TECHNICAL MEMORANDUM

DATE: April 20, 2020 **PROJECT #:** 605.1608

TO: Greg Ghidotti, RESOLUTION COPPER

FROM: Montgomery & Associates

PROJECT: Resolution Copper

SUBJECT: Response to Groundwater Work Group Action Item WR-12: Assessment of Potential Sources of Impact in the Queen Valley Area

INTRODUCTION

Montgomery & Associates (M&A) has prepared this technical memorandum in response to Groundwater Work Group Action Item WR-12 "*Pull well records and other information for QV and model the impacts*" to provide information to address Draft Environmental Impact Statement (DEIS) comments about potential impacts to Queen Valley, Arizona water supplies from proposed Resolution Copper mining activities. Comments in the DEIS about impacts to Queen Valley centered on two questions:

1. How will mine activities impact Queen Valley water supplies?

2. Should impacts to Queen Valley have been evaluated with either the mine impacts groundwater model or the mine water supply groundwater model?

Queen Valley is an unincorporated community located along Queen Creek west of Whitlow Ranch Dam and the proposed Resolution Copper Mine (Mine) and east of the Desert Wellfield where the Mine plans to source its water supply (**Figure 1**). Because of its location, three mechanisms have been identified that could cause impacts to Queen Valley water supply:

1. groundwater drawdown from Mine dewatering,

2. groundwater drawdown from Mine water supply pumping, and

3. reduced surface water flows from loss of contributing watershed caused by mine activities

The two regional groundwater models used to support groundwater impacts evaluation in the DEIS are the Resolution Mine Groundwater Impact Model (WSP, 2019) and the East Salt River Valley (ESRV) Model (M&A, 2018). Neither model includes Queen Valley in its model domain (**Figure 1**) because Queen Valley is relatively isolated within bedrock outcrops.

To the east of Queen Valley, the Resolution Mine Groundwater Impact Model assesses groundwater impacts associated with proposed mine dewatering activities east of the town of Superior. The model does not show groundwater drawdown from proposed mining activities near Whitlow Ranch Dam in any projections (personal communication with Chris Pantano, WSP, February 2020).

To the west of Queen Valley, the East Salt River Valley Model was used to assess groundwater impacts from proposed groundwater pumping at the Desert Wellfield (**Figure 1**). Current ESRV model predictions show some groundwater drawdown at the model boundary caused by combined pumping from RC and other regional groundwater users (M&A, 2018).

Two studies have been used to evaluate impacts of the proposed Mine on surface water flow volumes. BGC developed a hydrologic model to quantify potential impacts to runoff volume at Whitlow Ranch Dam which indicated an average annual volume reduction of 3.5% for DEIS Alternative 6 (BGC, 2018). Another study conducted by JE Fueller (2020) showed a decrease in peak-flow runoff between 1.0% and 2.1%.

This technical memorandum includes a summary the hydrogeologic/geologic setting, surface water conditions, groundwater conditions, and water demands of Queen Valley followed by an assessment of the expected mechanisms and magnitude of impacts to Queen Valley water resources.

HYDROGEOLOGIC/GEOLOGIC SETTING

Hydrogeologic Units

Geologic units and structural features in the Queen Valley area are shown on **Figure 2**. The depth to the bottom of the Tertiary basin-fill deposits as indicated by ADWR imaged records and Queen Valley lithologic logs are also shown on **Figure 2**. A cross section through Whitlow Ranch Dam and Queen Valley is presented on **Figure 3**. The Elephant Butte Fault located east of Queen Valley is a major west-side down, dip-slip, normal fault regional in scale which has resulted in substantial displacement of rock units (Ferguson and Skotnicki, 1995). The general descriptions of geologic units that occur in the Queen Valley area and their hydrogeologic significance are provided below:

Precambrian Pinal Schist (pCpi): Precambrian Pinal Schist outcrops along a broad belt east of the Elephant Butte Fault and is significant to the hydrogeologic conditions at the Whitlow Ranch Dam (M&A, 2013). The Pinal Schist is generally poorly permeable and is a strong barrier to groundwater movement resulting in a restriction of groundwater underflow to the narrow alluvium along Queen Creek and through the Whitlow Ranch Dam (M&A, 2013).

Tertiary Apache Leap Tuff (Tal): Isolated outcrops of Tertiary Apache Leap Tuff are present at the Whitlow Ranch Dam and tuff equivalent to the Apache Leap Tuff form low hills west of Queen Valley (M&A, 2013). This tuff equivalent is hereafter referred to as Apache Leap Tuff. Testing of the Apache Leap Tuff near the foundation of the Whitlow Ranch Dam indicated poor permeability (Lippincott, 1900). Testing at QV-5 located in Apache Leap Tuff low hills west of Queen Valley also indicated low permeability (Clear Creek, 2013).

Tertiary Basalt (Tb):

Small outcrops of Tertiary basalt are located directly south of Queen Valley (**Figure 2**). Ferguson and Skotnicki (1995) indicate thin Tertiary basalt layers at depth within the wedge of Tertiary basin-fills deposits. West of Queen Valley, in the Florence Junction area, a basalt layer was encountered at depth in two wells (**Figure 3**). In well 55-588620 the basalt layer has a thickness of 85 feet and is in the upper portion of the screened interval with cemented conglomerate below. In well 55-583450 the Tertiary basalt has a thickness of 280 feet and is in the lower portion of the screened interval.

Quaternary and Tertiary Basin-Fill Deposits (QTg): The Quaternary and Tertiary Basin-Fill Deposits include relatively thin veneers of Quaternary deposits older than the active alluvium and thick sequences of Tertiary basin-fill deposits significant for local aquifers. This unit is hereafter referred to as Tertiary basin-fill deposits. In the Queen Valley area, a localized east-dipping tilt-block of Tertiary basin-fill deposits is bounded by the Elephant Butte Fault to the east and basin-bounding faults to the west (M&A, 2013). The wedge of Tertiary basin-fill deposits in Queen Valley is essentially isolated from other basin-fill deposits to the east and west since it is separated by poorly permeable Pinal Schist and Apache Leap Tuff, respectively.

Conglomerates in the Tertiary basin-fill deposits are well consolidated, poorly sorted, and poorly permeable as evidenced by wells in the Superior Basin (M&A, 2013). Water supply wells completed in the Tertiary basin-fill deposits in Queen Valley indicate some permeability, but it is unclear whether this is due to primary characteristics of the deposit or presence of fracture zones (M&A, 2013). The thickness of the Tertiary basin-fill deposits in the Queen Valley area has been estimated to be over 1,000 feet thick and overly Apache Leap Tuff (Ferguson and Skotnicki, 1995). Depth to the bottom of the Tertiary basin-fill deposits as indicated by ADWR imaged records and lithologic logs provided by Queen Valley are shown on **Figure 2**.

Floodplain Alluvium (Qal): The floodplain alluvium includes unconsolidated alluvial floodplain deposits along Queen Creek, poorly consolidated surficial deposits adjacent to the floodplains, and tributaries to Queen Creek (M&A, 2013). Thickness of the floodplain alluvium overlying Pinal Schist is generally less than 30 feet east of Whitlow Ranch Dam and is documented to reach 42 feet at the dam (Lippincott, 1900). The floodplain alluvium is moderately to highly permeable, readily recharged by rainfall and surface water runoff, and can store groundwater. The principal source of sustained groundwater discharge at Whitlow Ranch Dam is from the floodplain alluvium which is forced through a dam intake culvert due to the installation of impervious materials through the dam core and footing (M&A, 2013). Downstream of Whitlow Ranch Dam in Queen Valley, the floodplain alluvium receives and stores surface water runoff events from the dam outlet and tributary drainages (M&A, 2013). Infiltration via the floodplain alluvium is likely the principal source of recharge to the aquifer(s) used for water supply in Queen Valley (M&A, 2013).

Hydraulic Conductivity

Aquifer tests were reviewed to evaluate the contrast in transmissivity and hydraulic conductivity between the Tertiary basin-fill deposits and Apache Leap Tuff. Hydraulic conductivities for these tests are summarized in **Table 1** and locations are shown on **Figure 4**. Both QV-1 and well 55-624609 are completed in Tertiary basin-fill deposits and show the contrast in transmissivity and hydraulic conductivity from the isolated wedge of deposits in Queen Valley to the larger, deeper basin in ESRV. The hydraulic conductivity of the Tertiary basin-fill deposit well near ESRV (55-624609) is about two orders of magnitude higher than the Apache Leap Tuff (QV-5). The contrast in conductivity between QV-5 and 55-624609 indicates that pumping in the QTg can readily draw water from elsewhere in the QTg while the Tal acts as a relative barrier to flow.

Table 1. Transmissivity and Hydraulic Conductivity in the Queen Valley Area

Area	Well Identifier	Hydrogeologic Unit	Transmissivity (ft²/day)	Saturated Thickness (ft)	Hydraulic Conductivity (ft/day)	Hydraulic Conductivity (cm/s)	Initial Source
Queen Valley	QV-1	QTg	7,733.87	449.48	17.2 [a]	6.1×10^{-3} [a]	M&A (2013)
	QV-5	Tal	431.3 [d]	415	1.0 [b]	3.7×10^{-4} [b]	Clear Creek (2013)
Desert Wellfield	55-624609 (Well No. 4)	QTg	18,714 [c]	455.3	41.1 [a]	1.5×10^{-2} [a]	M&A (2016)
Devils Canyon Area	Multiple [e]	Tal	106	---	0.2	7×10^{-5}	M&A (2014); M&A (2015)

[a] Hydraulic conductivity values estimated in this memo from Transmissivity and saturated thickness; not reported by source
[b] A geometric mean was estimated from the reported hydraulic conductivity of fractures (5.5×10^{-3} cm/s) and matrix (7.8×10^{-5} cm/s) weighted by the percentage of intervals indicated as fracture and matrix
[c] Transmissivity converted from reported gpd/ft to ft²/day for this memo

[d] Transmissivity calculated from representative geometric mean of hydraulic conductivity and saturated thickness
[e] Summary of aquifer tests for 15 sites representing Apache Leap Tuff

SURFACE WATER CONDITIONS

Water flows into the Queen Valley community from a narrow bedrock gap at Whitlow Ranch Dam representing the discharge point for all surface water runoff from upper Queen Creek in the Superior Basin (M&A 2013). The Whitlow Ranch Dam was completed in 1960 with an impervious core and footing through the entire thickness of the floodplain alluvium to force groundwater to the surface and the dam intake culvert (M&A, 2013). Previous investigations indicate the permeability of the rocks adjacent to and underneath of the floodplain alluvium is small (Lippincott, 1900). Therefore, little groundwater underflow likely occurs through the underlying Pinal Schist or Apache Leap Tuff at the dam abutment (M&A, 2013). Surface water and groundwater are discharged through the dam by a 5.5 foot diameter culvert (M&A, 2013). The flow downstream of the dam rarely travels more than a few miles as it is either diverted to an irrigation canal used by the Queen Valley Country Club or percolates into the alluvium and underlying rock units (M&A, 2013; U.S. Army Corps of Engineers, 1975).

Discharge from the outlet culvert at Whitlow Ranch Dam has been measured by a stream gage operated by the USGS since 2001 (USGS #09478500 "Queen Creek Below Whitlow Dam Near Superior") and the USACE since 1961 (M&A, 2013). **Figure 5** shows both stream gage data sets from the period of 1984 to present with total monthly precipitation from the Precipitation-Regression on Independent Slopes Model (PRISM) (PRISM Climate Group, 2020). For both stream gage data sets, peak flows correlate with large, successive precipitation events which generally occur during winter months (2004-2005, 2007-2008, 2009-2010, 2016-2017). Surface water flow is sustained for several months following large winter runoff events before the creek typically dries out in the late spring and early summer (M&A, 2013). An inspection of **Figure 5** shows that streamflow does not exhibit consistent seasonality over the period of record (M&A, 2017)

A staff gage (Maricopa Alert Station #6739) was installed at the Whitlow Ranch Dam in 1998 to measure ponding height with data available starting in August 2000. **Figure 5** also shows peak ponding volume during runoff events at Whitlow Ranch Dam as estimated from a staff gage height-volume relationship. The significant peak ponding events at Whitlow Ranch Dam with estimated volumes more than 5,000 acre-feet correlate to the large winter precipitation and runoff events in 2004-2005 and 2009-2010. Peak ponding volumes are otherwise generally less than 1,500 acre-feet with 57% occurring during summer monsoons and 43% occurring during winter months.

During periods where the creek above the dam is dry, discharge through the dam is continuous as evidenced by **Figure 5** (M&A, 2013). Groundwater in the floodplain alluvium continues to migrate downstream to the dam during these periods and is therefore an important component of discharge from the Whitlow Ranch Dam (M&A, 2013). Daily streamflow data were analyzed using the delta-filter baseflow hydrograph separation method to characterize baseflow by M&A in 2017 and was updated for this memorandum to show the 2011 to 2019 period (**Figure 5**). The median daily baseflow for this period was 1.46 cubic feet per second (1,057 acre-feet per year) for winter months and 1.11 cubic feet per second (~804 acre-feet per year) for the period of record. An inspection of the baseflow shown in **Figure 5** shows that baseflow variability depends primarily on the intensity of winter precipitation and does not show consistent seasonality over the period of record (M&A, 2017). Abrupt rises in baseflow follow exceptionally wet winters and are followed by a recession period lasting from months to years (M&A, 2017). **Table 2** provides an estimated annual total contribution of baseflow through the outlet culvert in acre-feet based on this analysis:

Table 2. Estimated Total Annual Baseflow at Whitlow Ranch Dam

Year	Estimated Total Annual Baseflow (acre-feet)
2001	1,511
2002	875
2003	714
2004	781
2005	2,892
2006	1,682
2007	2,025
2008	3,033
2009	1,399
2010	2,922
2011	814
2012	379
2013	820
2014	786
2015	397
2016	728
2017	2,801
2018	1,107
2019	1,757

The highest estimated total annual baseflow occurred in 2005, 2008, 2010, and 2017. Each of these years result in a major shift in the baseflow hydrograph due to large, successive winter precipitation events. These years seemingly fall into two scenarios: a significant peak winter precipitation event or multiple low-level ponding events over a period. In 2005 and 2010, successive winter precipitation with a significant peak event resulted in significant ponding at Whitlow Ranch Dam and an increase in the baseflow hydrograph. The receding limb of the baseflow hydrograph declines relatively quickly for both 2005 and 2010. In 2008 and 2017, successive winter precipitation events result in multiple low-level volume ponding events and a baseflow shift. Importantly in both 2008 and 2017, additional low-volume ponding occurs during the monsoon season which results in a more gradual decline of the hydrograph receding limb.

The lowest estimated total annual baseflow occurred in 2012 and 2015. In both cases, the baseflow generally declined over the course of three years due to drought and insufficient recharge events. In 2012 and the preceding baseflow decline, there is a lack of surface water runoff peaks for both the winter and monsoon periods. In 2015 and the preceding baseflow decline, although multiple surface water runoff peaks are observed during the monsoon periods, a lack of sufficient precipitation in winter results in an overall baseflow decline.

Both the highest and lowest estimated total annual baseflows shows the importance of large, sustained winter precipitation events to recharge in the floodplain alluvium and baseflow discharge at the Whitlow Ranch Dam. Ponding events at the Whitlow Ranch Dam prolong durations of increased discharge at the outlet culvert.

GROUNDWATER SYSTEM

Groundwater in Queen Valley occurs in a wedge of Tertiary basin-fill deposits and Apache Leap Tuff that is overlain by floodplain alluvium deposits to locally form an aquifer. As previously described in the hydrogeologic conditions, the floodplain alluvium serves an important role of capture and storage of surface water runoff which in turn recharges the underlying Tertiary basin-fill deposits and Apache Leap Tuff (M&A, 2013). Direct contribution of the floodplain alluvium to wells in Queen Valley is likely minimal, as review of drillers' logs and current groundwater levels suggests the alluvium is locally dewatered near the wells (M&A, 2013).

Figure 6 shows conceptual block diagrams for dry and wet climatic regimes in the Queen Valley area and response of the Queen Valley aquifer. During dry periods, groundwater in the floodplain alluvium upstream of the dam is forced through a dam intake culvert and then discharged to the outlet works (M&A, 2013). The discharge is diverted to a canal to deliver water to a series of ponds and lakes and irrigation of the golf course (M&A, 2013). Some degree of continuous recharge to the Queen Valley aquifer via the floodplain alluvium probably occurs from some limited seepage from canals and ponds (M&A, 2013). Overall, the floodplain alluvium is generally dry during these conditions and groundwater levels in the Queen Valley aquifer decline (M&A, 2013). During wet conditions, surface water runoff from the Whitlow Ranch Dam outlet culvert and tributary drainages recharge the Queen Valley aquifer (M&A, 2013). Both increased recharge and decreased groundwater pumping for irrigation result in groundwater level rise in the Queen Valley aquifer (M&A, 2013).

Groundwater level hydrographs were prepared for the production wells in Queen Valley and wells completed in the floodplain alluvium upstream of the Whitlow Ranch Dam. Sources of water level data include the ADWR Groundwater Site Inventory (GWSI) database, files of RCM and Queen Valley Domestic Water Improvement (QVDWID), and measurements by M&A. Hydrographs for the period of 1984 through 2019 are shown on **Figure 7**. Upstream of the Whitlow Ranch Dam, two shallow stock wells completed in the floodplain alluvium in Queen Creek (Bakers Well and Scales Well) have variable water levels but overall are responsive to periodic recharge from runoff events (M&A, 2013). Downstream of the Whitlow Ranch, QVDWID production wells QV-1, QV-2, and QV-4 are completed in the Tertiary basin-fill deposits while QV-3 and QV-5 are completed in the Apache Leap Tuff in the low hills west of Queen Valley. Water level trends in the Tertiary basin-fill wells are characterized by periods of water level decline followed by rapid water level recovery from surface water runoff events (M&A, 2013). This pattern is most clearly shown in QV-1 and QV-2 while QV-4 generally shows a similar response (M&A, 2013). Water levels in the Apache Leap Tuff at QV-3 decline rapidly and do not fully recover with runoff events which may be the result of dewatering the uppermost portion of the aquifer from local groundwater pumping with an absence of substantial aquifer recharge due to prolonged drought conditions (M&A, 2013). Water levels measurements have not been collected at QV-3 since 2006 due to an obstruction in the well (M&A, 2013). QV-5 was drilled in late 2012 to target deeper fractures in the Apache Leap Tuff (Clear Creek, 2013). Inspection of the hydrograph for QV-5 (**Figure 7**) shows water levels are deeper than the last measured water levels at QV-3 with declines likely due to groundwater pumping followed by a water level increase due in part to recharge from surface water runoff.

WATER DEMAND

Queen Valley water supply is sourced from surface water rights from the Whitlow Ranch Dam outflow and groundwater from Queen Valley wells. On the downstream side of the dam, a diversion structure at the outlet culvert permits a portion of the water to enter an irrigation canal for use by the Queen Valley Country Club to irrigate a golf course and maintain water levels in recreational lakes (M&A, 2013). The Queen Valley Golf Association holds a surface water permit (36-105072) for the total allocation of 1,715.84 acre-feet per year for multiple water uses. The primary uses of the surface water right are to irrigate a golf course and maintain water levels in recreational lakes (M&A, 2013).

Water supply for Queen Valley residents is provided by the following production wells operated by QVDWID: QV-1, QV-2, QV-3, QV-4, and QV-5. Over the past 15 years, combined annual production from these wells has averaged about 139 acre-feet per year for domestic and irrigation supply according to ADWR records available through 2015. 575 connections are served by QVDWID (M&A, 2013). In addition to the QVDWI wells, domestic water supply is provided by a number of private wells (M&A, 2013).

Water demand at Queen Valley for both surface water and groundwater are shown together on **Figure 8** to compare both to total annual discharge from the outlet culvert at Whitlow Ranch Dam. The total annual discharge from the outlet culvert indicates the potential water availability for Queen Valley's surface water demand and recharge for groundwater supply. The total annual discharge was calculated from USACE instantaneous daily measurements and USGS daily average measurements separated by baseflow and peakflow contributions from the baseflow analysis conducted by M&A to assess the importance of each component to meeting demand. The annual pumped groundwater volume from QVDWID wells shows cumulative pumping volumes were variable through the 1990s and then relatively steady before a general decline beginning in 2009. The past 15 years have shown QV-1 and QV-2 are the main contributors of groundwater supply from QVDWID wells. **Figure 8** also shows the surface water right by the Queen Valley Golf Association of 1715.84 acre-feet per year compared to the estimated total annual flow at the outlet culvert from Whitlow Ranch Dam. For the period of 1984 through 2019, the total annual discharge from the outlet culvert exceeded surface water rights for 24 years (67%) and did not meet the surface water right for 12 years (33%). The total annual discharge was separated by baseflow and peakflow contribution starting in 2001 and shows the baseflow contribution alone met the surface water right allocation for 7 years (37%) while 4 years (21%) met the right with both baseflow and peakflow contributions from the dam. The remaining 8 years (42%) did not meet the surface water right due to drought conditions.

DISCUSSION

Queen Valley is not directly modeled by either the Resolution Groundwater Impact Model or ESRV Model because it is relatively isolated within bedrock outcrops at a watershed boundary. This memo provides a review of the hydrologic setting and water resources of Queen Valley to evaluate the appropriateness of not including Queen Valley in a groundwater flow model and assess potential impacts to Queen Valley water resources. The two potential sources of impact previously identified and to be assessed are the 1) reduction in groundwater levels from groundwater pumping in the Desert Wellfield or mine dewatering and 2) the reduction of flow at Whitlow Ranch Dam from either surface water runoff or groundwater contribution.

Proposed groundwater withdrawals modeled for the Desert Wellfield have shown projected drawdown at the ESRV model boundary in the Tertiary basin-fill deposits (M&A, 2020). These deposits are separated from the Queen Valley Tertiary basin-fill deposits, which host the Queen Valley aquifer, by continuous outcrops of Apache Leap Tuff. Lower hydraulic conductivities and limited groundwater level recovery from recharge events (QV-3 and QV-5) indicate that the Apache Leap Tuff is an effective barrier to propagation of drawdowns from the west. Based on available evidence, the proposed groundwater withdrawals at the Desert Wellfield are not expected to impact the Queen Valley water supply. In addition, the Resolution Mine Groundwater Impact model did not show groundwater drawdown in relation to proposed mining activities east of Whitlow Ranch Dam (personal communication with Chris Pantano, WSP, February 2020). Based on WSP model projections, the proposed mine dewatering is not expected to impact groundwater levels in Queen Valley.

Review of the water supply of Queen Valley indicates that both groundwater and surface water supplies in Queen Valley are primarily dependent on surface water flows either directly or through recharge events. The reduction in contributing watershed area from the mine subsidence crater is expected to reduce runoff resulting in some impacts to the water supply in Queen Valley.

A monthly rainfall runoff model was developed by BGC for the Queen Creek watershed to estimate reductions in runoff volume at the Whitlow Ranch Dam (BGC, 2018). The results of this study indicate average monthly stream flows would be reduced at the Whitlow Ranch Dam for the Skunk Camp alternative between 2.9% and 3.7% with an average reduction of 3.5% (BGC, 2018). Another study conducted by JE Fueller (2020) assessed potential impacts to peak-flows, such as peak-flow frequency and volume-duration-frequency, and showed a decrease in peak-flow runoff between 1.0% and 2.1%.

To assess the outcome of a reduction in peak-flow runoff of 2.1% and flow volume of 3.5%, this reduction was applied to estimated historic total annual discharge for the period of 2001 to 2019, during which more accurate flow measurements were available. This period represents periods of drought and wet conditions and is a representative analog. **Table 3** shows a comparison of historic total annual discharge at Whitlow Ranch Dam to reduced flow from the potential impact to surface water runoff. These estimates indicate that the reduction in surface water runoff usually does not affect whether the total annual discharge at Whitlow Ranch Dam meets the surface water right of the Queen Valley Golf Association of 1,715.84 acre-feet per year. When the total annual discharge is greater than the surface water right, it mostly remains above with the reduction in flow. The historic analog shows that the reduction in surface flows would only have prevented Queen Valley from meeting its surface water right during the year 2014.

The discharge at Whitlow Ranch Dam has an important role in providing recharge to the Queen Valley aquifer via the floodplain alluvium. The hydrographs for water supply wells show responses in groundwater levels due to discharge from the Whitlow Ranch Dam outlet culvert and local groundwater pumping. The effects of a reduction in discharge volume at the Whitlow Ranch Dam outlet culvert alone to groundwater recharge cannot easily be discerned with a historic data analog because of groundwater pumping. In years where the historic total annual discharge at the outlet culvert did not meet the surface water right, a reduction in flow volume of 3.5% would result in potential reductions of 14 to 58 acre-feet. This would influence available groundwater recharge due to less surface water supply for recharge. In years where the historic total annual discharge at the outlet culvert met the surface water right, a reduction in flow volume of 3.5% would result in potential reductions of 61 to 543 acre-feet. This would also influence available groundwater because less surface water would be available to recharge the Queen Valley aquifer via the floodplain alluvium.

Table 3. Comparison of Historic Total Annual Discharge at Whitlow Ranch Dam to Reduced Flow from Potential Surface Water Runoff Impact

Year	Total Annual Discharge Volume from Baseflow and Peak-flow (acre-feet)	Discharge Volume After a Reduction of 2.1% [a] (acre-feet)	Change in Discharge Volume from a Reduction of 2.1% [a] (acre-feet)	Discharge Volume After a Reduction of 3.5% [b] (acre-feet)	Change in Discharge Volume from a Reduction of 3.5% [b] (acre-feet)
2001	2,703	2,646	-38	2,608	-95
2002	880	862	-12	850	-31
2003	878	860	-12	847	-31
2004	1,468	1,437	-21	1,416	-51
2005	13,019	12,746	-182	12,564	-456
2006	3,052	2,988	-43	2,945	-107
2007	2,423	2,372	-34	2,338	-85
2008	4,992	4,887	-70	4,817	-175
2009	1,554	1,521	-22	1,499	-54
2010	15,514	15,188	-217	14,971	-543
2011	815	798	-11	787	-29
2012	396	388	-6	382	-14
2013	1,369	1,340	-19	1,321	-48
2014	1,731	1,695	-24	1,671	-61
2015	526	515	-7	507	-18
2016	2,821	2,762	-39	2,723	-99
2017	8,703	8,520	-122	8,399	-305
2018	1,648	1,614	-23	1,591	-58
2019	5,583	5,466	-78	5,387	-195

[a] The estimated reduction of 2.1% is the maximum reduction to flood duration flows provided by JE Fueller (2020).
[b] The estimated reduction of 3.5% is the average reduction to runoff volume provided by BGC (2018).

RECOMMENDATIONS

The expected reduction in surface water discharge at Whitlow Ranch Dam may result in impacts to Queen Valley water resources. Discharge at Whitlow Ranch Dam and groundwater levels in Queen Valley will continue to be monitored as part of Resolution's monitoring and mitigation plan.

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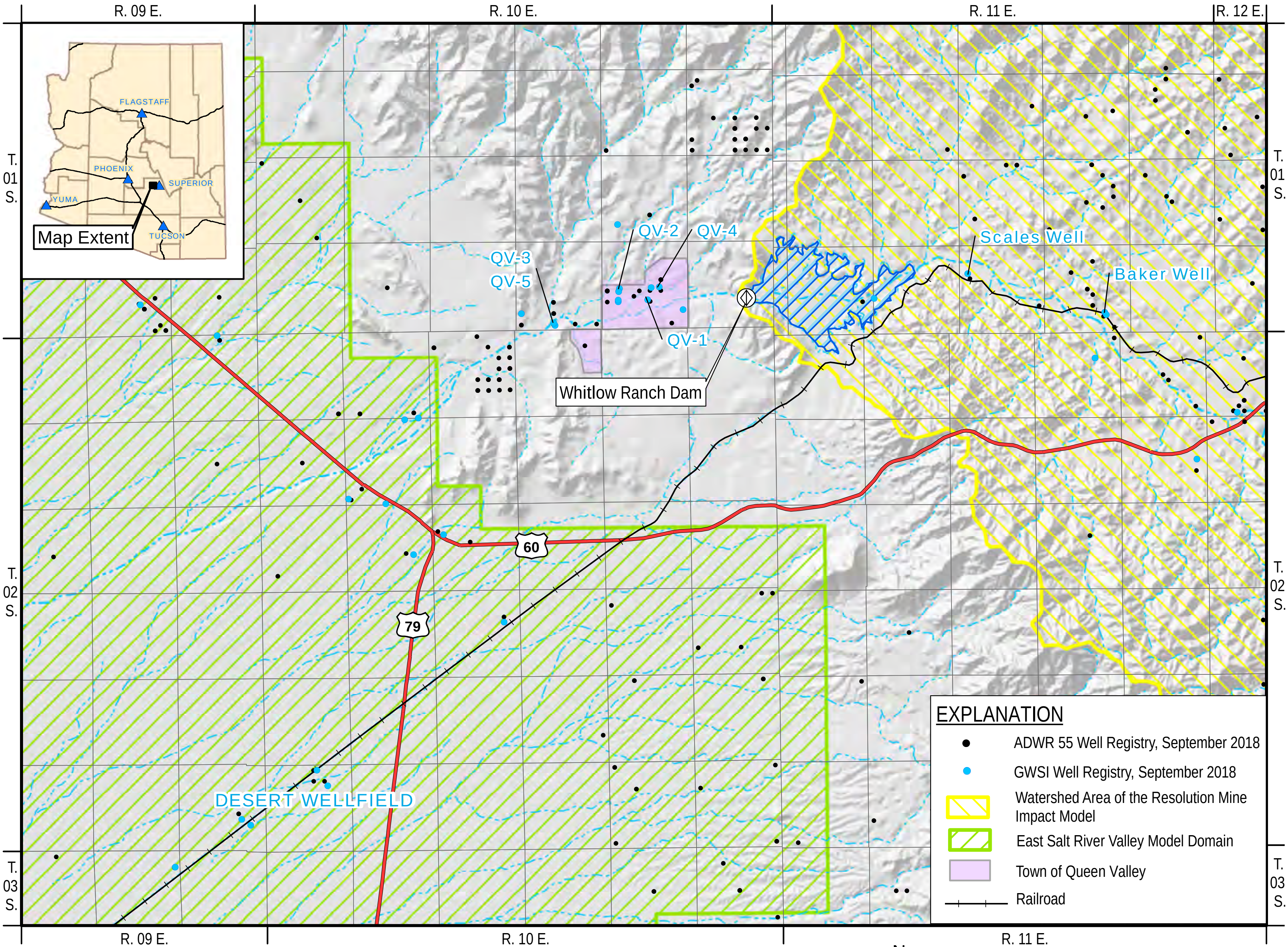

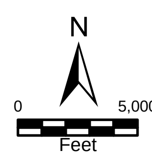

FIGURE 1. SITE LOCATION MAP

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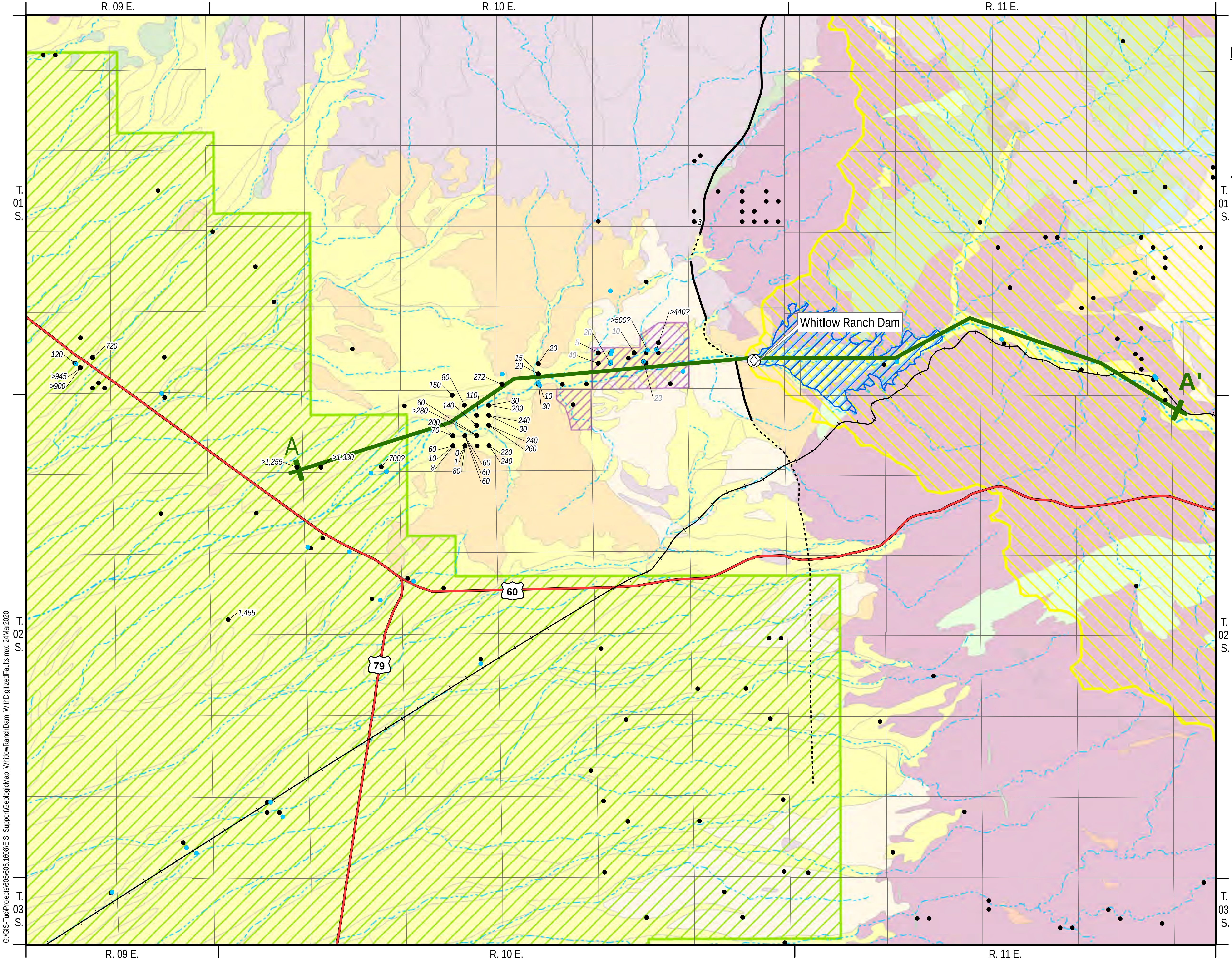

EXPLANATION

- ADWR 55 Well Registry, September 2018
- GWSI Well Registry, September 2018
- 20 — Depth to Bedrock from ADWR Imaged Record or Queen Valley lithologic log (gray where questionable)
- Elephant Butte Fault; dotted where inferred; bar and ball on downthrown side
- A — A' Hydrogeologic Section
- Watershed Area of the Resolution Mine Impact Model
- East Salt River Valley Model Domain
- Town of Queen Valley
- Railroad

Geologic Units

d	Disturbed Surficial Deposits
Qal	Quaternary Alluvial Deposits and Surficial Deposits
QTg	Quaternary and Tertiary Basin-Fill Deposits
Tal	Tertiary Apache Leap Tuff
Tvu	Tertiary Volcanic Rocks, Undifferentiated
Tw	Tertiary Whitetail Conglomerate
TKg	Cretaceous and Tertiary Intrusive Rocks
Pz	Paleozoic Sedimentary Rocks, Undifferentiated
p€y	Younger Precambrian Sedimentary and Intrusive Rocks, Undifferentiated
p€gu	Undifferentiated Precambrian Intrusive Rocks
p€pi	Older Precambrian Pinal Schist

N

0 5,000 Feet

RESOLUTION COPPER

GEOLOGIC MAP
QUEEN VALLEY AREA

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FIGURE 2

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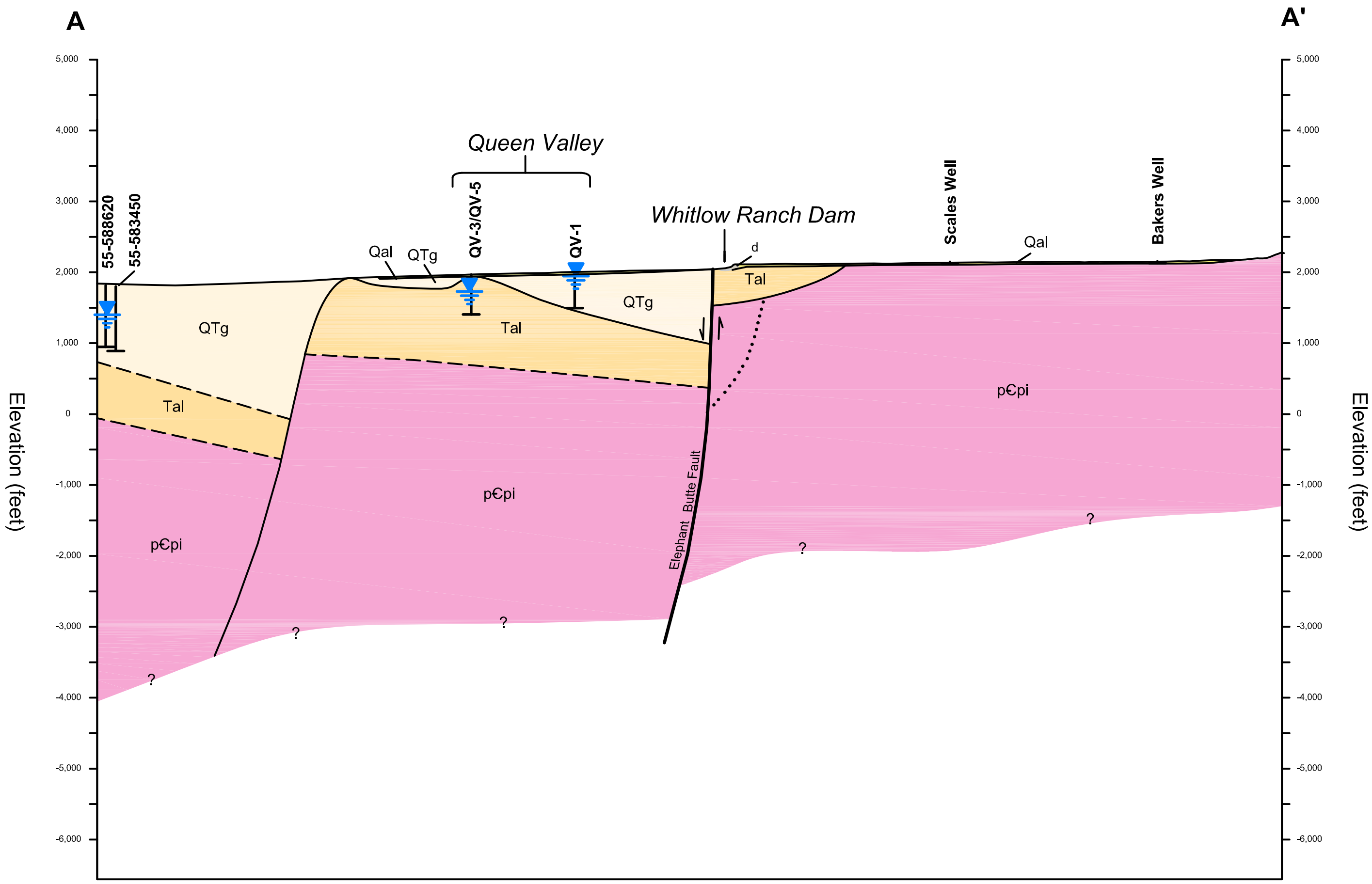

EXPLANATION

Geologic Units

d	Disturbed Unit
Qal	Quaternary Alluvial Deposits and Surficial Deposits
QTg	Quaternary and Tertiary Basin-Fill Deposits
Tal	Tertiary Apache Leap Tuff
pЄpi	Older Precambrian Pinal Schist

0 2,000 4,000 6,000 8,000 10,000

Feet

VERTICAL EXAGGERATION 2.5:1

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FIGURE 3. HYDROGEOLOGIC CROSS-SECTION A-A'

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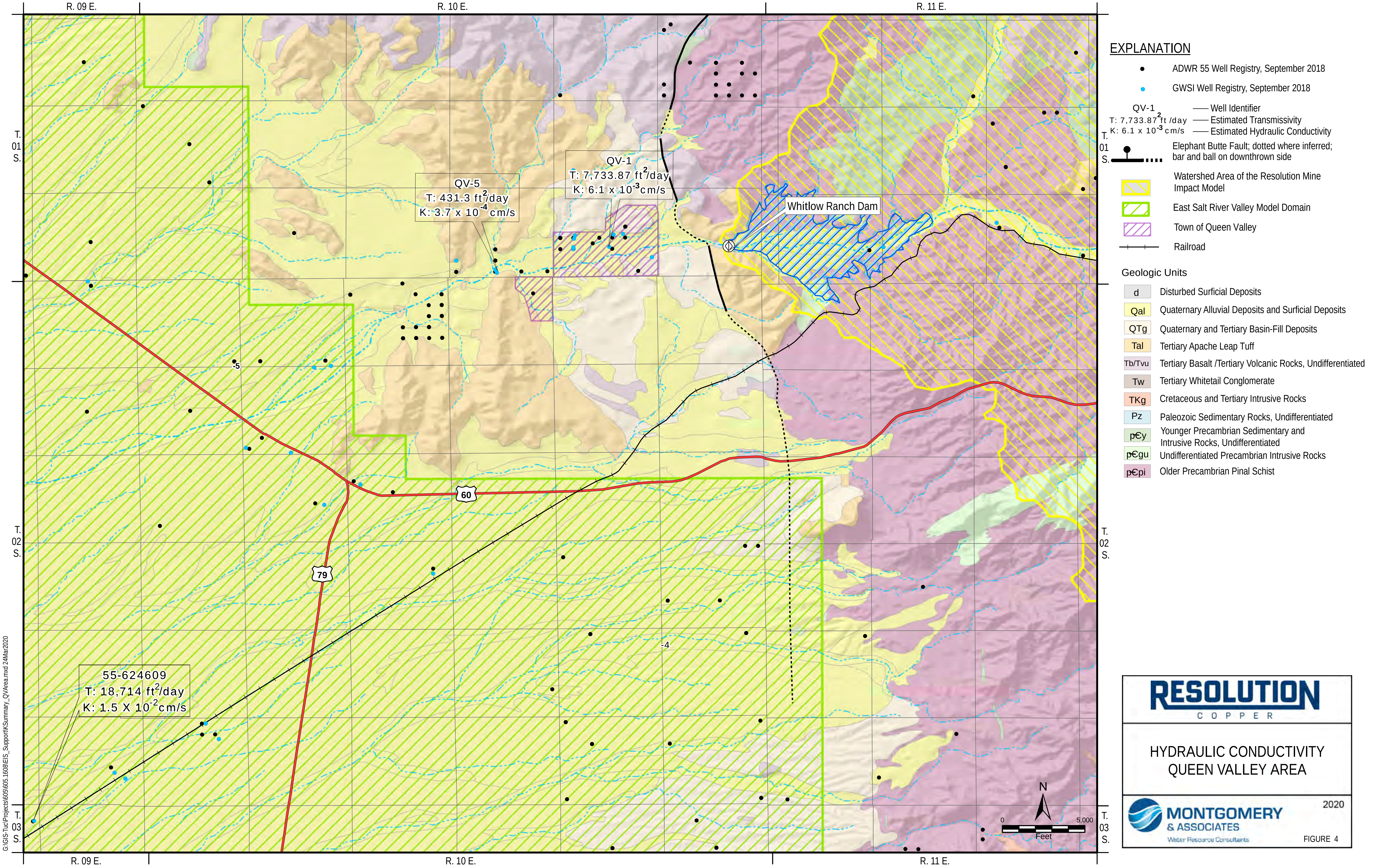

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HYDRAULIC CONDUCTIVITY
QUEEN VALLEY AREA

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FIGURE 4

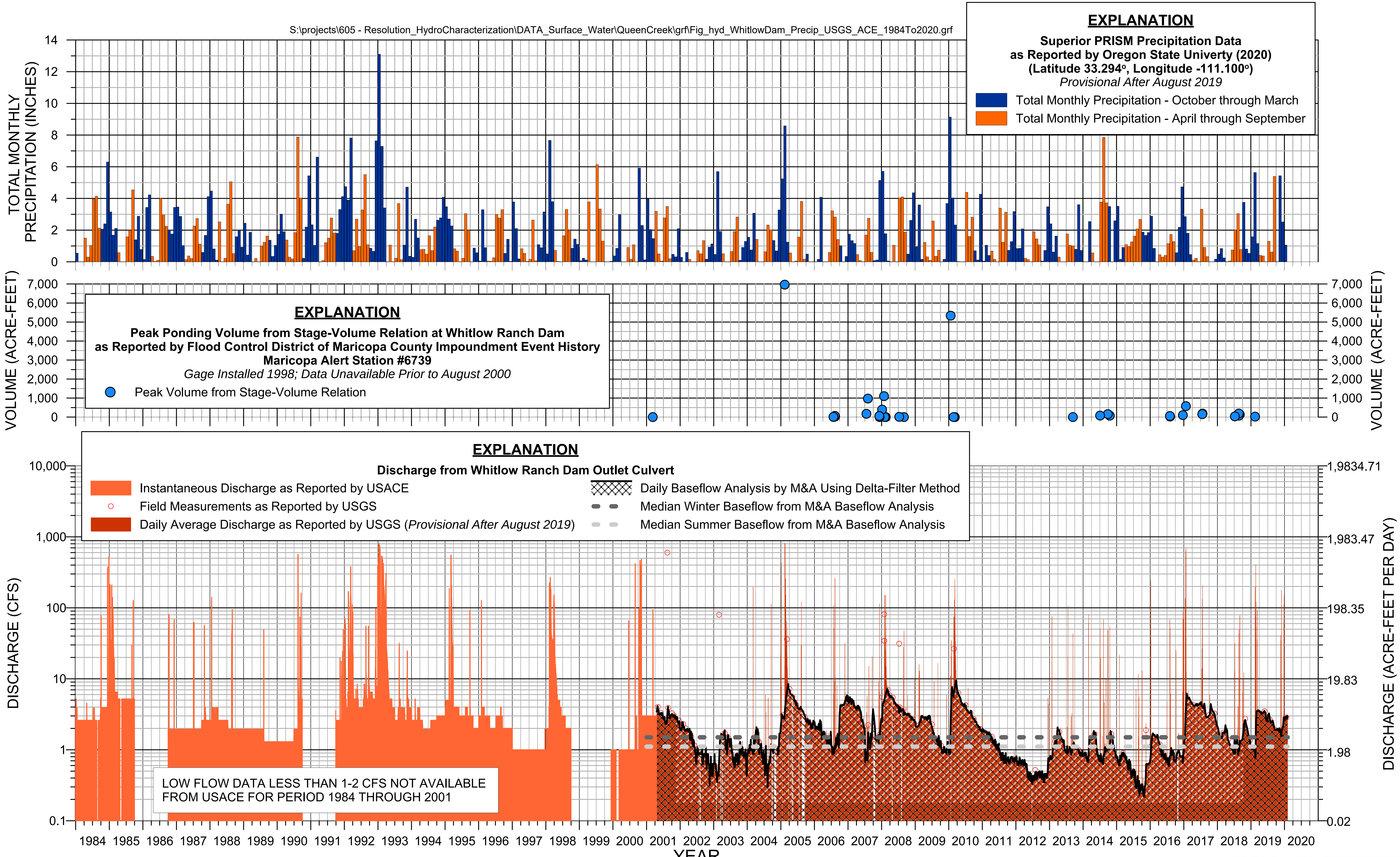

FIGURE 5. DISCHARGE FROM OUTLET CULVERT AT WHITLOW RANCH DAM COMPARED TO PEAK PONDING VOLUME AND TOTAL MONTHLY PRECIPITATION AT SUPERIOR

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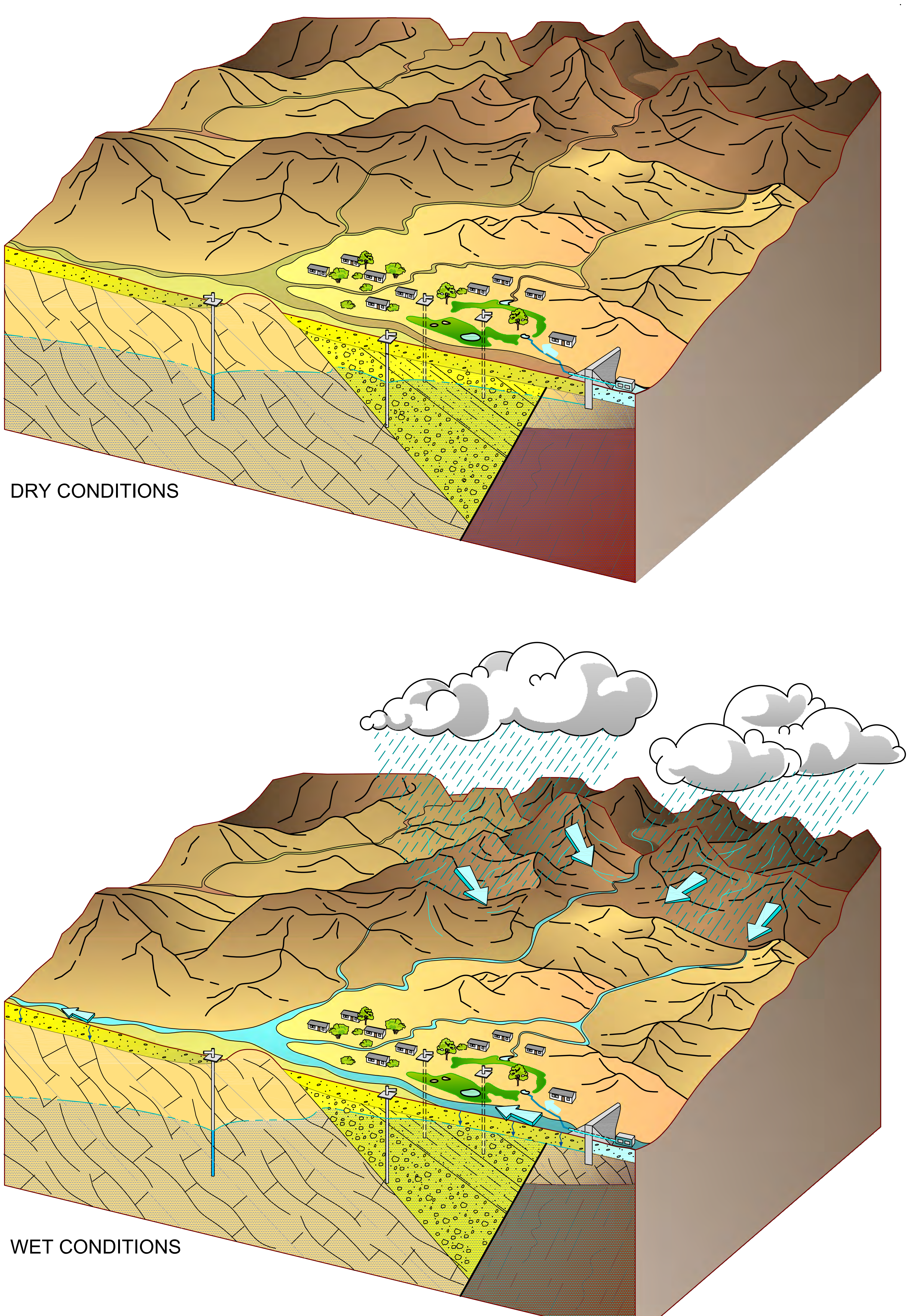

FIGURE 6. CONCEPTUAL BLOCK DIAGRAM FOR REACH OF QUEEN CREEK AT QUEEN VALLEY AND WHITLOW DAM - DRY AND WET CONDITIONS

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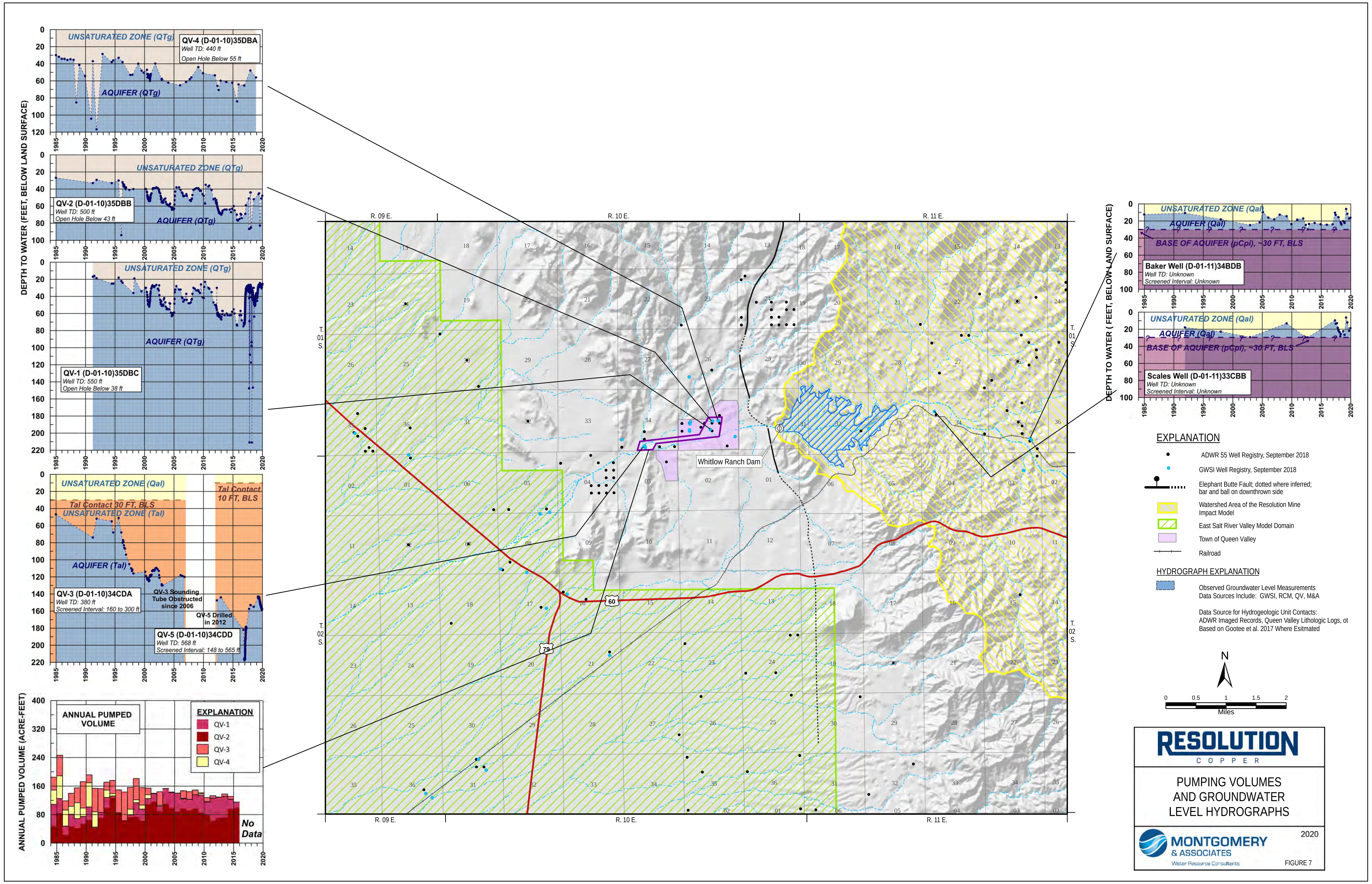

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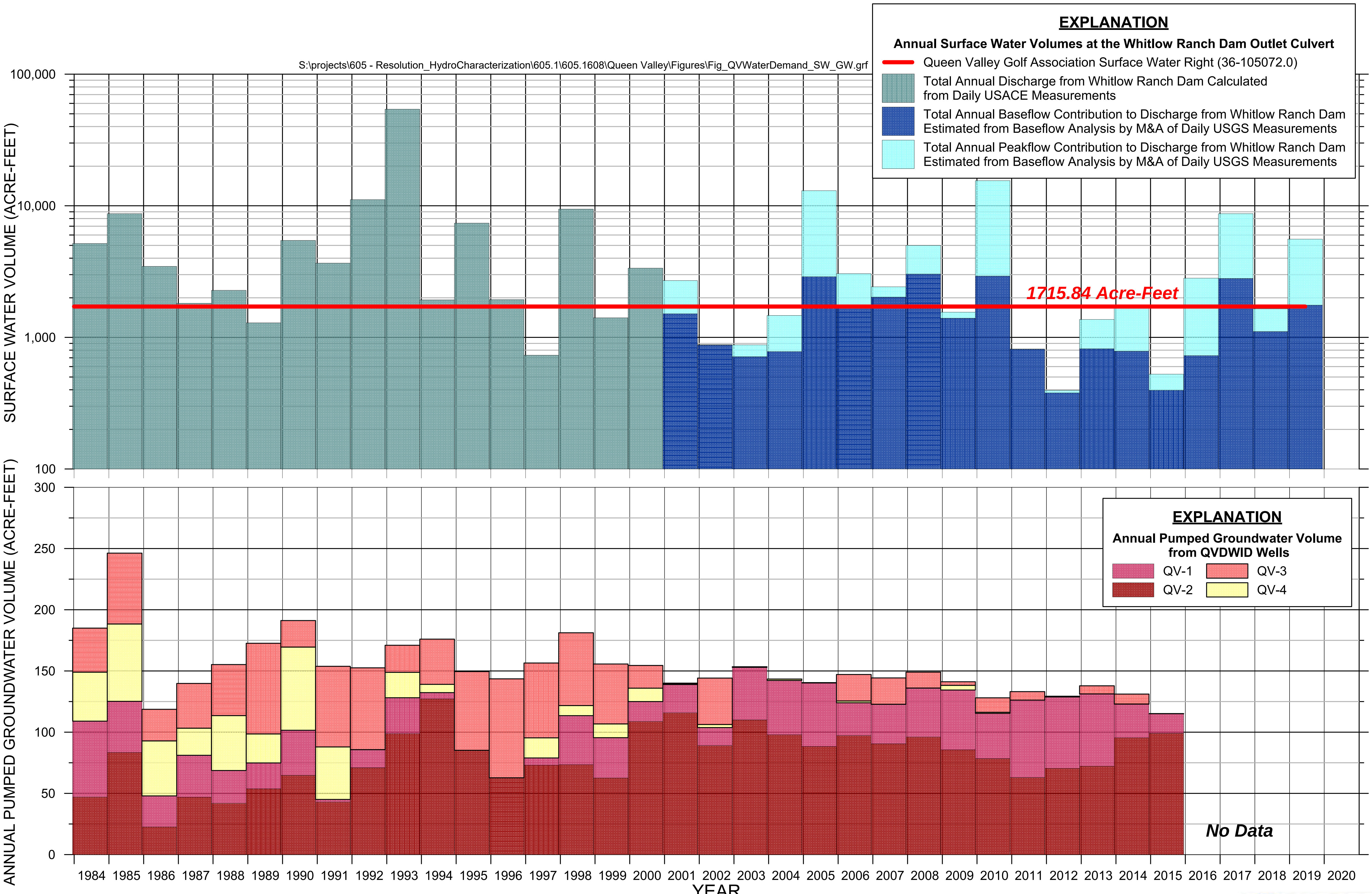

FIGURE 8. SURFACE WATER AND GROUNDWATER DEMAND IN QUEEN VALLEY COMPARED TO TOTAL ANNUAL DISCHARGE AT OUTLET CULVERT FROM WHITLOW RANCH DAM

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