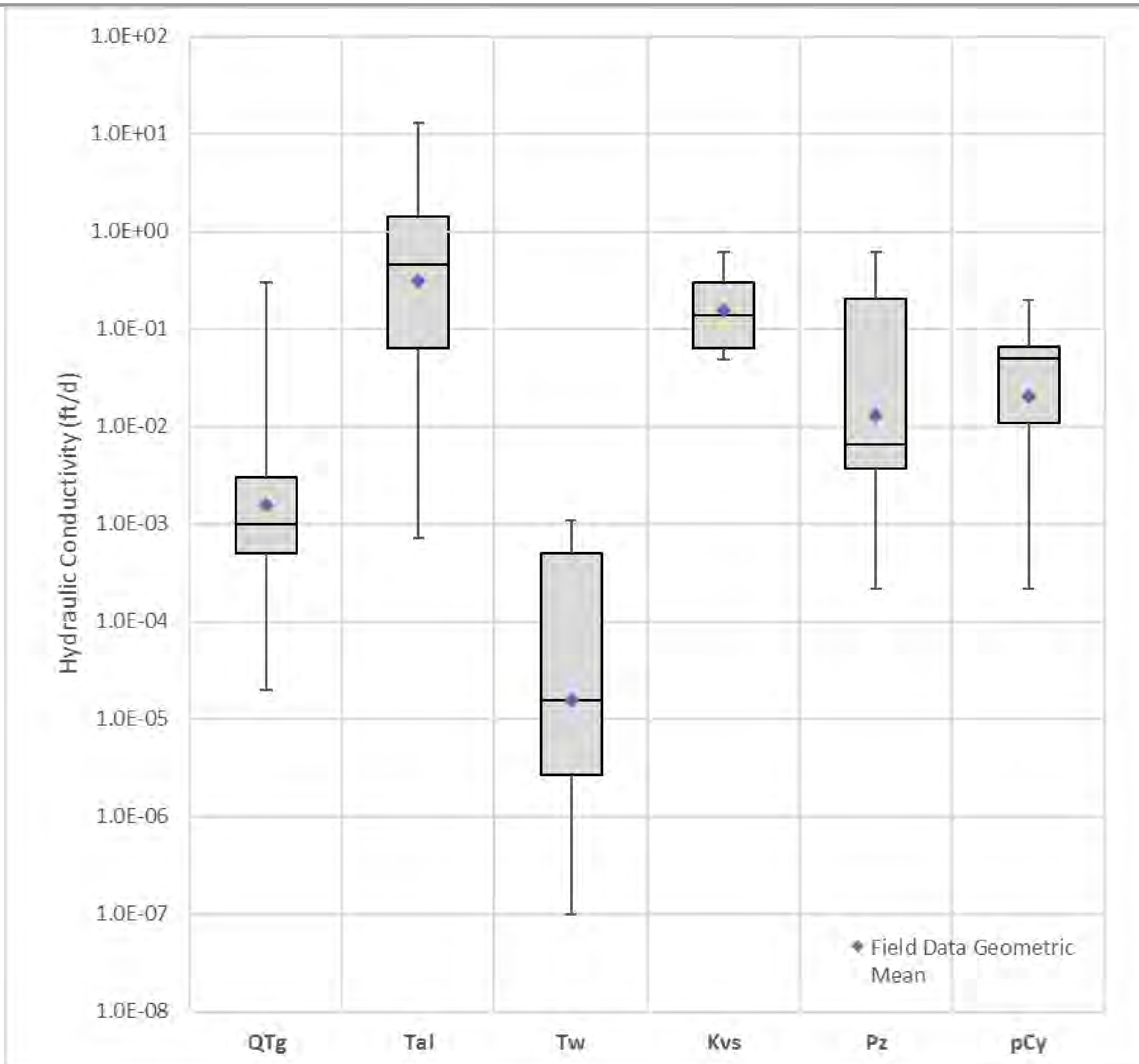
SCALE: 1:2750

* Wells and shafts projected onto section
Projected up to 4000 feet
Shown as true elevations

WSP

Hydrogeologic cross section B-B'

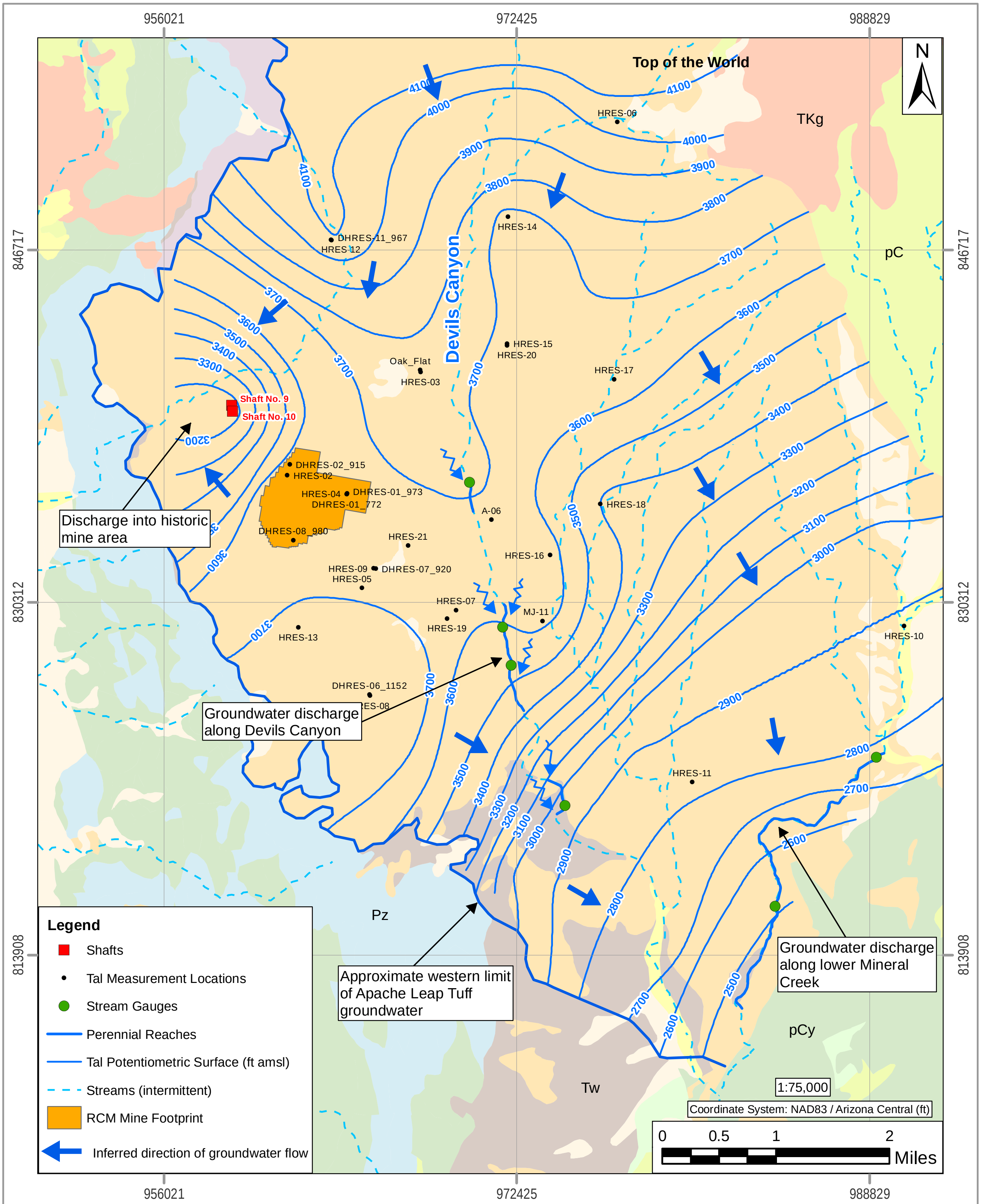
PROJECT: Regional Groundwater Model		FIGURE: 2.4	
CLIENT: Resolution Copper		PROJECT #: 31400680	
DRAWN: CP	CHECKED: DO	DATE: January 2019	



Box and Whisker plot shows:

- Quartiles 2 & 3 as shaded boxes.
- The median is the middle line.
- The whiskers represent the maximum and minimum values

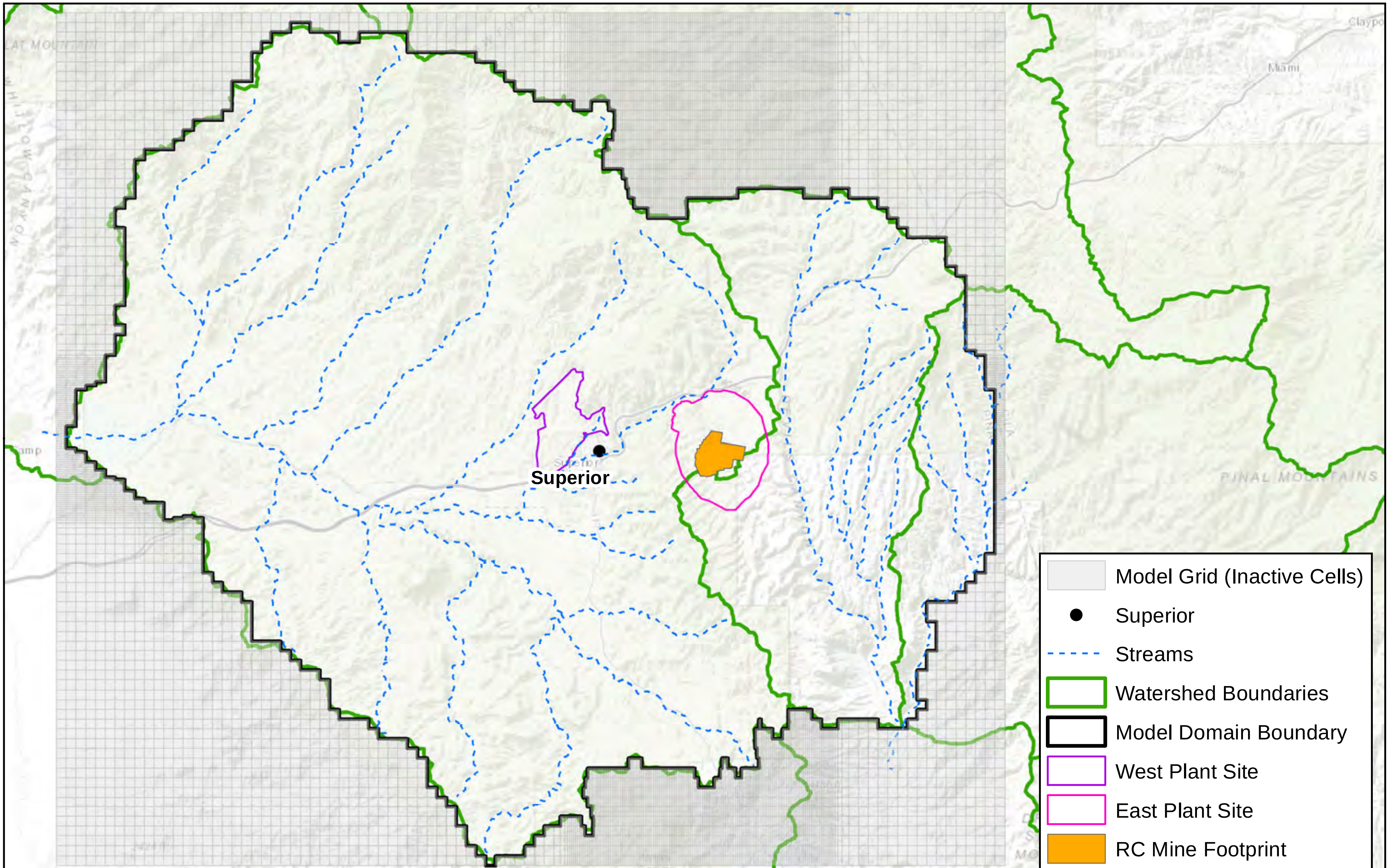
Hydraulic Conductivity Values from Aquifer Tests - Box and Whisker Plot			
PROJECT: Regional Groundwater Model		FIGURE #: 2.5	
CLIENT: Resolution Copper		PROJECT #: 31400680	
DRAWN: CP	CHECKED: DO	DATE: January 2019	



Apache Leap Tuff Potentiometric Surface Contours (May 2015)

PROJECT: Regional Groundwater Model		FIGURE #:	2.6
CLIENT: Resolution Copper		PROJECT #:	31400680
DRAWN: GM	CHECKED: DO	DATE:	January 2019

Document Path: C:\Users\USGM02889\Projects\Resolution\2019\GW Model Report\Figures\Figure 2.6 - Apache Leap Tuff Potentiometric Surface.mxd



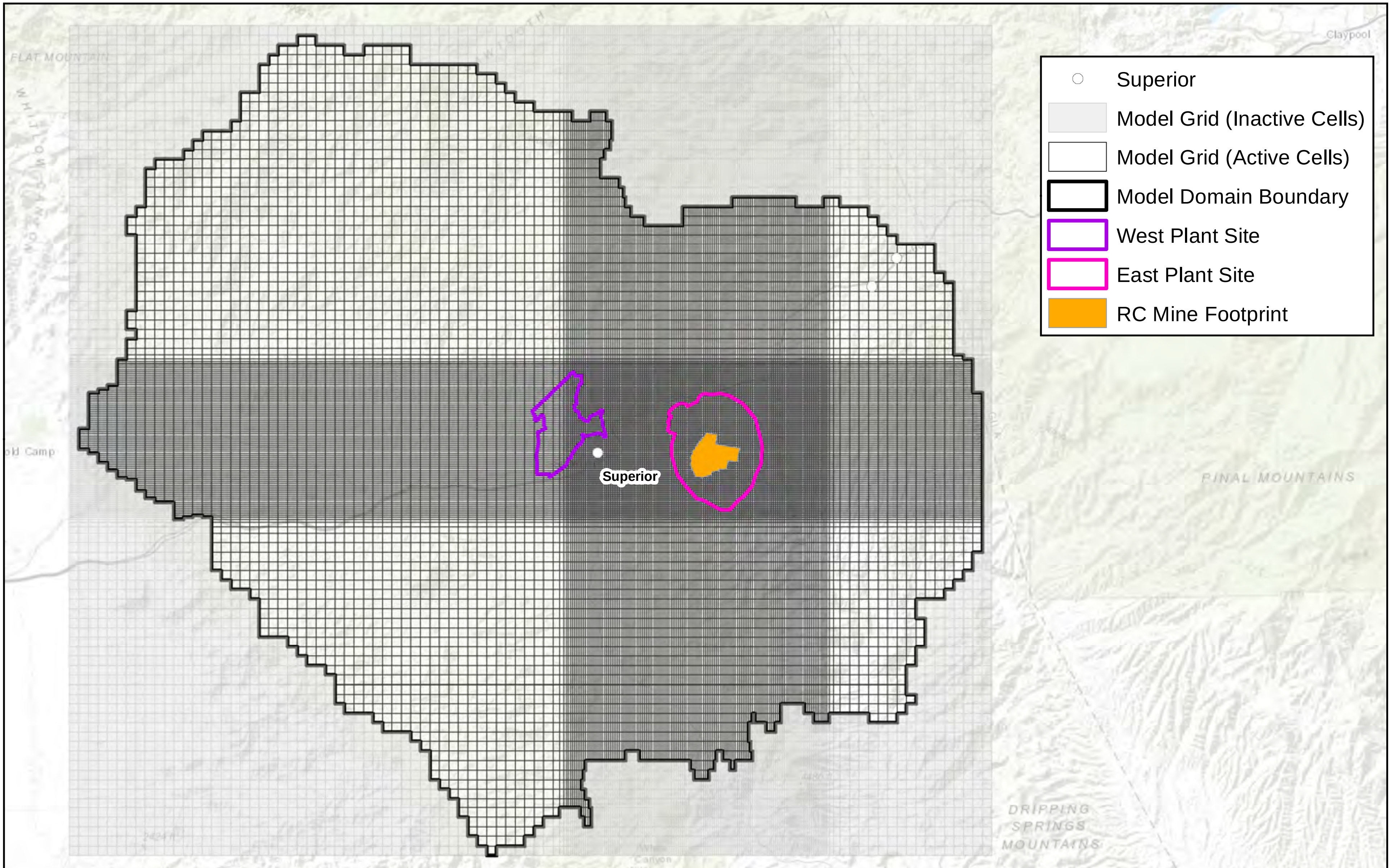
1:170,000

Coordinate System: NAD 1983
2011 StatePlane Arizona Central
FIPS 0202 Ft IntlTransverse Mercator

Model Domain

PROJECT:	Regional Groundwater Model	FIGURE #:	3.1
CLIENT:	Resolution Copper	PROJECT #:	31400680
DRAWN: CDM	CHECKED: GM	DATE:	January 2019

Document Path: C:\Users\USGM02889\Projects\Resolution\2019\GW Model Report\Figures\Figure 3.1 - Model Domain.mxd



N

0 0.5 1 2 3 Miles

1:175,000

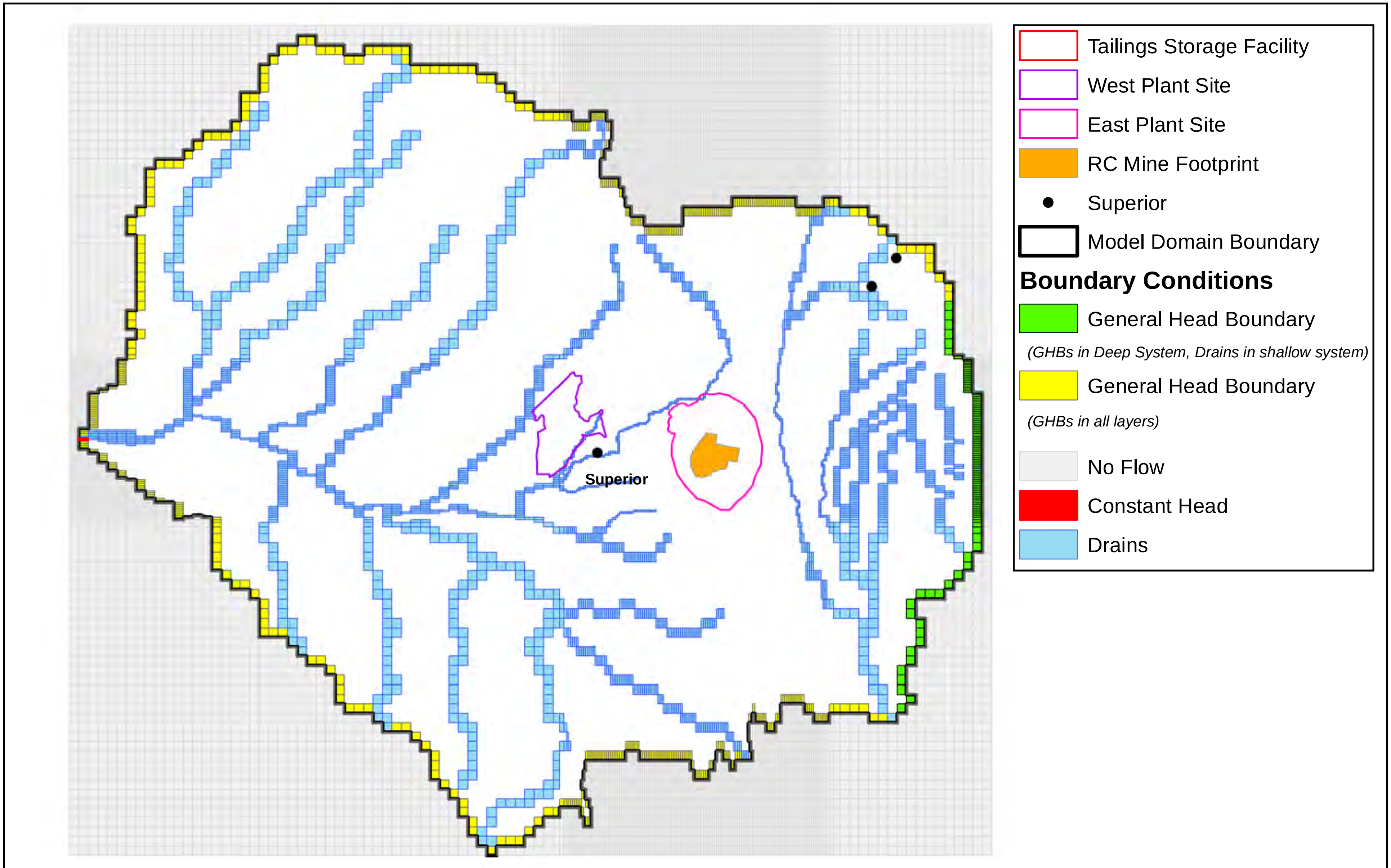
Coordinate System: NAD 1983
2011 StatePlane Arizona Central
FIPS 0202 Ft IntlTransverse Mercator

wsp

Model Grid

PROJECT: Regional Groundwater Model		FIGURE #:	3.2
CLIENT: Resolution Copper		PROJECT #:	31400680
DRAWN: CDM	CHECKED: GM	DATE:	January 2019

Document Path: C:\Users\USGM02889\Projects\Resolution\2019\GW Model Report\Figures\Figure 3.2 - Model Grid.mxd

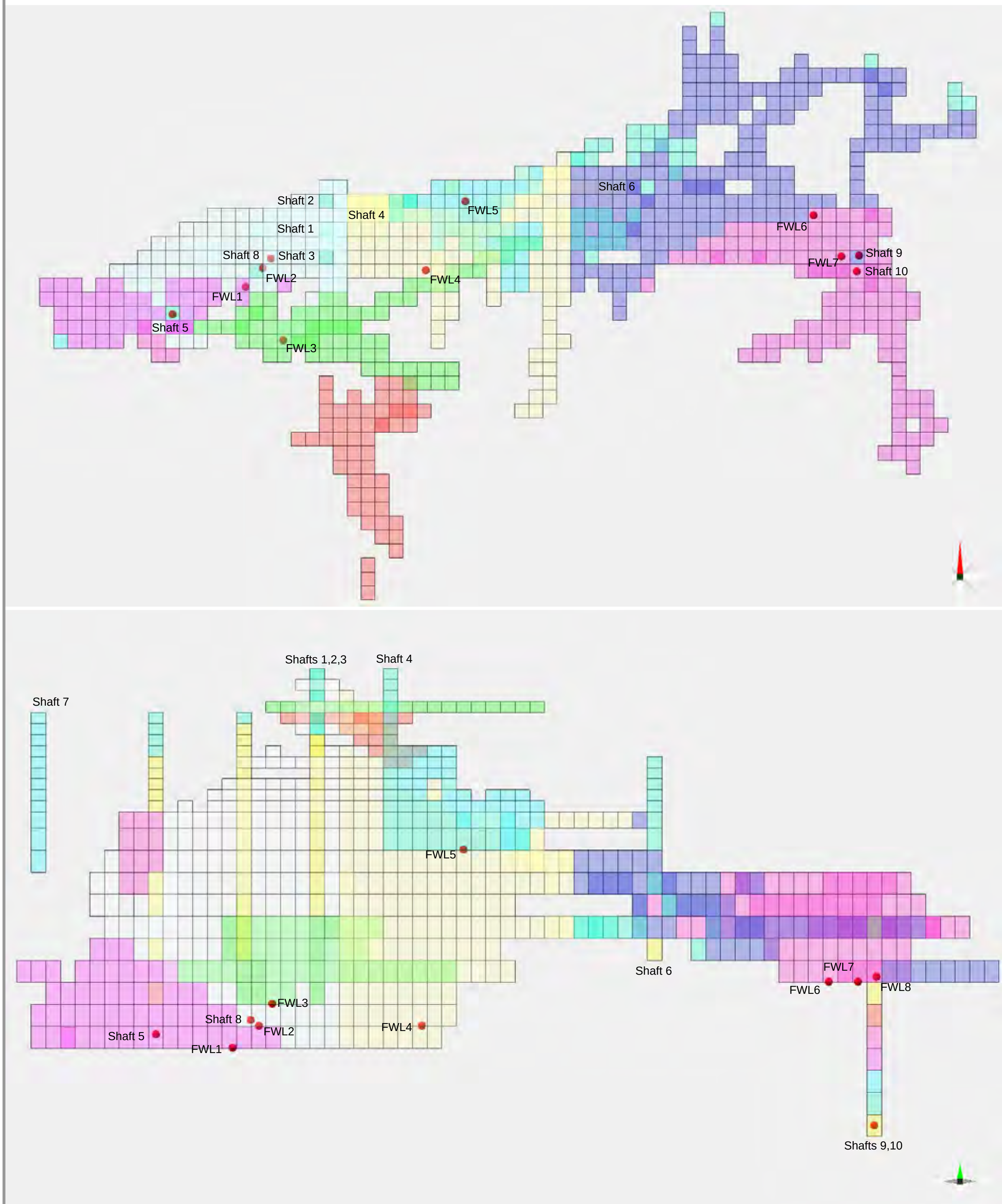


Coordinate System: NAD 1983
2011 StatePlane Arizona Central
FIPS 0202 Ft IntlTransverse Mercator

Boundary Conditions

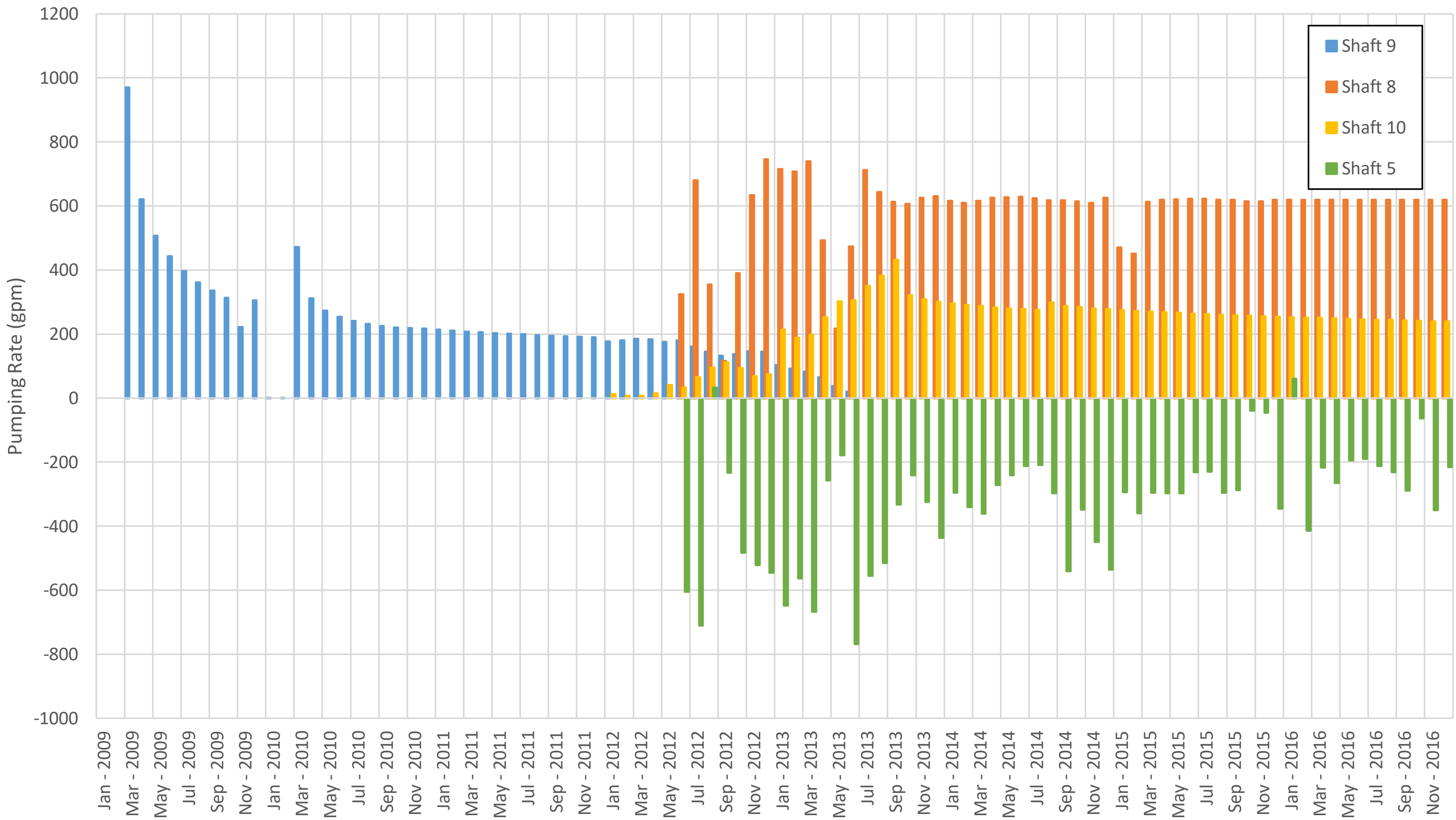
PROJECT: Regional Groundwater Model		FIGURE #: 3.3	
CLIENT: Resolution Copper		PROJECT #: 31400680	
DRAWN: CM	CHECKED: GM	DATE: January 2019	

Document Path: C:\Users\USGM02889\Projects\Resolution\2019\GW Model Report\Figures\Figure 3.3 - Boundary Conditions.mxd



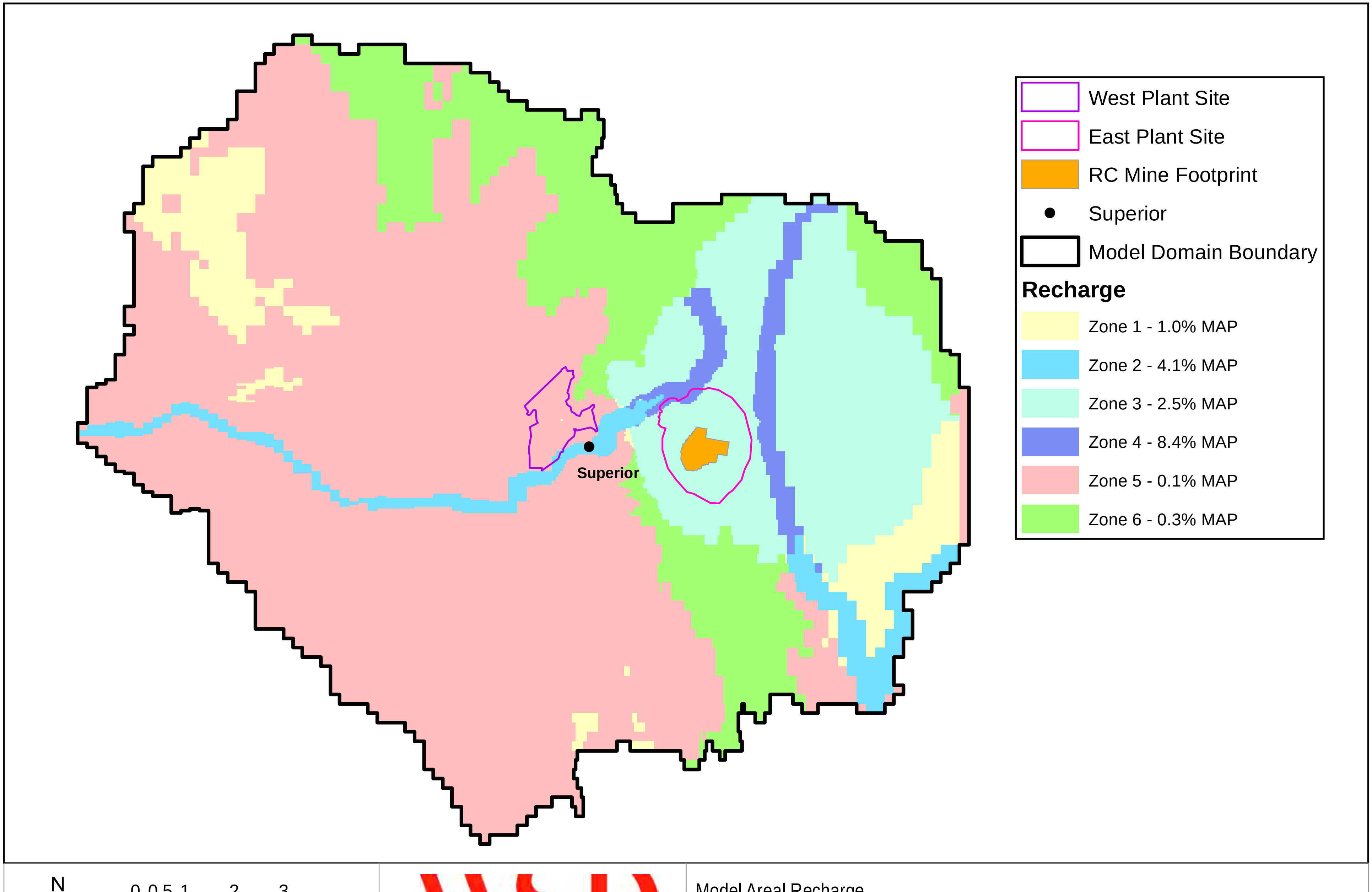
Underground Workings and FWL Nodes

PROJECT: Regional Groundwater Model		FIGURE:	3.4
CLIENT: Resolution Copper		PROJECT #:	31400968
DRAWN: GM	CHECKED: DO	DATE:	January 2019



Note: Actual pumping rates for Shafts 8, 9, 10 are negative (withdrawals) in the model and Shaft 5 rates are positive (injection).

FWL Pumping Rates		
PROJECT: Regional Groundwater Model		FIGURE #: 3.5
CLIENT: Resolution Copper		PROJECT #: 31400680
DRAWN: GM	CHECKED: DO	DATE: January 2019

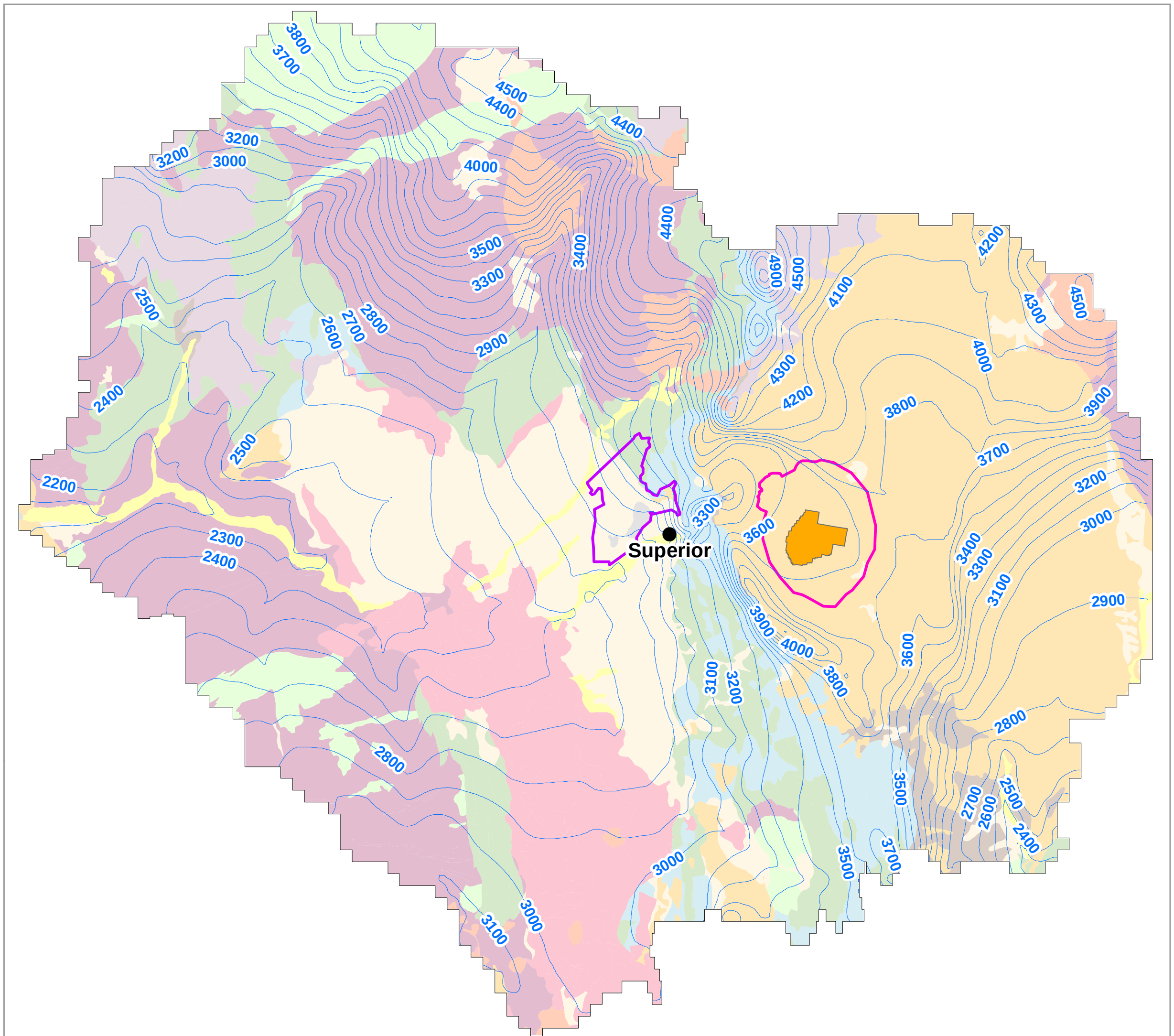


Coordinate System: NAD 1983
2011 StatePlane Arizona Central
FIPS 0202 Ft IntlTransverse Mercator

Model Areal Recharge

PROJECT: Regional Groundwater Model		FIGURE #:	3.6
CLIENT: Resolution Copper		PROJECT #:	31400680
DRAWN: CM	CHECKED: GM	DATE:	January 2019

Document Path: C:\Users\USGM02889\Projects\Resolution\2019\GW Model Report\Figures\Figure 3.6 - Recharge.mxd



Surface Geology
- Pz - Paleozoic Sedimentary Rocks
- QTg - Quaternary-Tertiary Basin-Fill Deposits
- Qal - Quaternary Alluvial Deposits
- TKg - Createceous and Tertiary Intrusive Rocks
- Tal - Tertiary Apache Leap Tuff
- Tvo - Tertiary Volcanics - Older
- Tvy - Tertiary Volcanics - Younger
- Tw - Tertiary Whitetail Conglomerate
- d - Disturbed Surficial Deposits
- pCgu - Undifferentiated Precambrian Intrusive Rocks
- pCpi - Older Precambrian Pinal Schist
- pCy - Younger Precambrian Sedimentary Rocks, Basalt, and Diabase

- Water Level Contours (100 ft)
- Superior
- Groundwater Model Domain
- West Plant Site
- East Plant Site
- RC Mine Footprint

Model Results: RCM_H_180730

1:185,000

Coordinate System: NAD83 / Arizona Central (ft)

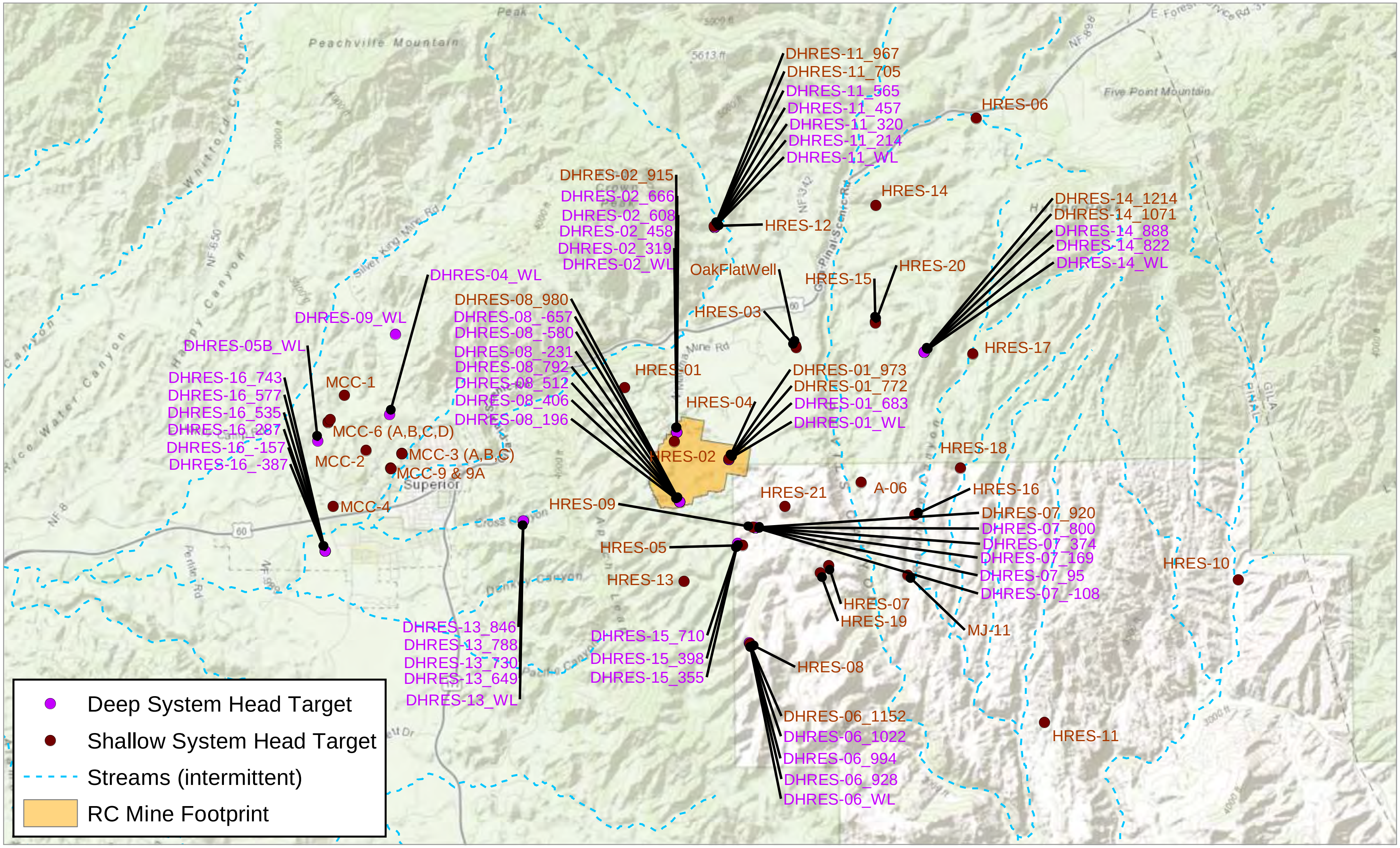
N

0 2.5 5 10 Miles

Initial Conditions (Steady State) - 1910 Modeled Heads

PROJECT: 3D Regional Groundwater Model		FIGURE #:	3.7
CLIENT: Resolution Copper		PROJECT #:	31400968.001
DRAWN: CP	CHECKED: DO	DATE:	December 2018

Document Path: I:\Resolution\Reporting\GW Action Items\WL Difference (1910-2016)\180730_HistoricalModel_SS1910Heads.mxd



Note: colors of sensor labels indicate whether it is a deep or shallow system target

N

1:90,000

0 0.75 1.5 3 Miles

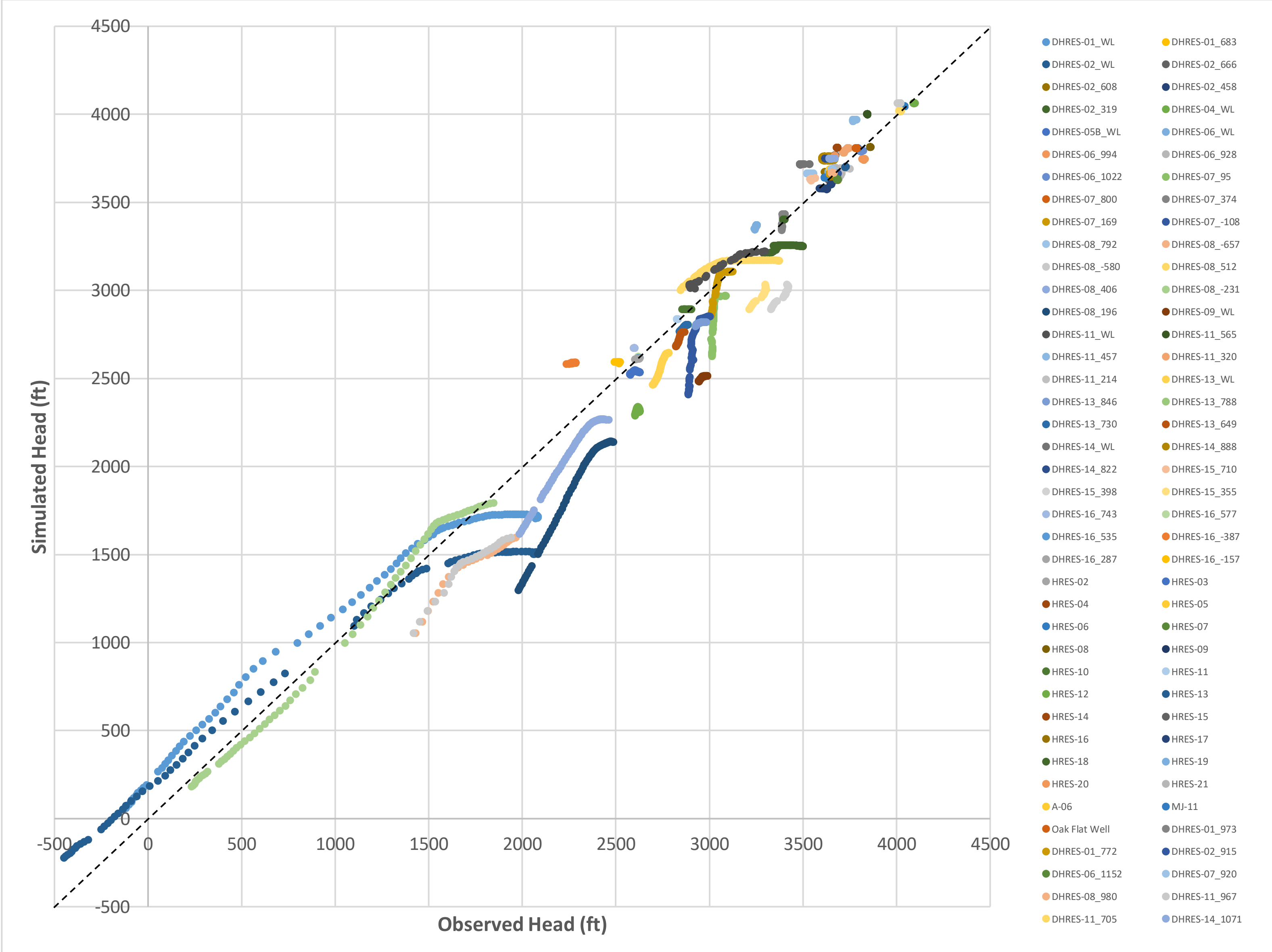
Coordinate System: NAD83 / Arizona Central (ft)

wsp

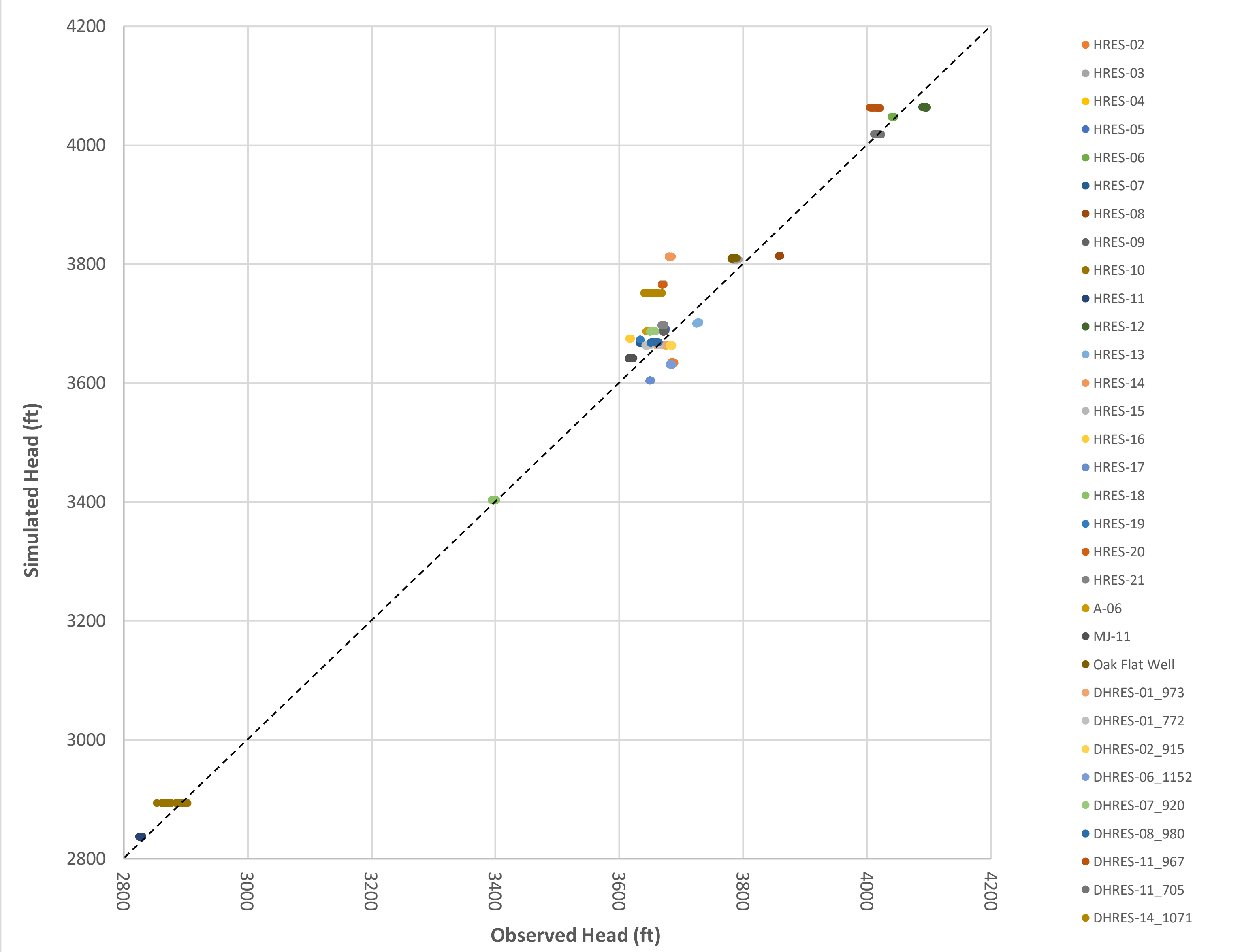
Location of Calibration Targets

PROJECT:	Regional Groundwater Model			FIGURE #:	3.8
CLIENT:	Resolution Copper			PROJECT #:	31400680
DRAWN:	GM	CHECKED:	DO	DATE:	January 2019

Document Path: \\ENDENFIL02\Jobs\Resolution\31400680 Model Update 2017\500_Deliverables\Draft Report\Figures\mxd\Figure 3.7 - Head Targets (V2).mxd



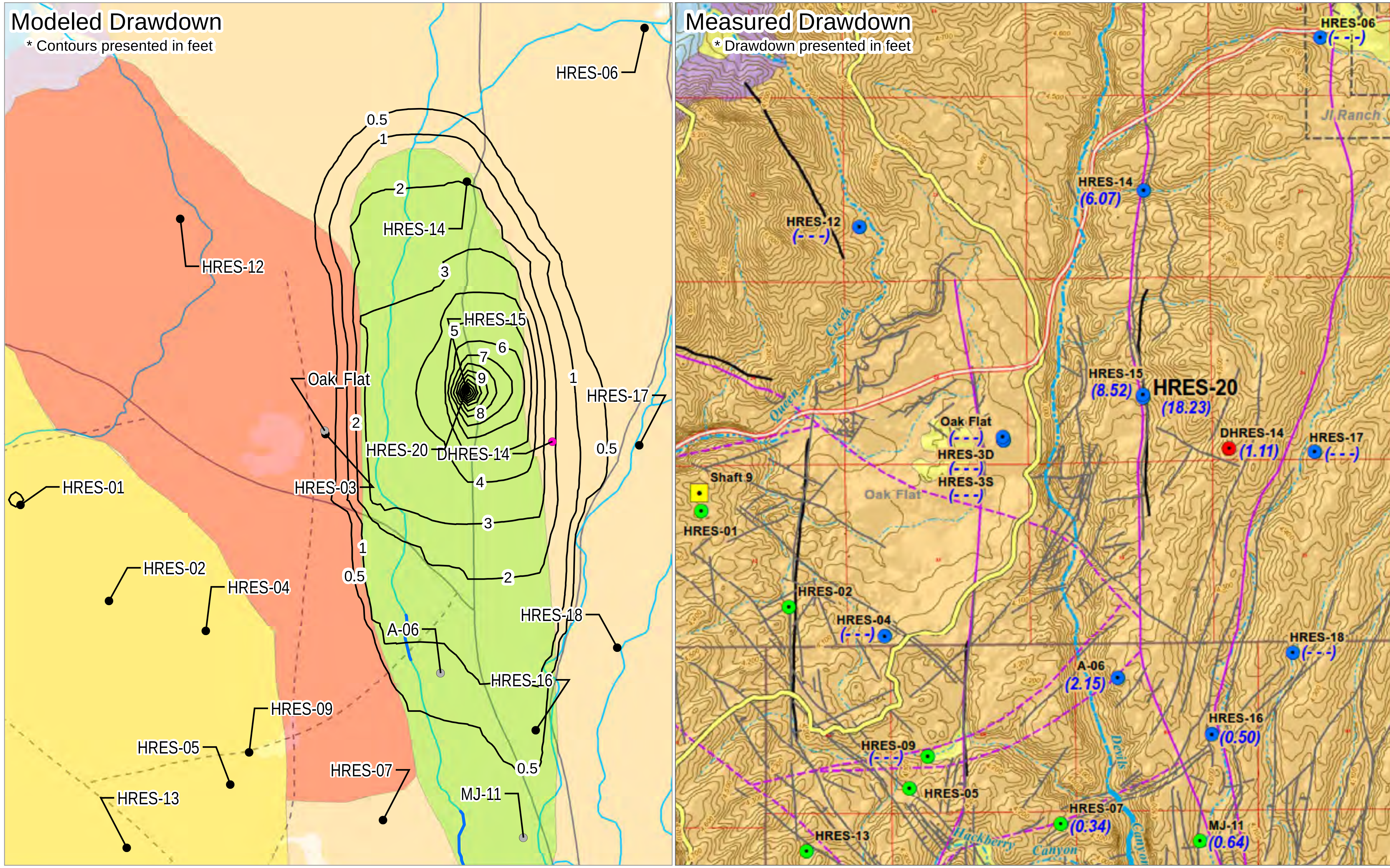
Scatter Plot – All Calibration Targets			
PROJECT: Regional Groundwater Model		FIGURE #: 3.9	
CLIENT: Resolution Copper		PROJECT #: 31400680	
DRAWN: GM	CHECKED: DO	DATE: January 2019	



wsp

Scatter Plot – Apache Leap Tuff Calibration Targets

PROJECT:	Regional Groundwater Model	FIGURE #:	3.10
CLIENT:	Resolution Copper	PROJECT #:	31400680
DRAWN: GM	CHECKED: DO	DATE:	January 2019



Stream
Continuously Saturated Reach
Modeled Drawdown Contours (ft)

Monitoring Points
- DHRES
- HRES
- Non-Resolution

Conceptual Tal K Zones
- High
- Moderate
- Low

Faults
- Concealed
- Surface

N

1:37,000

Coordinate System: NAD83 / Arizona Central (ft)

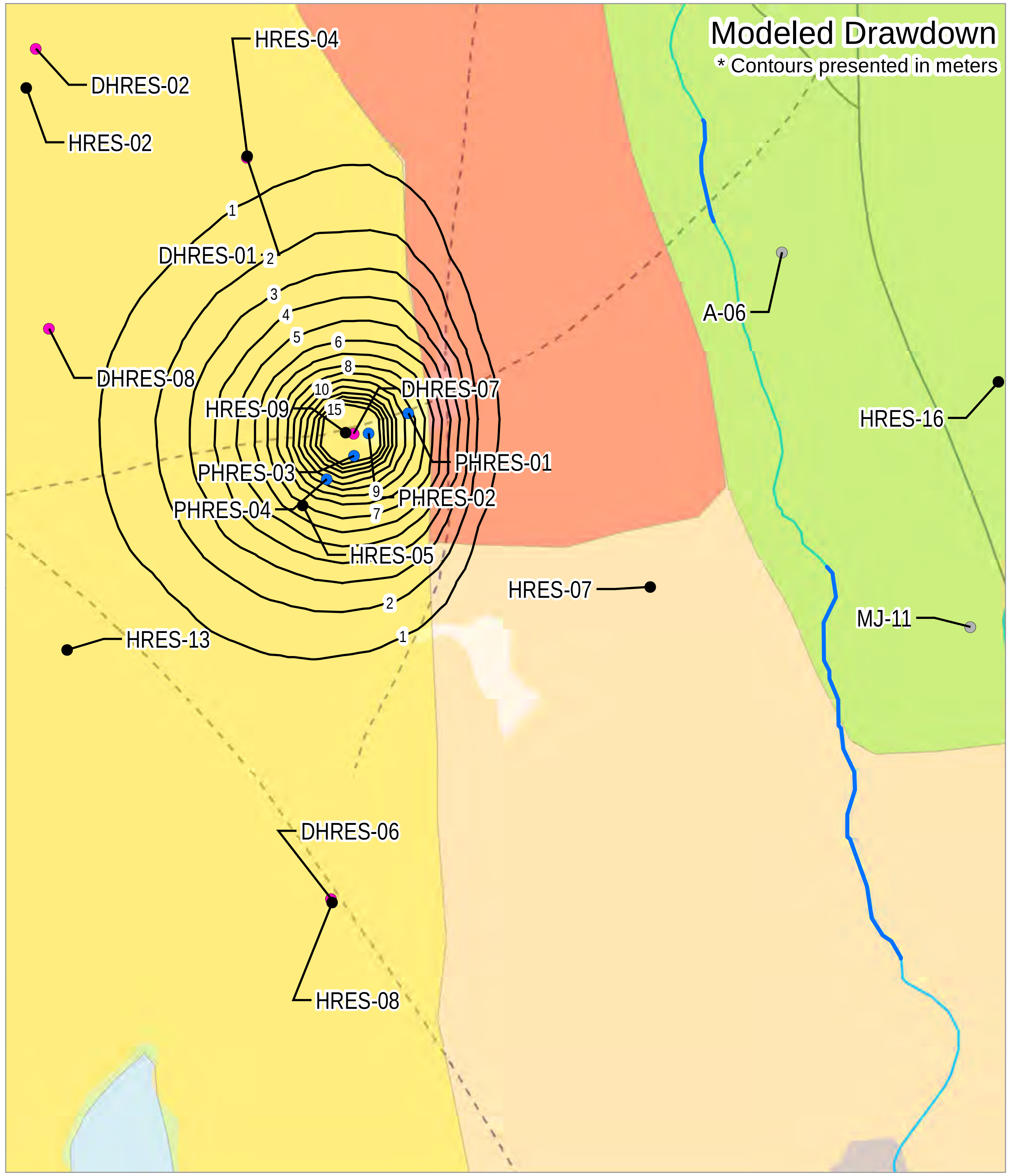
0 2,000 4,000 8,000 12,000 16,000 Feet

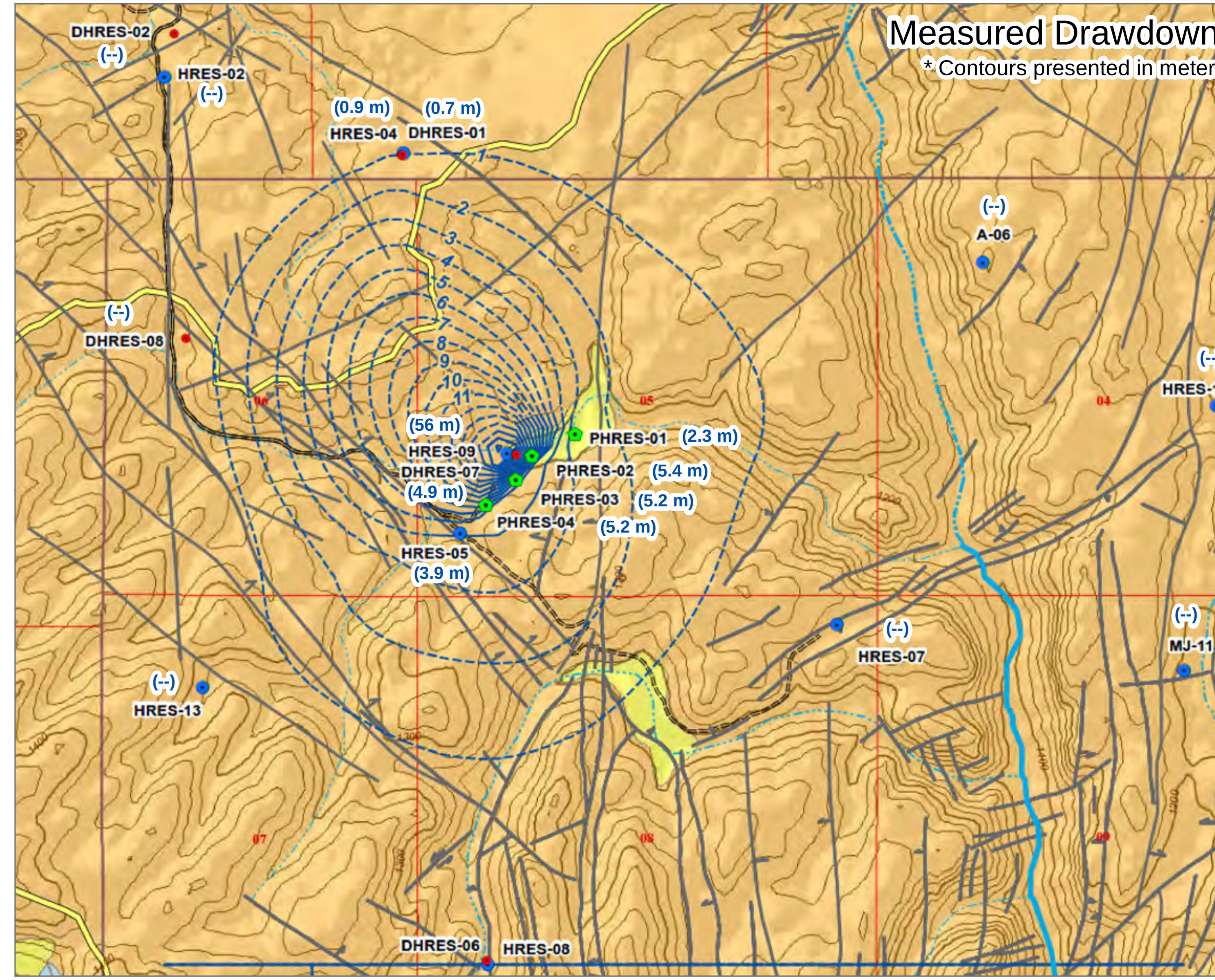
wsp

HRES-20 Aquifer Test Re-Creation

PROJECT: Regional Groundwater Model		FIGURE #:	3.11
CLIENT: Resolution Copper		PROJECT #:	31400968.001
DRAWN: CP	CHECKED: GM	DATE:	January 2019

Document Path: D:\Resolution\Hydraulic Testing\180406a_HRES-20_M&AInset.mxd





Stream	Monitoring Points	Conceptual Tal K Zones	Faults
Continuously Saturated Reach	DHRES	High	Concealed
Modeled Drawdown Contours (m)	HRES	Moderate	Surface
	Non-Resolution	Low	
	PHRES		

N

1:22,000

Coordinate System: NAD83 / Arizona Central (ft)

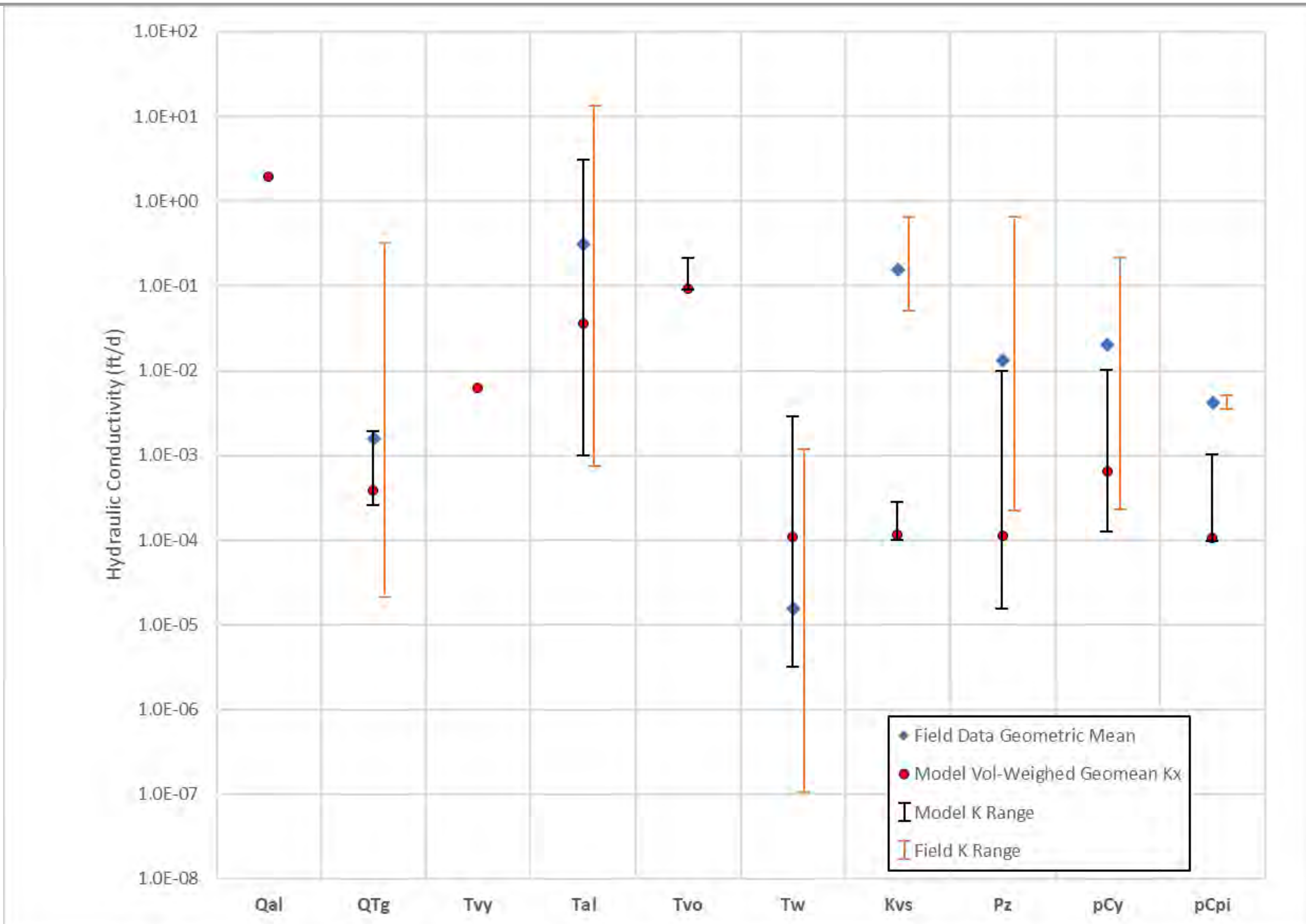
0 1,250 2,500 5,000 7,500 10,000 Feet

wsp

HRES-09 Aquifer Test Re-Creation

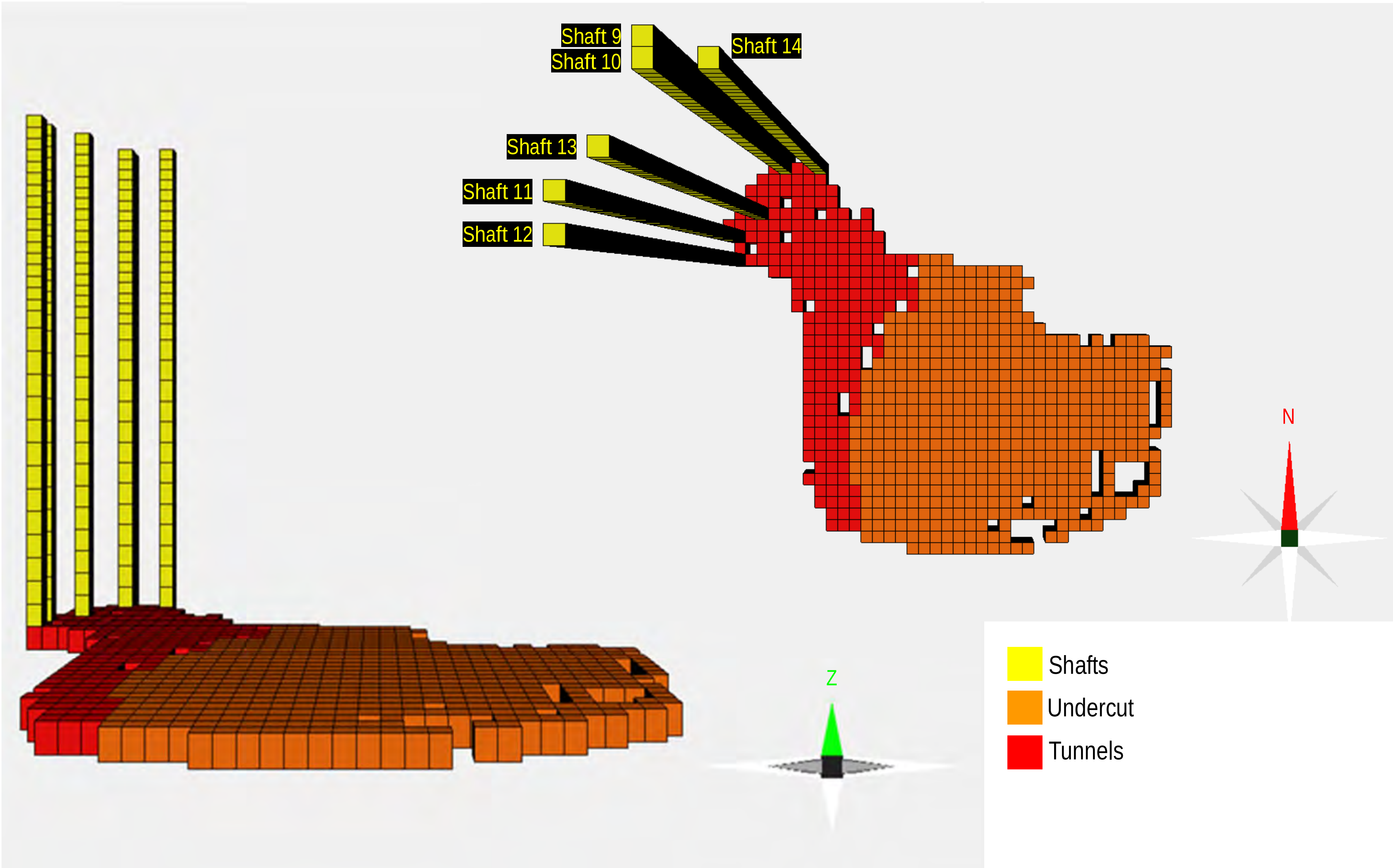
PROJECT: Regional Groundwater Model		FIGURE #:	3.12
CLIENT: Resolution Copper		PROJECT #:	31400968.001
DRAWN: CP	CHECKED: GM	DATE:	January 2019

Document Path: D:\Resolution\Hydraulic Testing\180406a_HRES-09_M&AInset.mxd



Source:	Hydraulic Conductivity - Field Data versus Model Values		
	PROJECT: Regional Groundwater Model		FIGURE #: 3.13
	CLIENT: Resolution Copper		PROJECT #: 31400680
	DRAWN: CP	CHECKED: DO	DATE: January 2019

C:\Users\USCP02914\Desktop\Figure 4.X RCM Workings.docx



	RC Workings – Simulated Drains

PROJECT:	Regional Groundwater Model	FIGURE #:	4.1
CLIENT:	Resolution Copper	PROJECT #:	31400680
DRAWN: CP	CHECKED: DO	DATE:	January 2019

Victoria Boyne

From: ResolutionProjectRecord
Subject: FW: EXTERNAL:Grounwater Action Item GW-84 - Reissue Oct 2017 WSP Report
Attachments: 20190215 RC GW Model Report - WSP Feb 2019 without Figures.pdf

From: Peacey, Victoria (RC) <Victoria.Peacey@riotinto.com>
Sent: Monday, February 18, 2019 10:31 AM
To: mcrasmussen@fs.fed.us
Cc: Morissette, Mary (RC) <Mary.Morissette@riotinto.com>; Chris Garrett <cgarrett@swca.com>; Donna Morey <dmorey@swca.com>; RCPermitting <RCPermitting@riotinto.com>
Subject: EXTERNAL:Grounwater Action Item GW-84 - Reissue Oct 2017 WSP Report

Hello Mary,

In response to GW-84, WSP has re-issued their October 2017 groundwater model report consistent with the direction from the GW working group. Due to e-mail size constraints, I will send report figures in a separate follow-up e-mail.

Thanks,

Vicky Peacey
Senior Manager – Environment, Permitting and Approvals

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Victoria Boyne

From: ResolutionProjectRecord
Subject: FW: EXTERNAL:Groundwater Action Item GW-84 - Reissue Oct 2017 WSP Report - Figures
Attachments: 20190215 RC GW Model Report Figures.pdf

From: Peacey, Victoria (RC) <Victoria.Peacey@riotinto.com>
Sent: Monday, February 18, 2019 10:50 AM
To: mcrasmussen@fs.fed.us
Cc: Donna Morey <dmorey@swca.com>; Chris Garrett <cgarrett@swca.com>; RCPermitting <RCPermitting@riotinto.com>; Morissette, Mary (RC) <Mary.Morissette@riotinto.com>
Subject: EXTERNAL:Groundwater Action Item GW-84 - Reissue Oct 2017 WSP Report - Figures

Figures are attached.

Vicky Peacey
Senior Manager – Environment, Permitting and Approvals

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